MECHANICAL PERFORMANCE OF INORGANIC POLYMER-BASED MORTARS WITH GLASS FIBRE REINFORCED POLYMER BARS

Pavel Leonardo LOPEZ GONZALEZ[1], Valter CARVELLI[2], Yiannis PONTIKES[1]

[1] Department of Materials Engineering, KU Leuven, 3001 Heverlee, Belgium
[2] Department A.B.C, Politecnico di Milano, 20133 Milan, Italy

pavelleonardo.lopezgonzalez@kuleuven.be, valter.carvelli@polimi.it, yiannis.pontikes@kuleuven.be

Introduction

Glass fibre reinforced polymer (GFRP) bars have found a place in specific structural applications as concrete reinforcement[1] thanks to certain advantages regarding chemical attack behaviour, corrosion resistance, non-conductive characteristics, high strength/weight ratio and production simplicity[2]. However, the negative effect that elevated temperatures have on the mechanical performance of these bars constrains their spread adoption[3]. In contrast, inorganic polymers (IP) are characterised by a low thermal conductivity, good mechanical performance and stability at elevated temperatures[4]. The aim of the study is the preliminary evaluation of the mechanical interaction between an IP mortar made by alkali activated fayalite slag (FS) and the embedded GFRP bars used for reinforcement, defining the bearing capacity of the dual system under flexural loading.

Materials and Methods

Four mortar specimens, reinforced with an unidirectional E-glass fibre reinforced polymer (GFRP) bar of diameter 8 mm, were tested in a three point bending setup after 33 days of curing at 25°C and 90% relative humidity. The dimensions of the samples and test setup are presented in Figure 1; load was carried out using a Dartec hydraulic machine (maximum load capacity 5000 kN; 100 kN subcell) with displacement rate set to 1 mm/min. Three of the specimens were made of FS mortar and one was made of traditional Portland cement-sand mortar (OPC); mixture proportioning for each set is presented in Table 1. Digital image correlation technique (DIC) was used to track the 2D full-field displacement and to calculate the strain developed on a lateral side of the specimens during testing. The LIMESS system by “Messtechnik und Software GmbH” was adopted acquiring 2 images per second of the side, with an image size of 1392 x 1040 px. The displacement and strain fields were obtained using VIC-2D software[5] (subset size 40, step size 3, filter size 15).

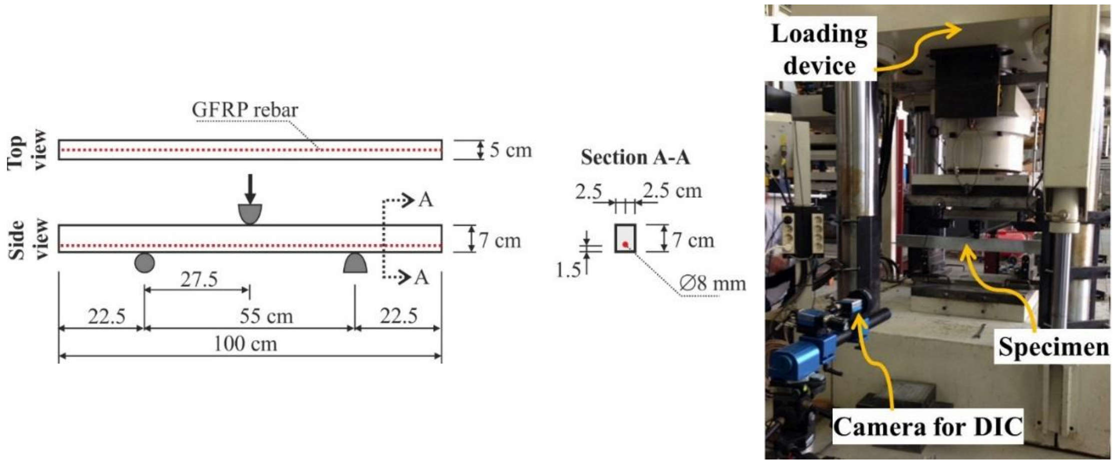

Figure 1: Dimension of reinforced beam specimens and 3-point bending set-up (left) general overview of test set-up (right)

Table 1: Mortar mixture proportions expressed as wt%

FS mortar mixture		OPC mortar mixture	
Material	wt%	Material	wt%
Fayalite aggregates	64.3	Cement	22.7
Finely milled fayalite	27.3	Coarse sand	47.5
Activating solution SiO_2/K_2O= 1.6 molar, H_2O/K_2O= 14.9 molar	8.4	Fine sand	20.8
		Water	9.0

Results

The global response of the beams is summarised in Figure 2. The accuracy of the DIC measurement was assessed comparing the displacement of a small portion of the surface's centre to the mid-span displacement measured by the stroke of the loading device. The good agreement for both OPC and FS mortar measurements is detailed in Figure 2. Fayalite-slag mortar specimens tested to establish the strain fields presented shrinkage cracking at the upper surface (around 5 mm depth in most cases); its impact was neglected considering that cracking was located in compression zone during testing. A qualitative analysis of failure modes, exhibited by the GFRP reinforced specimens tested, showed a typical shear failure of the beams: an expected outcome considering the lack of shear reinforcement. A specimen after failure is shown in Figure 3. Clear similarities in the interaction between OPC mortar and GFRP rebars, and between FS mortar and GFRP rebars during bending were corroborated by the strain field analysis. GFRP rebars did not suffer any visible damage during the test.

