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The Effect of Glass Fiber Reinforcement on Flexural Strength of Lime-Based Mortars

J. Trejbal [1,*], L. Kopecký [1], Š. Potocký [2], J. Fládr [1]

[1] *Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29 Prague, Czech Republic*

[2] *Institute of Physics AS CR, v.v.i., Cukrovarnická 10, 16200 Prague, Czech Republic*

[*] *jan.trejbal@fsv.cvut.cz*

Abstract: The goal of the presented work was to investigate the effect of glass fiber reinforcement amount on the flexural strength of lime-based mortars. Two different amounts were added into the mixtures so that the influence of fiber reinforcement on the strength of the mortars could be assessed. The fibers were added in a concentration of 1.8 kg/m^{3}and 93.75 kg/m^3, representing poor and rich mixtures. Destructive four-point bending tests were chosen as a proper indicator of the mortar performance. The maximum load-bearing capacity reached during the testing was equal to 1.16 kN (± 0.06 N), 1.61 kN (± 0.07 N) and 2.08 kN (±0.19 N) in the case of plain reference (R), poor in fibers (MS1) and rich (MS2) mortar, respectively.

Keywords: Glass Fiber; Lime-Based Mortar; Four Point Bending Tests; Flexural Strength; Reinforcement.

1 Introduction

In recent years, there has been an increased interest in the application of microfibers to composite materials. In general, fiber reinforced concrete is already widespread [1–3], however there are a many types of materials with brittle matrix which require reinforcement with fibers, e.g. lime mortars for reconstruction of historical monuments [4,5]. The use of glass fibers or basalt fibers is suitable for their suitable mechanical properties, high specific surface (this allows efficient transfer of stress from the composite matrix into the fibers) and relatively low cost [6,7]. On the other hand, their low adhesion with the surrounding matrix (low interfacial bond) is very frequent. Therefore, it is advisable to modify the fiber surface, e.g. by means of plasma termination, chemical treatment, etc. [8,9].

At first, maximum fiber volume content in the mortar mix must be determined. Increasing amount of the fibers causes enhancement of flexural strength, tensile strength and durability of the mortar, but the mortar workability is decreasing. The goal of the presented work was to find minimum and maximum bounds regarding an acceptable amount of fibers. For the minimum amount of fibers the manufacturer recommendations were pursued (1.2 – 1.8 kg/m^3) [10]. The maximum amount was established experimentally. The mixing consisted of a careful mix homogenization, followed by application according to traditional procedures. The mechanical properties of such prepared mortars were subjected to a conventional material testing.

2 Experimental Methods

2.1 Prepared Mortar Mixtures

As a model mixture, lime mortar with metakaolin was used in the study and three types of mortars were prepared (marked R, MS1, MS2) and these differed mainly fiber amount. Type marked R was prepared as a reference material without fibers. The amount of aggregates, binder and water was identical for all three mixtures. The amount of glass fiber and plasticizer was different. Mass percentage composition of these mortars is shown in Tab. 1. Glass fibers (Cem-FIL® AntiCrack HD^{TM}) made of alkali resistant enamel, were

Tab. 1: Mass portions of individual components in the studied mortars.

	lime CL90 [%]	metakaolin [%]	sand ST2 [%]	sand STJ25 [%]	water [%]	plasticizer [%]	fibers [%]
R	14.54	4.85	35.85	22.29	22.47	0	0
MS1	14.51	4.81	35.76	22.22	22.42	0.21	0.07
MS2	14.15	4.72	34.90	21.70	21.90	0.38	2.25

Tab. 2: Glass fiber parameters.

	length [mm]	tensile strength [MPa]	elastic modulus [GPa]	density [g/cm^3]	diameter [µm]	amount [pcs/kg]	ductility [%]
filament	12	1700	72	2.68	14	200×10^6	2.4

used as micro reinforcement. The fiber surface was treated by water solvable industrial glue to protect their surface from damage, to guarantee perfect fiber dispersion in the mixture, and to improve bond with cement or lime-based matrix. The industrial glue was made of starch-based material; basic glass fiber parameters are summarized in Tab. 2 [10].

