EFFECT OF 40-DAY SEAWATER TREATMENT OF SPANISH BROOM FIBERS ON THE MECHANICAL PROPERTIES OF REINFORCED CEMENT MORTAR

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Abstract: *Recently, there has been increasing interest in natural fibers as reinforcement for cement composites. Natural fibers are low-cost, low-density, non-abrasive, biodegradable, and non-toxic materials. The limits for the application of natural fibers are their high absorption of water, improper adhesion to a matrix material, high dispersion of mechanical properties, and decomposition of fibers in cement composites due to the influence of alkalis. Some of these problems can be overcome by treating the fibers. The most common chemical treatment method uses alkaline, which dissolves lignin and hemicellulose in fibers. Treatment of fibers with seawater, which is a more natural and environmentally friendly process, can be used as an alternative to chemical treatment. This paper considered Spanish broom fibers treated with seawater for 40 days. After the seawater treatment, half of the Spanish broom branches were immediately washed, and the fibers were separated under tap water. The other half of the branches were left to dry for a few days, and the fibers were washed with tap water after separation from the dry woody part. The fibers of the second group broke under a low tensile force. Thirteen series of cement mortars were made: a reference mortar and mortars reinforced with fibers of 1, 2, and 3 cm in length and in amounts of 0.5% and 1% of the total volume. Compressive strength and flexural strength were tested on 28-day-old specimens. Reinforced mixtures had weaker mechanical properties than the reference mixture. Specimens reinforced with fibers that were immediately washed in water had a 3–8% higher flexural strength, and the compressive strength of the reinforced specimens was almost the same. The mixture with the first group of fibers (1 cm long and added to the mixture in a ratio of 0.5%) achieved the highest strength of all reinforced specimens.*

Keywords: *spanish broom fibers; cement mortars; mechanical properties; seawater maceration*

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1. INTRODUCTION

Industries are looking for natural fibers that can replace artificial fibers in composite materials. Natural fibers are biodegradable and non-toxic and possess high strength and stiffness. They are chemically composed of cellulose, hemicellulose, lignin, ash, and wax. The environment, geographical factors, and the method of fiber extraction affect the chemical composition of fibers (Hamada et al. 2023). Natural fibers undergo various pretreatment methods in order to improve their properties and durability. Pretreatment methods include physical and biological methods, but chemical treatment is by far the most commonly used method. Chemical treatments improve the surface characteristics of fibers, but they are expensive and can harm the environment (Ishak et al. 2009). Biological treatment with seawater is a low-cost, safer, more natural, and environmentally friendly process. Ishak et al. (2009) found that sugar palm fibers treated with seawater during a 30-day period have better toughness and flexural strength than untreated fibers. Yousif et al. (2012) tested kenaf fibers treated with four different solutions: water, salt water, diesel, and motor oil. They concluded that the most suitable environment for natural fibers is a 6% solution of salt water. Juradin et al. (2019) found that cement mortars reinforced with fibers of Spanish broom shoots that underwent a 28-day seawater maceration and a 19-day maceration in a 5% NaOH solution acquired the best mechanical characteristics of all the specimens tested. Jiang et al. (2021) treated rice husk and rice straw fibers with seawater and concluded that seawater modification has the potential to improve the properties of the fibers.

The objective of this paper is to investigate the influence of treating Spanish broom fibers with seawater for 40 days on the mechanical properties of reinforced cement mortar/micro concrete. The influence of the amount and length of the fibers on the properties of the mortar is also examined.

2. MATERIALS AND METHODS

2.1. Preparation of Spanish broom fibers

Spanish broom (*Spartium junceum L.)* is a shrub plant that grows in the Mediterranean area. As a wild or cultivated plant, it usually grows 1–1.5 meters in height (**Figure 1**). The plant's branches are very sturdy and have two basic layers: a woody inner layer and an outer layer with fibers and skin. Compared with those of other plants, the fibers of Spanish broom have a low specific weight (Juradin et al. 2018).

Fiber extraction in seawater: Freshly picked Spanish broom shoots were put into a mesh bag and then soaked in seawater for 40 days. After resting in seawater, the shoots from the bag were divided into two groups.

