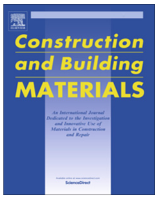
Construction and Building Materials 181 (2018) 325–334

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat



Influence of environmental loading on the tensile and cracking behaviour of textile reinforced cementitious composites

M. De Munck [a,*], M. El Kadi [a], E. Tsangouri [a], J. Vervloet [a], S. Verbruggen [a], J. Wastiels [a], T. Tysmans [a], O. Remy [b]

[a] *Department Mechanics of Materials and Constructions, Vrije Universiteit Brussel (VUB), Pleinlaan 2, 1050 Brussels, Belgium*
[b] *CRH Structural Concrete Belgium nv, Marnixdreef 5, 2500 Lier, Belgium*

HIGHLIGHTS

- Compared to freeze-thaw cycles, heat-rain cycles cause a larger degradation of the mechanical properties.
- Hydration of unreacted cement particles during heat-rain cycles leads to further strength development.
- The stress level at which cracks are formed diminishes after being subjected to environmental loading.

ARTICLE INFO

Article history:
Received 15 March 2018
Received in revised form 4 June 2018
Accepted 5 June 2018

Keywords:
Cracking stress
Digital Image Correlation (DIC)
Durability
Freeze-thaw
Heat-rain
Tension tests
Textile reinforced cementitious composites (TRC)

ABSTRACT

In outdoor applications, textile reinforced cementitious composites (TRCs) are susceptible to varying weathering conditions. To guarantee their performance during the entire life-time, it is necessary to evaluate the long-term behaviour. In this paper, the mechanical behaviour of reference specimens is compared to aged specimens, which are subjected to heat-rain and/or freeze-thaw cycles. Results show that subjection to heat-rain cycles leads to a larger degradation of the tensile behaviour compared to subjection to freeze-thaw cycles. Besides the macroscopic tensile behaviour, also the cracking behaviour is evaluated. Analysis shows that cracks are formed at lower stress levels after being subjected to environmental loading.

© 2018 Published by Elsevier Ltd.

1. Introduction

In the last decades there is a strong growing interest in textile reinforced cementitious composites (TRCs). Reinforcing a cementitious matrix with a non-corroding technical textile leads to a promising material for a variety of applications. This material combination has already proven its effectiveness for repairing and/or strengthening of reinforced concrete structures [1–3], but also for the realization of slender structures, such as facade panels [4–6] and pedestrian bridges [7].

Carbon, glass, basalt, and even natural fibres are used for reinforcing cement based matrices. Because of their relatively low cost, glass textiles are the most economical solution. However, in alkaline environments the glass fibres are attacked and dissolve in the cementitious matrix. To resolve this, Alkali-Resistant (AR) glass fibres are most commonly used. During their service life in outdoor applications, TRCs are subjected to varying weathering conditions: wind, rain, freeze, heat, etc. To guarantee the performance of a TRC during its entire lifetime it is important to understand the long-term behaviour under environmental loading conditions. Several studies have been performed to assess the durability of TRCs reinforced with AR glass fibres [8–12]. Some evaluated the effect of the matrix on the long-term behaviour [13–15], showing that the alkalinity of the matrix plays a key role [13]. Others focused on the matrix-fibre bond, as well for static loading [8,16], as under sustained loading [17]. Besides this experimental work on the degradation of aged TRCs, different research teams modelled the loss of performance after accelerated ageing conditions [18–21]. This state-of-the-art has highlighted that TRCs are a promising material with a good resistance to aggressive environments.

---

* Corresponding author.
E-mail address: matthias.de.munck@vub.be (M. De Munck).

https://doi.org/10.1016/j.conbuildmat.2018.06.045
0950-0618/© 2018 Published by Elsevier Ltd.

Up to now, accelerating the ageing of TRC specimens was mainly done by immersion in hot water for several days. To simulate the influence of varying weathering conditions, a cyclic environmental loading, such as heat-rain (HR) and freeze-thaw (FT) cycles is more adequate. In the past, few research teams have performed durability cycles on TRC specimens [22,23]. Focus of their work was put on the degradation on the stiffness and strength properties. Their main findings were that the stiffness was not influenced, but that the tensile capacity and cracking strength were affected after being subjected to FT or HR cycles. The degradation after applying both FT and HR cycles (FTHR) was not investigated. Another important aspect that wasn't studied up to know is the cracking behaviour of accelerated aged TRC specimen. The tensile behaviour of TRC is strongly defined by the occurrence of cracks.