2.2 Tested Specimens

Six samples of each batch were tested to obtain statistically representative data. The dimensions of the tested specimens were 40 × 40 × 160 mm. The glass fibers were added into the mixtures together with aggregates in the case of mortar type MS1 and separately into the water in case of mortar type MS2. The samples were storied in the common laboratory conditions at room temperature and relative humidity about 95 %. The samples were tested after 28 days of curing and hardening.

2.3 Four-Point Bending Test

Destructive four point bending tests were chosen as a proper indicator of mortar performance. The testing was carried out using Heckert FP 100 loading frame at the rate of 0.05 mm/min in case of mortar type R and 0.15 mm/min in case of MS1 and MS2 mortars. Deformation was monitored using two shift sensors Essa (final displacement value is averaged both the sensors). The span between supports was 120 mm and 60 mm between the movable supports that loaded the specimens. The diameter of the supports made of steel was equal to 11 mm. The presented results, summarized in Fig. 2 and Fig. 3, were averaged from 6 measurements for each mortar type.

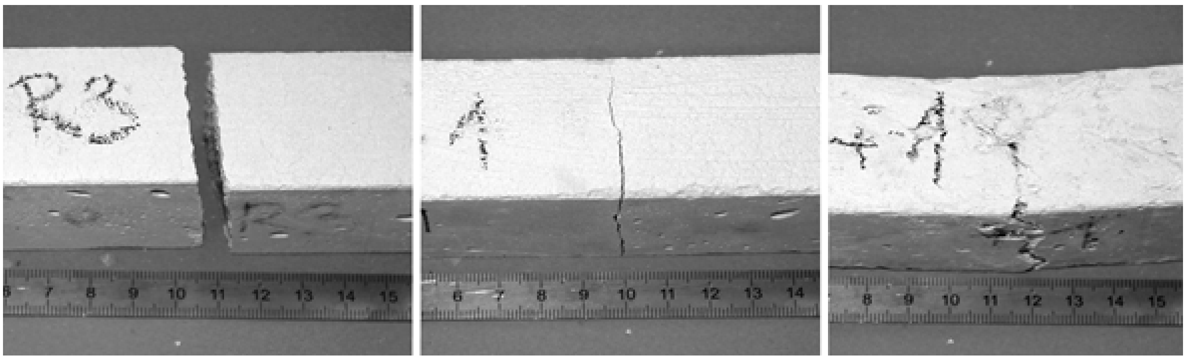

Fig. 1: Cracking pattern after the destructive four-point bending tests (R left, MS1 center, MS2 right).

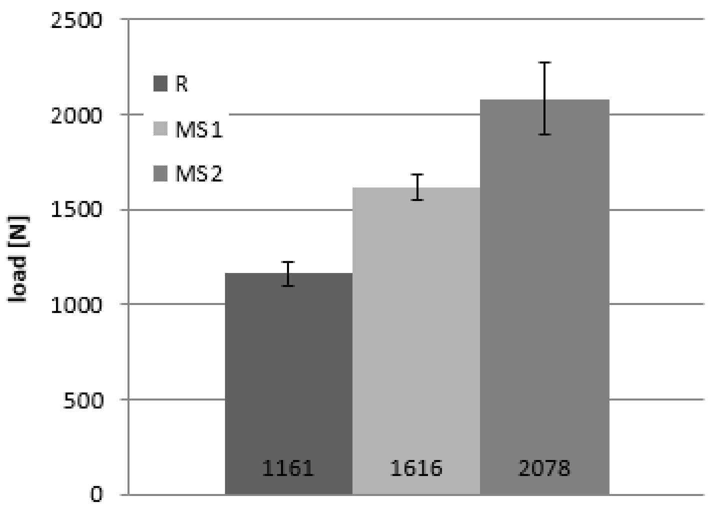

Fig. 2: Maximum load-bearing capacity obtained during four-point bending tests.