Figure 1 *Spanish broom as a wild and cultivated plant*

The first group of branches was immediately soaked in tap water, and the fibers were manually separated under running water. After separation, the fibers were thoroughly washed in water and then dried at room temperature. Bundles of shoots in water, separated fibers, and the remaining woody part of the shoots are shown in **Figure 2**. This group is designated as sample A. The second group of branches was left to dry in a bag for a few days, and then the fibers were separated from the dry woody part. The bag with branches, dry branches, and the remaining woody parts of the branches are shown in **Figure 3**. After the fiber separation was complete, the fibers were washed in tap water and dried at room temperature. This group is designated as sample B.

Figure 2 *Bundles of shoots in water, separated fibers, and the remaining woody part of the shoots (sample A)*

The fibers of sample A were tested for tensile strength, while the fibers of sample B broke under low tensile force when they were manually stretched. The salt on the fibers likely affected their quality. Salt deposits on woody parts are visible in **Figure 3.** The test results of the sample A fibers are given in **Figure 4.** The average tensile strength was 39.41 N/mm^2, although the individual values deviated considerably from the mean value.

Figure 3 *The bag with branches, dry branches, and the remaining woody part of the branches (sample B*)

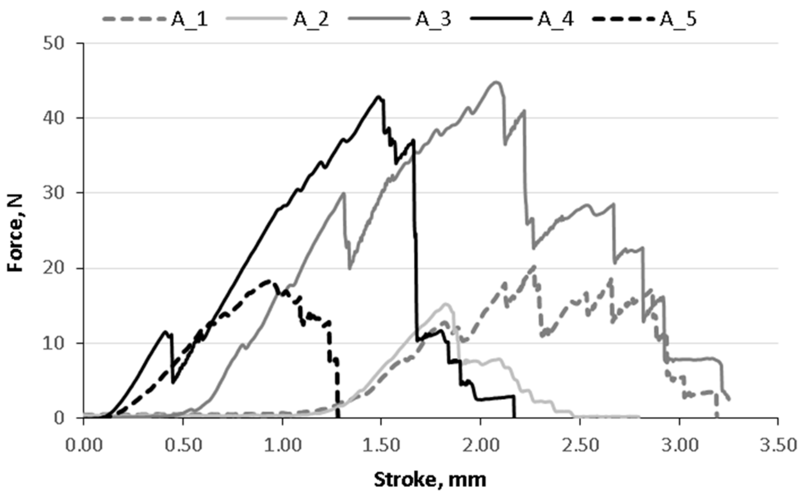

Figure 4 *Force-stroke diagram for fibers A_1, A_2, A_3, A_4, and A_5 of sample A*

2.2. Mortar preparation

In the experimental part, 12 series of prisms of cement mortar reinforced with Spanish broom (SB) fibers and one series of reference mortar were prepared. The cement CEM I 42.5 R and the CEN standard sand according to EN 196-1 were used. The Spanish broom fibers of both groups were manually cut to lengths of 1, 2, and 3 cm. The fibers were added to the cement mortar in a quantity of 0.5% and 1% of the total volume. The reference mortar is marked with RM, and the reinforced mortars are marked with A or B according to the type of fiber. In the designation of the reinforced mortars, the first number represents the length of the fibers in cm, and the second number represents the amount of fiber in %. The composition of the mortar mixtures is given in **Table 1.**

The mortar was mixed in an automatic mortar mixer. After cement, water, and sand had been mixed for 30 + 30 + 30 seconds, the standard program was stopped, Spanish broom fibers were added, and the process continued with manual mixing. The mortar was placed into standard three-gang molds on the vibrating table. After 24 hours in a wet chamber, the specimens were de-molded and placed in water at a temperature of 20 ± 2 °C. The compressive and flexural strength of the mortar specimens were tested at the age of 28 days.

