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# Effect of Sisal Fibers on Flexural Behavior of Cement Mortar

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**Abstract**: The development of techniques, manufacturing processes and the production of new materials in construction are topical. Algeria is one of the countries that have extraordinary resources in plant fibers (Palm, Alfa, Cotton, Sisal, etc.), unfortunately, their valorization in building materials is still little exploited. The aim of this research is to highlight, through an experimental investigation, the mechanical behavior of cement mortar matrix lightened by Sisal fiber under three-point bending loading. Our approach consists in taking into account the influence of the Sisal fibers slenderness, hence the use of two different lengths (7 cm and 10 cm). Several fiber percentages were used: 0%; 0.25%; 0.5%; 0.75%; 1%; 1.25% and 1.5%. After 28 days of curing, we evaluated the mechanical performance by three-point bending tests on specimens (4×4×16) $cm^3$.The best variant will be used in the manufacture of the multi-layer panels. The results showed that the fiber-reinforced mortars presented higher resistances compared to the control mortar. For the two slenderness studied, the best variant is given by the mortar from 1% fibers.

**Keywords:** Sisal fiber, Mortar, Valorization, Mechanical tests, Analyzes.

## Introduction

For a long time, attempts have been made to reinforce fragile construction materials using fibers of different natures, for example: clay bricks reinforced with straw, lime mortar reinforced with animal hair, plaster reinforced with fillasse, etc. Fibers of all kinds have been tested in the reinforcement materials. The most answered are: glass, steel, plastic, carbon, and vegetable fibers.

Currently, within framework of sustainable development, considerable efforts are being made by researchers to develop building materials that respect the 'eco-friendly' environment. Among these ecological materials, plant fibres from the forestry or agricultural sector are considered today as an interesting alternative to conventional fibres (glass, carbon and aramide). The use of vegetable fibres continues to increase due to their advantages: low density compared to glass fibres, renewable, low cost, satisfactory mechanical properties. In addition, the availability of fibre plants in underdeveloped countries allows it to produce plant fibres with little technology and a small amount of grey energy.

Plant fibers have a porous structure, which leads to good thermal and acoustic insulation. On the other hand, because of their flexibility, the handling of plant fibers is very easy, especially if the percentage of fibers mixed with the matrix is high, unlike other types of fibers such as steel fibers. Natural fibers are therefore part of the new generation of reinforcements that respect the environment and can be incorporated into various matrixes to make them ecological, light and low-cost materials.

The proposed design, which has both a reduced self-weight and an acceptable resistance threshold, is intended for applications of insulation between the walls, thus making it possible to improve the thermal and acoustic properties of the structure for acceptable mechanical stresses. First of all, we will look at the influence of the slenderness of the Sisal fibers, hence the use of two different lengths (7 cm and 10 cm). Note that this fiber is very easy to grow with a short renewal time, grows wild in a hot climate in arid regions. These sisal fibers come from the leaves extracted manually and treated with mechanical means according to a protocol. The production rate of a sisal plant is around 200 to 250 leaves per plant and each leaf contains 1000 to 1200 fibers.

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## Experimental Procedure

### Materials

A single type of mortar mix was used for the confection of the different specimens. The formulation was determined using the Dreux-Gorisse method.

*Cement*

The cement used is a Portland cement class CEM I 42.5R. The chemical composition and physical properties of cement are shown in Tables 1 and 2.

Table 1. Chemical composition of cement

| Chemical composition | % |
|---|---|
| $SiO_2$ | 22 |
| $Al_2O_3$ | 5.5 |
| $Fe_2O_3$ | 3 |
| CaO | 64.5 |
| MgO | 1.7 |
| $SO_3$ | 1.9 |
| $Na_2O$ et $K_2O$ | 0.2-1.3 |
| $Cl^-$ | 0.02 |
| PAF | < 1.5 |

Table 2. Physical properties of cement

| Physical characteristic | Value |
|---|---|
| Apparent density (kg/m$^3$) | 1130 |
| Absolute density (kg/m$^3$) | 3100 |
| Specific surface (cm$^2$/g) | 3917 |
| Normal consistency(%) | 27.48 |

*The Sand*

Granular class 0/3 sand from a sand pit in the Tizi-Ouzou region, drinking tap water will serve as mixing water. To identify our sand we carried out characterization tests, all the results are shown in Table 3

Table 3. Characteristics of sand

| Gravel | Apparent density(g/$cm^3$) NF P 18-554 | Absolute density (g/$cm^3$) NF P 18-555 | Fineness module MF NF P 18-101 | Sand equivalent (%) NFP18-598 |
|---|---|---|---|---|
| Sand 0/3 | 1,485 | 2,63 | 2,87 | 79.25 |

*Sisal Fiber*

The mortar matrix is reinforced with natural fibers (Sisal fiber) whose characteristics and quantities used are shown in tables 4 and 5.

Table 4. Property of sisal fiber

| Property | |
|---|---|
| Width or diameter | 50-300 |
| Density (kgm$^{-3}$) | 1450 |
| Cellulose / lignin content (%) | 67/12 |
| Module E (GNm$^{-2}$) | 9.4-22 |
| Tensile strength (MNm$^{-2}$) | 530-640 |
| Élongation (%) | 3-7 |


Figure 1. a) Sisal fiber, b) length sisal fiber 7cm, c) length sisal fiber 10cm.

## Mix Proportions

According to Dreux-Gorisse method, our specimens were prepared. After 24 h, the samples are demolded, and kept immersed in a water basin. The proportions of the different constituents are presented in Table 5 and table 6.