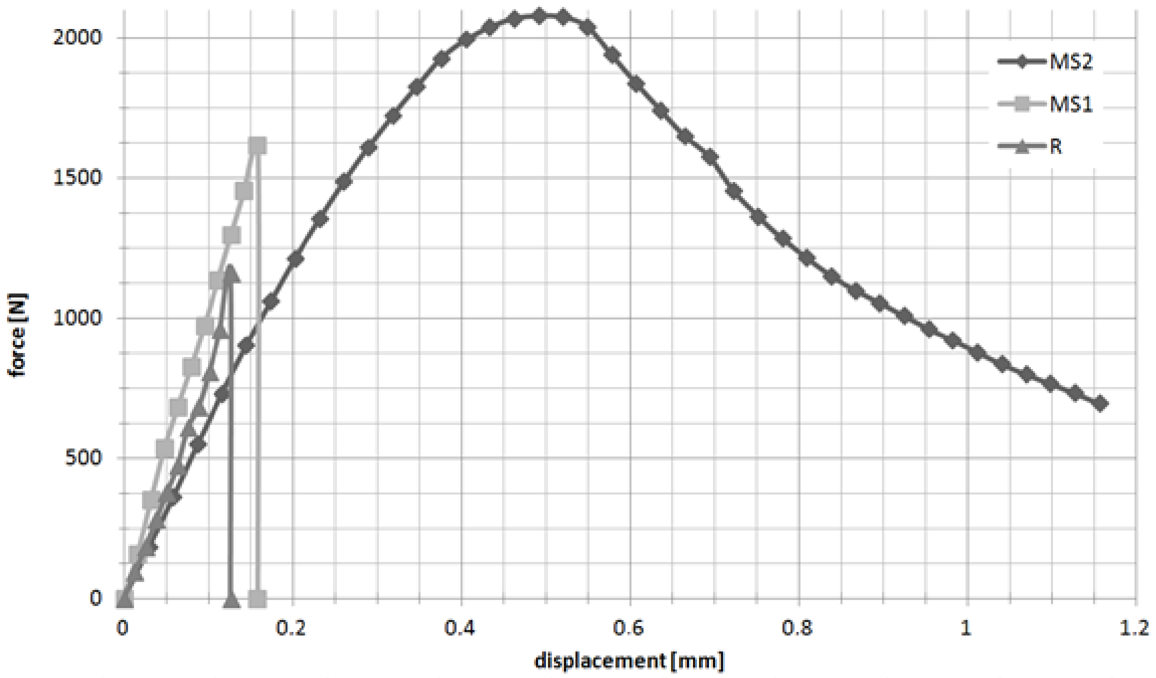

Fig. 3: Load-displacement diagrams obtained during four-point bending tests.

3 Result and Discussion

The results averaged from six measurements on 40 × 40 × 160 mm specimens representing each mix indicate that the dependence between the load and displacement is linear-brittle in the case of R and MS1 mortars. On the other hand the MS2 mortar rich in fiber content exhibited multiple cracking reflected by the post-linear hardening and after crack localization a slow material softening was present. Such behavior can be explained by an effective bridging of cracks through the fibers and the pullout of the individual fiber required a significant amount of energy [1]. Behavior of loaded specimens is shown in Fig. 3.

The maximum load-bearing capacity reached during the testing was equal to 1.16 kN (± 0.06 N), 1.61 kN (± 0.07 N) and 2.08 kN (± 0.19 N) in the case of R, MS1 and MS2 mortar, respectively. The maximum load-bearing capacity is shown in Fig. 2. It is evident from the load-bearing capacity results that mortar type MS2 rich in fiber content is uneconomical. MS2 in comparison with MS1 contains very high amount of glass fiber (52 times more), but the load-bearing capacity is higher 1.25 times only. Cracking shapes incurred after the destructive four point bending tests are shown in Fig. 1.

4 Conclusion

Three types of lime-based mortar with different amount of glass fiber reinforcement were tested – the reference plain mortar without any reinforcement, MS1 and MS2 containing 1.8 kg/m^{3}and 93.75 kg/m^3 glass fibers (Cem-FIL® AntiCrack HD^{TM}), respectively. The amount of aggregates, binder and water was identical for all three mixtures. The results of four-point bending tests demonstrated that the flexural strength increased with the addition of glass fibers and the fiber-rich mix exhibited significant increase in fracture energy due to formation of smeared cracking.

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