Table 1 *Composition of the mortars*

Mixtures	Cement (g)	Water (g)	Sand (g)	SB fibers (g)
RM	450	225	1350	-
A-x-0.5; B-x-0.5	450	225	1350	4.8
A-x-1.0; B-x-1.0	450	225	1350	9.6
x – fiber length: 1, 2, and 3 cm				

3. RESULTS AND DISCUSSION

The results for the compressive and flexural strength and the compressive and flexural strength relative to the reference mixture (RM) are shown in **Table 2.**

Table 2 *Compressive and flexural strength and values relative to the reference mixture (RM)*

Mixtures	Flexural strength (MPa)	Relative flexural strength	Compressive strength (MPa)	Relative compressive strength
RM	8.47	1.00	53.32	1.00
A-1-0.5	8.34	0.98	46.14	0.87
A-1-1.0	7.35	0.87	39.64	0.74
A-2-0.5	8.08	0.95	43.53	0.82
A-2-1.0	7.30	0.86	39.71	0.74
A-3-0.5	7.81	0.92	43.97	0.82
A-3-1.0	7.32	0.86	36.94	0.69
B-1-0.5	7.66	0.90	44.81	0.84
B-1-1.0	7.10	0.84	39.50	0.74
B-2-0.5	7.67	0.91	44.12	0.83
B-2-1.0	7.08	0.84	39.35	0.74
B-3-0.5	7.26	0.86	44.62	0.84
B-3-1.0	6.88	0.81	40.41	0.76

According to Table 2, none of the reinforced specimens exceed the strength of the reference mixture. Relative to the RM, the reduction in flexural strength is 2–18%, and the reduction in compressive strength is 13–31%. A higher quantity of fiber resulted in lower values. The results are in accordance with previous research (Peirere et al. 2015; Juradin et al. 2019). The aim of this research is to determine how differences in fiber treatment affect the quality of cement mortar. **Figures 5** and **Figure 6** show the relative value of the flexural and compressive strength of sample B specimens in relation to the strength of the corresponding sample A specimens. According to **Figure 5**, specimens reinforced with fibers of sample B have a 3–8% lower flexural strength than specimens reinforced with fibers of sample A. With the compressive strength, the situation is different: B samples generally have a higher strength (**Figure 6**). Sample B-3-1.0 has a 9% higher strength than sample A-3-1.0. According to **Figure 7**, the fibers of sample A are not evenly distributed throughout the mortar, which resulted in a lower compressive strength. The results show that the flexural strength is influenced by fiber quality and that the compressive strength is significantly influenced by mortar preparation and installation method.

