Construction and Building Materials 170 (2018) 13–19

Contents lists available at ScienceDirect

Construction and Building Materials

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

The usage of newly developed glass fibre in cement structure and their characterization

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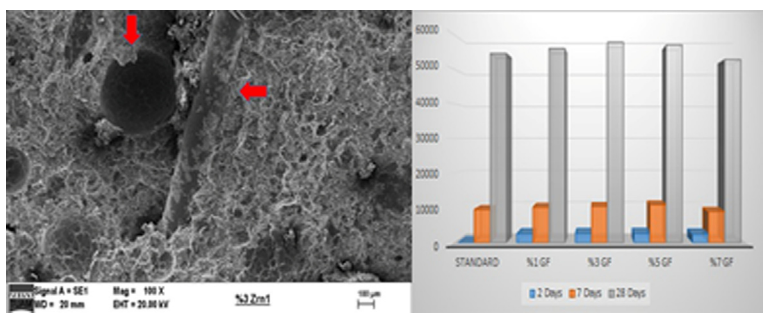
HIGHLIGHTS

- $SrO–Mn_2O_3–Fe_2O_3–MgO–ZrO_2–SiO_2$ (SMFMZS) glass fibres were incorporated into cement matrices.
- Compressive strength value was increased to 2.610 N/mm^2 with 3 wt% of Zrn1 fibres.
- Good chemical compatibility between fibre and cement structures was observed via SEM.
- Zrn1 fibres was a good candidate for cement reinforcement.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 6 September 2016
Received in revised form 25 February 2018
Accepted 6 March 2018

Keywords:
Glass fibre
Reinforcement
Cement
Characterization
Microstructure
Mechanical properties

ABSTRACT

In this work, recently developed Zrn1 glass fibres belonging to the $SrO–Mn_2O_3–Fe_2O_3–MgO–ZrO_2–SiO_2$ (SMFMZS) system have been used as reinforcing materials in cement. The highest (2.610 N/mm^2) compressive strength value was obtained with the addition of 3 wt% of Zrn1 fibres into Portland cement. The microstructural behaviour of these fibres along with commercially available ones in the cement structure were investigated using a scanning electron microscope (SEM). Microstructures were fully compatible with mechanical results obtained. Eventually, it was determined that Zrn1 fibre can be a good candidate for cement reinforcement leading to high strength values.

1. Introduction

High strength glass fibre-reinforced concrete or glass fibre-embedded cement can be obtained by adding alkali-resistant glass fibres into the matrix. This type of concrete consists of cement, mortar, aggregate and uniformly-dispersed fibres, which enhance the concrete durability and also act as crack preventing components by small addition [1]. Fibre-reinforced concrete products have indicated considerable improvement since 1980 s in the construction industry. Steel, glass or plastic fibres have been employed for their production with different geometric shapes and lengths nowadays [2].

Concrete is the most conventional and durable material being suitable for building countertops, planters and sidewalks as well as working well for more artistic uses, such as statuary, but even

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https://doi.org/10.1016/j.conbuildmat.2018.03.062
0950-0618/

something as strong as concrete can use a little help now and then. However, it has some disadvantages like low strength and brittleness. If exposed to tensile load, the concrete elastically deforms. Increasing elastic tension will lead to micro-cracking and complete fracture of unreinforced base matrix [3]. One way to increase the strength of concrete, while making it lighter, is to incorporate glass fibres as reinforcing agents. During the usage of the glass fibres in such a composite structure, both physical and chemical properties of fibres and their surroundings can be protected [4,5]. The most significant advantages of such a composite material are to obtain considerably improved structure with respect to both glass and concrete's properties supplied by their own. Fibers can be described as the main load carrying elements [2]. Matrix surrounding fibre is protecting them from environmental effects, and also known load-conducting host that makes stable fibers' motions in it. In particular, excess amount of fibres in the matrix can increase tensile strength easily. Moreover, the fibres provide more flexibility without any cracking in the concrete if they are coated with polymer-based materials. The necessary amount of fibre for better alkaline resistivity of concrete is an important issue. Because of having favourable physical properties and relatively low cost of the glass fibres, they are located in a most suitable group of the selections [6].

The first glass group used for fibre production is referred as soda-lime-silica glass or A-glass which is not resistant to alkali environment in concrete. Borosilicate glass (E-glass) with low alkali oxide (<2%) content has been developed instead and the first continuous glass fibre was prepared with this group [7]. Especially, highly alkali resistant glass fibres can be evaluated in the composite structures of the concrete for the purpose of reinforcement [8]. It is a very well-known fact that concrete can be damaged due to alkali-silica reactivity (ASR) [5].

As well as design for the desired properties of composite, the chemical structure of glass fibres can also be a crucial factor [9]. Accordingly, the selection of suitable glass fibre is very important to produce glass fibre-reinforced concrete structure. Because it may change the properties such as strength, elastic modulus and alkali endurance. In a previous study, the production of fibres with high chemical and abrasion-resistance was made by using the SMFMZS glass system. According to the chemical durability test results of fibres obtained, it was reported that such compositions had more alkali resistance than the commercially available ones [10].