TRC is characterised by a linear behaviour in compression, defined by the characteristics of the mortar, and a non-linear behaviour in tension (Fig. 1). This tensile non-linear behaviour has been studied by various research groups [24–28], leading to the definition of three different stages and some distinctive parameters. The first stage is a linear stage, the stiffness E_1 during this stage is strongly dependant on the stiffness of the matrix. Once the tensile stress of the matrix is exceeded, a macrocrack is formed. From this point, called the first cracking stress σ_{crack}, a significant decrease in stiffness is observed [24]. After redistribution of the loads, a new crack is formed at another location. This process repeats itself until the matrix is fully saturated with cracks. The formation of these cracks is identified as the multiple cracking stage. Necessary condition to attain this multiple cracking stage is related to the fibre volume fraction. A certain amount of fibres needs to be inserted to obtain strain hardening and a ductile tensile behaviour. The minimum amount of reinforcement is defined by the critical fibre volume fraction, dependent on the E-modulus and the ultimate strength of both the matrix and the fibres [29]. The last branch in the tensile behaviour is the post-cracking stage. No further matrix cracking occurs. Since the load is carried only by the fibres in this third stage, the stiffness E_3 is solely dependent on the stiffness of the textile reinforcement and the fibre volume fraction [30]. Induced by tensile rupture of the textile, a cementitious composite fails at its ultimate stress $\sigma_{ultimate}$, at a strain largely exceeding the tensile failure strain of the matrix.

To contribute to the knowledge on the long-term structural and cracking behaviour of TRCs, this paper quantifies experimentally the degradation of TRCs under environmental/ageing conditions. In this study, in total 30 rectangular specimens with dimensions of 475 mm × 50 mm × 10 mm were subjected to 100 FT-cycles, 50 HR-cycles, and a combination of both cycle types, following the European standard NBN EN 12467 [31]. Afterwards uniaxial tensile tests were performed to compare the tensile behaviour of unaged and aged specimens. To have an accurate measurement of strains and displacements Digital Image Correlation (DIC) was used. Doing so the influence of weathering conditions on the tensile behaviour, and the most important design parameters in particular was identified. The resulting observations were linked to changes within the microstructure of the material by using a Scanning Electron Microscope (SEM). Using DIC also enabled to map crack patterns and to determine crack widths and crack spacings. Conclusions were drawn on both the structural and cracking behaviour of TRC subjected to different durability programs (FT, HR, FTHR).

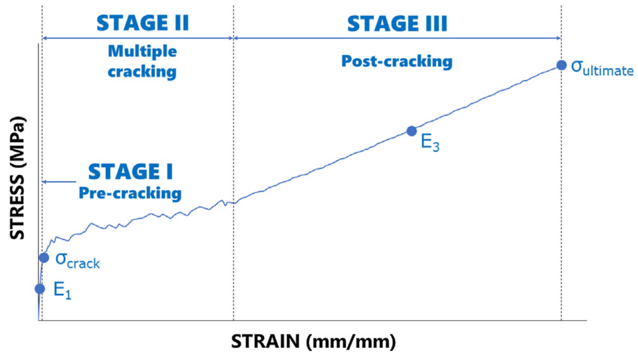


Fig. 1. Characteristic tensile behaviour of TRC.

2. Materials & methods

2.1. Material characteristics

The investigations were performed on 30 similar specimens made from one specific material combination, obtained by reinforcing a premix mortar with multiple layers of alkali-resistant (AR) glass fibre textiles. The material properties of both the mortar and the textile are described below.

2.1.1. Mortar

For the matrix of the composites a commercially available mortar was used. It is a Portland cement based mortar to which a series of polymers was added in order to obtain a shrinkage-compensated mortar. The maximum grain size equals 0,5 mm. For preparation of the mortar, a water to binder mass ratio of 0,125 was considered.

The main mechanical characteristics were determined by performing six flexural and twelve compression tests following the European Standards (EN 196-1:2016) [32]. The flexural strength $f_{ct,f}$ and compressive strength f_{cc} are listed in Table 1.

2.1.2. Textile reinforcement

The cementitious matrix is reinforced with a technical textile made of AR glass rovings [33], polymer coated and woven into an orthogonal mesh with a surface weight of 220 g/m^2 and a mesh opening of 6 mm in both directions (Fig. 2). The textile has a nominal tensile strength of 2500 N per 50 mm.

2.2. Test specimen preparation

The experiments were carried out on similar prismatic TRC specimens, cut out of larger rectangular plates, fabricated using the hand lay-up technique. In a formwork with inner dimensions of 500 mm × 500 mm × 10 mm, a first layer of the mortar was spread out. Like this, a cover thickness of 3 mm was ensured. Afterwards, the reinforcement fibre net was placed and impregnated in the mortar. Next a second layer of mortar was smeared and a

Table 1
Structural properties of the used mortar.

	$f_{ct,f}$ (MPa)	f_{cc} (MPa)
Average	4,96	29,60
Standard Deviation	0,56	4,49

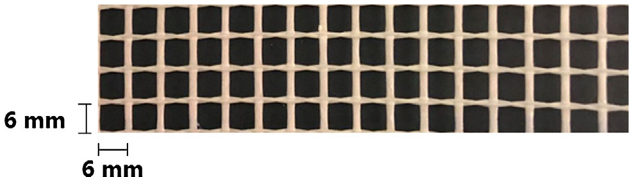


Fig. 2. An AR glass textile with a mesh size of 6 mm was used.

Download English Version:

https://daneshyari.com/en/article/6712307

Download Persian Version:

https://daneshyari.com/article/6712307

Daneshyari.com