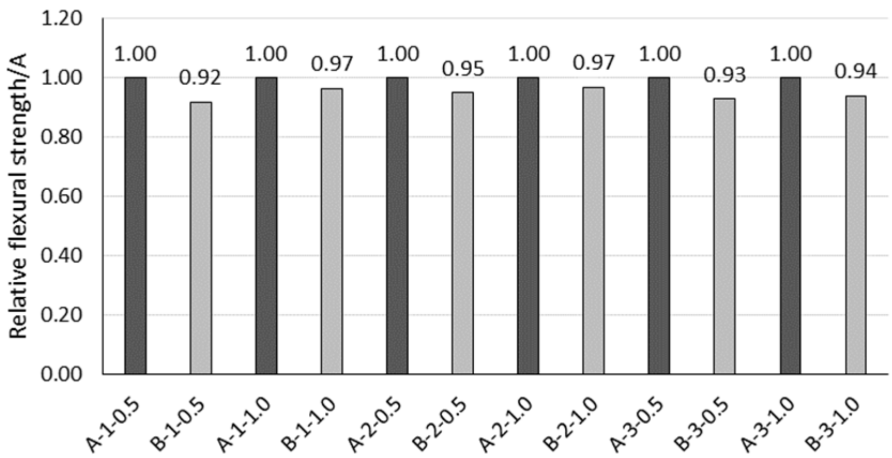

Figure 5 *Flexural strength relative to mortar A*

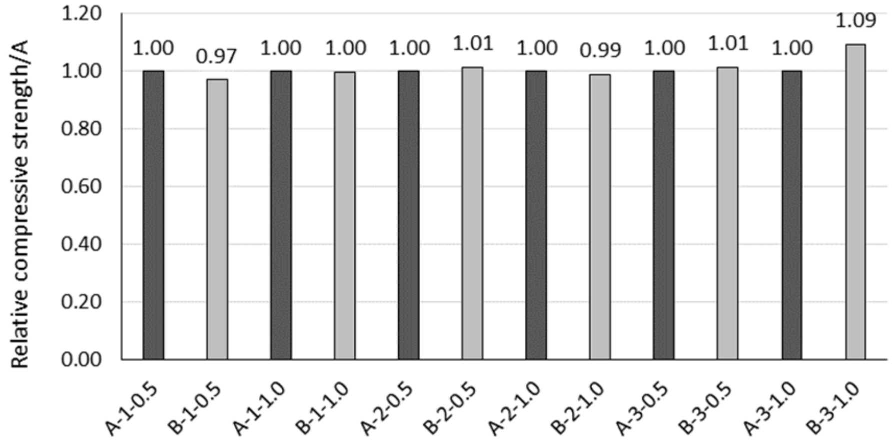

Figure 6 *Compressive strength relative to mortar A*

Figure 7 *Specimen A-3-1.0 (left) and specimen B-3-1.0 (right)*

Figures 8 and **Figure 9** show the influence of fiber length and quantity on the mechanical characteristics of the mortars.

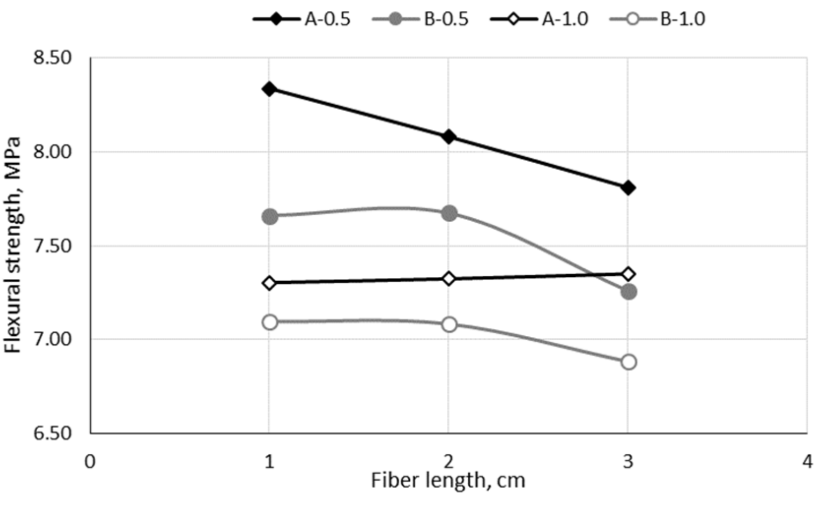

Figure 8 *Influence of fiber length and quantity on the flexural strength of the mortars*

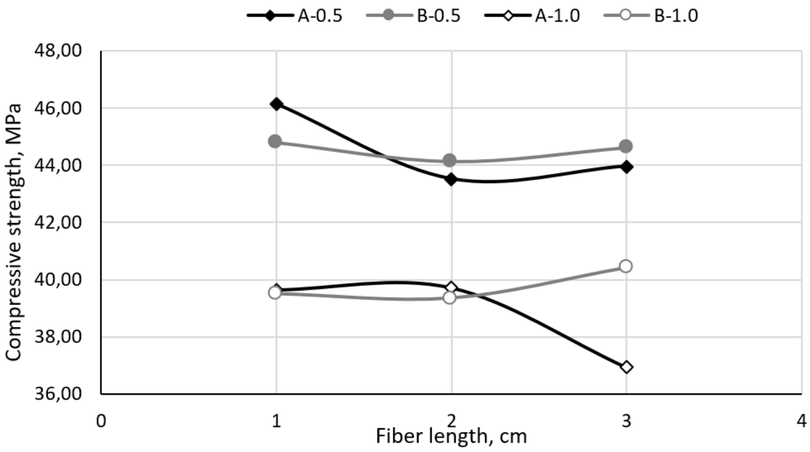

Figure 9 *Influence of fiber length and quantity on the compressive strength of the mortars*

According to **Figures 8** and **Figure 9**, the best results for flexural and compressive strength are obtained for specimen A-1-0.5.

4. CONCLUSION

In this research, the flexural and compressive strength of mortars reinforced with Spanish broom fibers were tested. Spanish broom fibers were treated with seawater for 40 days. Half of the fibers were immediately washed with water, and the other half after a few days. Sea salt affected the quality of the fibers that were not immediately washed in tap water. The best results were achieved by the mortar with the lowest amount and length of immediately washed fibers, but none of the mortars reached the value of the unreinforced reference mortar. Regardless of the results obtained, seawater is a good choice for fiber treatment. It is still the most ecologically and economically acceptable method of fiber processing.

5. ACKNOWLEDGMENTS

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