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Modelling of ageing effects on crack-bridging behaviour of AR-glass multifilament yarns embedded in cement-based matrix

M. Butler, S. Hempel, V. Mechtcherine *

Institute of Construction Materials, TU Dresden, Dresden, Germany

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ABSTRACT

This article focus on modelling of ageing effects on crack-bridging behaviour of AR-glass multifilament yarns embedded in cement-based matrix. In the first step, age-dependent changes in the crack-bridging behaviour of AR-glass multifilament yarns were investigated at the meso and micro levels. Two cementitious matrices were considered where the binder contained Portland cement clinker and ground granulated blast furnace slag cement, respectively. Mechanical characteristics of the bond between matrix and multifilament yarns after accelerated ageing were measured by means of double-sided yarn pullout tests. In these tests the multifilament yarns bridged a single crack in the matrix arising in a notched area of the specimen. Losses in performance with increasing age differed widely depending on matrix material composition. The essential cause of such losses was discovered to be the microscopic densification of the fibre-to-matrix interface. This led to increased bond intensity and restricted slip-ability of the filaments. Subsequently, these micro-structural phenomena were related to the mesoscopic material behaviour by means of a phenomenological bond model. This cross-linkage model describes the crack-bridging effect of the entire multifilament yarn at the single filament level. According to the model, each filament possesses a specific deformation length depending on its position in the cross-section of the yarn. This deformation length depends on bond characteristics between single filament and cementitious matrix, which vary with age. Characteristic values of the model were computed from load-crack width curves obtained from the yarn pullout tests. The changes in the microstructure were represented by the characteristic values of the model.

1. Introduction

Textile-reinforced concrete (TRC) is a composite construction material consisting of high performance, multifilament yarns of glass or carbon fibre and a matrix of fine-grained concrete. In existing applications of TRC, chiefly fabrics made of alkali resistant glass fibres (so-called AR glass) are used. The main features of TRC are its toughness, high tensile strength and pronounced ductile behaviour. TRC can be applied both in the fabrication of new structures and in the strengthening and repair of structural elements made of reinforced concrete or other traditional materials as well [1].

Most of these applications require that the high tensile strength and toughness of TRC do not degrade significantly with increasing age. Changes in the mechanical performance of the composite can result from deterioration of the reinforcing AR-glass fibres themselves due to the attack of OH^--ions in the pore solution (e.g. [2–4]), the static fatigue (delayed failure) of the glass fibre under sustained load in the highly alkaline environment (e.g. [5–8]), and changes in the bond between matrix and fibres (e.g. [9–12]). The last-mentioned effect results mainly from the densification of the matrix adjacent to the filaments and the intensified fibre–matrix bond with continued hydration. Furthermore, accumulation of hydration products at the interface between filaments and matrix and in the empty spaces between the filaments of multifilament yarn (bundle filling) can precipitate these changes in the mechanical performance.

In this paper the contribution of individual damage mechanisms to degradation of crack-bridging behaviour of multifilament yarn and their interaction is shown by means of a simple phenomenological model. The model is based on experimental data obtained from multifilament yarn pullout testing and micro-structural investigation of the yarn–matrix interface [14–16]. Some of this data is briefly presented in the experimental part of this article.

2. Experiments

2.1. Test method – double-sided yarn pullout

The crack-bridging performance of multifilament yarn was evaluated using double-side pullout testing. In these pullout tests various artefacts resulting from a complex geometry of technical textiles are excluded, thus allowing a straightforward interpretation of the results obtained. Doubly symmetrical, bone shaped prisms

* Corresponding author. Tel.: +49 351 463 35 920.
E-mail address: MECHTCHERINE@tu-dresden.de (V. Mechtcherine).

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