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Composites with Inorganic Matrix for Repair of Concrete and Masonry Structures

Editors:
Gianmarco de Felice, Lesley H. Sneed,
and Antonio Nanni

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Preface

This SP is the result of two technical sessions held during the 2017 ACI Spring Convention in Detroit, MI. Via presentations and the resulting collection of papers, it was the intention of the sponsoring committees (ACI Committees 549 and 562 together with Rilem TC 250) to bring to the attention of the technical community the progress being made on a new class of repair/strengthening materials for concrete and masonry structures. These materials are characterized by a cementitious matrix made of hydraulic or lime-based binders, which embeds reinforcement in the form of one or more fabrics also known as textiles. The great variability of fabric architectures (for example, cross sectional area, strand spacing, and fiber impregnation with organic resin) coupled with the types of material used (aramid, basalt, carbon, glass, polyparaphenylene benzobisoxazole (PBO) and coated ultra-high strength steel) makes the characterization, validation, and design of these systems rather challenging. Irrespective of the reinforcement type (synthetic or ultra-high strength steel), the impregnating mortar is applied by trowel or spray-up. It should also be noted that fabric reinforced cementitious matrix and steel reinforced grout, in particular, are very different from other repair technologies such as FRC (fiber reinforced concrete) and UHPC (Ultra High-Performance Concrete) in that they utilize continuous and oriented reinforcement. In a sense FRCM and SRG can be viewed as the modern evolution of ferrocement.

The terminology adopted in ACI to identify this class of new products is FRCM (fabric reinforced cementitious matrix) when the reinforcement is made of man-made fibers and SRG (steel reinforced grout) when the reinforcement is made of ultra-high strength steel. While it is recognized that other organizations and professionals may refer to these systems with different acronyms and names (for example, TRM for textile-reinforced mortar, TRC for textile reinforced concrete), ACI Committee 549 has made the conscious decision to adopt FRCM and SRG to unequivocally identify systems solely intended for repair and strengthening as opposed to new construction.

The two technical sessions and the resulting Special Publication were also the first tangible outcomes of the partnership between ACI Committee 549 and Rilem TC 250 that has as its ultimate objective, jointly producing a design guide for the repair/strengthening of masonry structures using FRCM and SRG. The motivation of the partnership stems first from the desire to maximize efficiency by drawing from the experience and expertise of professionals from around the world. Additionally, the intention is to develop a guide that harmonizes the design procedure based on the approaches followed in the U.S. and European Union so that practitioners can adopt this technology irrespective of the geographical location and with the same outcome.

The editors of this SP are most grateful to the technical sessions presenters and the authors of the papers for having shared their precious knowledge. The editors hope that this SP will be a relevant contribution to the deployment of suitable technologies for the safe preservation and use of existing concrete and masonry structures.

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Determination of Material Properties of TRC Under Cyclic Loads

Karoline Holz, Elisabeth Schütze, Patricia Garibaldi, Manfred Curbach

Synopsis: To enable a widespread industrial application of carbon reinforced concrete, a reliable characterization of material properties, such as the tensile strength and bond behavior of the composite material, has been established using standard test methods. To allow for an even wider range of application, the fatigue behavior and corresponding appropriate test methods were examined in this paper.

A test method along with an experimental setup for determining both static and cyclic tensile behavior is presented. Test results using the proposed methods are shown and discussed. Based on the results of cyclic tests of a reference load combination, load frequency as well as load level were varied and their influence is documented in this paper. Finally, the temperature development during cyclic tests is documented for one test specimen. Based on these results, future research opportunities are presented.

Keywords: Carbon Concrete Composite, Carbon reinforced concrete, cyclic loading, experimental methods, fatigue, tensile strength, textile reinforced concrete, TRC

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INTRODUCTION

Over twenty years ago, researchers in Germany began to investigate a new material known today as textile reinforced concrete (TRC) (Scheerer et al. 2015). TRC consists of a high-performance textile reinforcement embedded in a fine-grained concrete. Today, given the high tensile strength of carbon reinforcement, corrosion-resistant carbon fiber materials are the preferred choice for building efficient TRC structures. This composite material has been successfully used in multiple pilot projects (see e.g. Frenzel et al. 2013); where it was used to construct thin structural elements, façade panels or precast elements for pavilions and for strengthening purposes, e.g. for shell roofs or silos. TRC is either cast in formwork or applied in layers.

Based on extensive groundbreaking research, the new research program *C^3 – Carbon Concrete Composite* was launched to investigate the material behavior further and to introduce the material into the construction industry. In this interdisciplinary project, more than 150 partners from research institutions and industry are working together towards this goal.

One of the first steps in this process was to establish reliable test methods for the characterization of the basic material properties. Thus, standard methods for testing tensile strength and bond behavior of the composite under predominantly static loads were defined and validated through multiple tests in the laboratories of the Institute of Concrete Structures at RWTH Aachen, MFPA Leipzig GmbH, and the Institute of Concrete Structures at TU Dresden.

To allow for an even wider range of application for example the strengthening of reinforced concrete bridges, the next step was to examine the fatigue behavior of TRC and the corresponding appropriate test methods. Previous research mainly focused on examining the components of the composite material textile reinforced concrete under fatigue loading. For instance, Marx et al. 2013 and the guidelines of the Model Code for Concrete Structures (fib 2013) showed that the fatigue behavior of concrete depends on the medium stress. Results on carbon fiber rovings or grids were not known. Carbon, in the form of CFRP, is considered unsusceptible to fatigue stress levels up to 80 % of its short-term strength (Nanni et al. 2014; fib 2013).

However, it cannot be simply assumed that the material behavior of the two individual components, is the same as that of the composite material. The interaction not only between concrete and reinforcement but between the individual carbon fibers in a roving also has to be taken into account. Jesse (2012) stated, that the bond between reinforcement and concrete, has a huge influence on the fatigue behavior. Research on the fatigue strength of TRC as a composite material has so far given inconsistent results. While Hansl (2014) found a significant increase in the stiffness of TRC specimens after cyclic preloading, Schütze et al. (2015a) could not confirm this. Instead, they found a slight increase in strain and no decrease in tensile strength due to cyclic loading. However, these investigations had