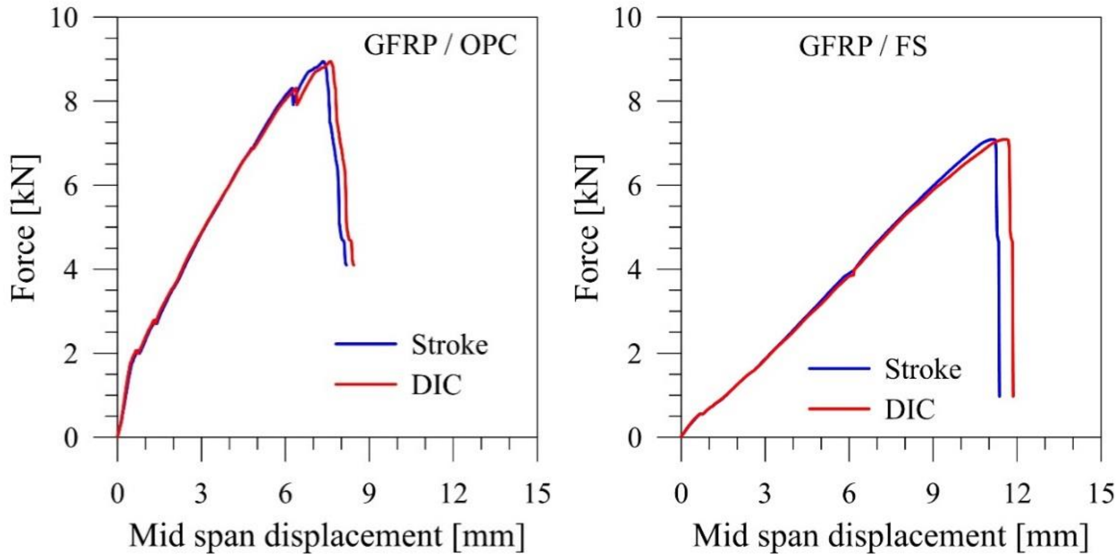

Figure 2: Bending test of reinforced beams. Force *vs.* mid span displacement measured by the stroke and DIC, for a GFRP reinforced OPC (left) and FS beam (right)

The specimens of FS mortar reinforced with GFRP bars bore a maximum average load of 6.50 kN, the correspondent mid-span displacement was 9.3 mm in average. For the reinforced OPC-mortar specimen the maximum load was 8.95 kN, 38% higher than that obtained for FS specimens, with a displacement of 7.4 mm. The difference is motivated by the high compressive strength obtained for the OPC mortar (almost 72 MPa in contrast to 45 MPa for the FS). Nevertheless, since nature and composition of mortars were inherently different, their mechanical behaviour comparison has to be kept only in qualitative terms; an eventual replicate test using mortars with equivalent compressive strength could provide more details into the actual performance and possibilities of alkali activated FS.

Figure 3: Map of the maximum principal strain field developed during 3-point bending test using DIC analysis on a reinforced FS-mortar specimen (left) and typical failure mode (right)

Conclusions

Fayalite slag (FS) mortars tested during this study presented flexural strength values high enough to be considered suitable for certain structural applications. Nevertheless, optimisation of alkali activator dosage, compositional mixture and curing method can improve the mechanical characteristics of this fayalite-based inorganic polymer. The load bearing behaviour and strain field developed by FS mortars reinforced with glass fibre reinforced polymer (GFRP) bars proved to be analogous to that established for traditional Portland mortars reinforced in the same way. This finding opens the possibility for the application of current known structural design principles to this new composite IP-GFRP system. Although comparison with OPC mortar is until certain extent possible, as in the case of mechanical interaction with the reinforcement bars, the mortar mixtures types used in this research are inherently different and developed to represent average recipes found in practice, not trying to achieve comparable mortar properties (neither strength nor workability). Finally, the overall mechanical performance information gathered in this study confirms the potential of fayalite slag as mortar for IP-GFRP reinforced elements and encourages research of its behaviour when exposed to transient high-temperature conditions.

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