The aim of the present work was to use the SMFMZS system glass fibres in the cement structure. Firstly, commercially available E-glass fibres were used as standard and incorporated into cement structure to enhance overall mechanical properties. During the preparation of specimens, the vital point was to employ an additive called as ADVA Flow 501 being synthetic-based carboxylate polymer, which is necessary to obtain stable product under restricted condition where it can be selected to give a considerable amount of fluidity and durability to the cement [11,12]. With the help of this additive, the water content can also be remarkably decreased. The manufacture of cement without segregation and loss of endurance, the low rate of water/cement was provided with its use. When some studies have been conducted about cement reinforcement with glass fibres, the amount of glass fibre in concrete bodies were investigated up to 3 wt% [13–15]. Glass fibre content is a crucial factor to contribute the mechanical properties similar with mortars [16].

In the current work, commercial fibres were added to cement structure up to 2%. After 7 days of curing in the present situation, it was observed that the strength values were increased compared to un-reinforced sample. Hence, it was worked up to 7 wt% with Zrn1 coded fibre belonging to the SMFMZS system embedded to the cement structure as a reinforcing material. Moreover, it was pointed out that cracks propagated to the Zrn1 fibres and the direction of cracks changed due to fibre reinforcement. Cement samples, which contain 1, 3, 5 and 7 wt% Zrn1 glass fibres, were prepared in accordance with TS EN 196-1 standard procedure. SEM and EDX characterization techniques were applied to the cured samples as well as mechanical testing. This investigation also aims to clarify the structure-property relationship of the resulting glass fibre-reinforced cement (GFRC) samples.

2. Experimental procedure

First of all, glass fibre-reinforced composite materials were prepared with polymeric silane-coated (0.5, 0.8, 1 wt%) and un-coated commercial glass fibres (0.3, 0.5, 0.8, 1 and 2 wt%). Hence, the effect of polymeric material on the surface of commercial glass fibres was determined in cement structures. To obtain high performance composite, compositional studies were carried out with the chemical additive (CA) and commercial glass fibre (F). ADVA Flow 501 was used as a chemical additive in this study. Cement specimens were prepared with 450 g cement + 1350 g SiO_2 sand + 6.75 g ADVA Flow 501 (1.5 wt% of cement) and commercial glass fibres (0.3, 0.5, 0.8, 1 and 2% of the total weight).

Zrn1 coded fibre-reinforced cement samples were also produced. Glass fibres (GF) were used at the amounts of 1, 3, 5, 7 wt % and TS EN 196-1 standard procedure was applied to cement specimens. Besides the glass fibre ratio, the water/cement ratio (W/C = 0.5) was calculated and kept constant for all the mortar combination. All the mixtures were prepared homogeneously in the automatic mixing apparatus with a constant rotational speed, period and rotation time. Atom Teknik brand mixer was employed in the preparation of test specimens. Homogeneous mixtures obtained were poured into the plastic moulds (Fig. 1), which afterwards were exposed to shock 60 times during 1 min. process time. The procedure was applied to all the moulded samples kept in the curing cabinet set a constant temperature and moisture for one day. Then, composites were dropped into the water at constant temperature (20 ± 1 °C).

Three-point bending and compressive strength tests of GFRC samples were performed according to EN 197-1 standard at the end of 2, 7 and 28 days-cure. Atom Teknik brand device was used for mechanical test.

The test samples of each group dropped into the water for 2, 7 and 28 days. Then, uniaxial compressive strength device which has $4 \times 4\ cm^2$ area and the movement speed of 2400 ± 200 N/s was used. After this analysis, strength values obtained from the device was calculated by;

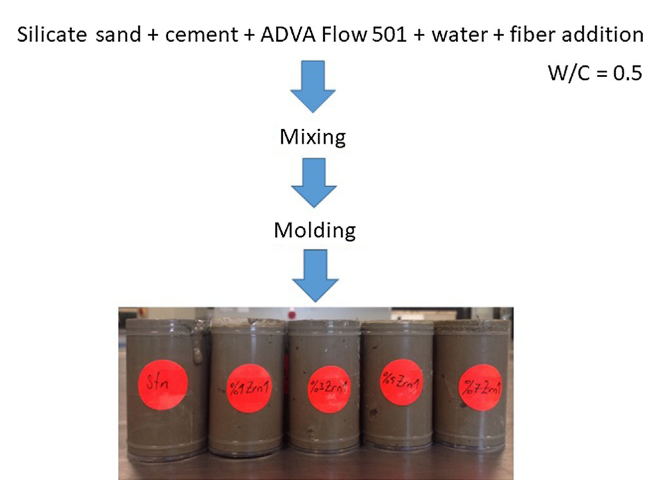

Fig. 1. Fiber reinforced cement production process.