Table 5. Mortar composition (1m3).

| Components | Quantity (Kg) |
|---|---|
| Cement | 450 |
| Sand | 1350 |
| Water (L) | 225 |
| W/C | 0.5 |

Table 6. Sisal fiber quantities (length 7 and 10 cm)

| Percentage (%) | Sisal fibers (g) |
|---|---|
| 0.25 | 0.96 |
| 0.5 | 1.92 |
| 0.75 | 2.88 |
| 1 | 3.84 |
| 1.25 | 4.8 |
| 1.5 | 5.76 |

Figure 2. Experimental procedure.

## Behavior in Three-Point Bending

Bending tests are carried out on specimens of dimensions (4×4×16) $cm^3$ according to standard NF T 54-606.

Figure 3. Bending test

The following table illustrates the mechanical flexural strengths of the fiber-reinforced mortars and the control mortar obtained for the two configurations of fiber dimensions.

Table 7. Flexural strength of the mortars studied.

| | Flexural strength (MPa) | | | | | | |
|---|---|---|---|---|---|---|---|
| % / Mortar | 0 | 0.25 | 0.5 | 0.75 | 1 | 1.25 | 1.5 |
| MFS7 | 8,84 | 7.53 | 7.37 | 7.34 | 8.11 | 7.99 | 7.92 |
| MFS10 | 8,84 | 8.12 | 7.534 | 9.09 | 8.44 | 9.00 | 9.49 |

MFS7: Sisal fiber mortar with a fiber length of 7 cm.
MFS10: Sisal fiber mortar with a fiber length of 10 cm.

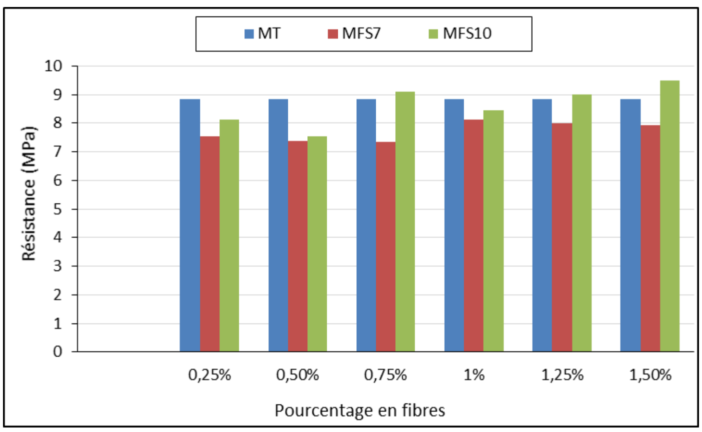


Figure 4. Three-point bending strength of the mortars studied

Figure 4 shows the evolution of the flexural strengths of unreinforced and sisal fiber reinforced mortars using two fiber lengths (MFS7) and (MFS10). The figure shows us that the mortars reinforced with sisal fibers 7 cm showed a drop in strength compared to the control mortar. While mortars reinforced with fibers 10 cm showed an increase in strength for fiber percentages greater than 0.75%.

**Influence of Fiber Length**

In this section, the influence of the length of Sisal fibers in the different mortars is presented and analyzed (see figure 5).

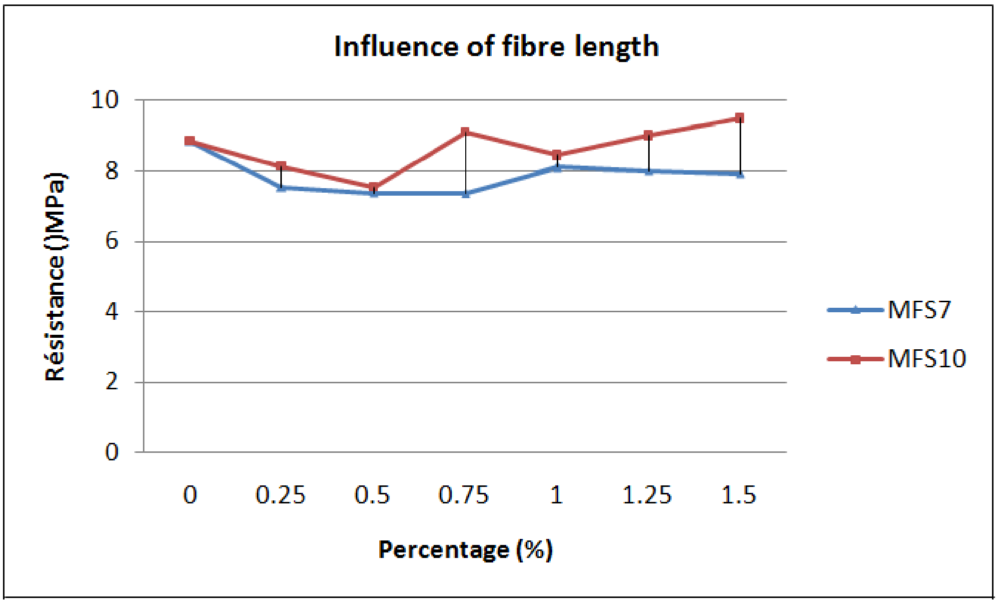


Figure 5. Influence of fiber length

The mortar (MFS10) presented a better post-peak behavior compared to the other percentages of the mortar (MFS7). It can be seen that the bending strength is closely linked to the length of the fiber incorporated into the mortar matrix. Indeed, the MFS10 mortar records a maximum resistance of 9.49MPa against a maximum resistance of 8.11MPa for the mortar (MFS7) i.e. a gain of 17%. The control mortar records a resistance of 8.84MPa. The length of the fiber of 10cm increases the resistance better, which limits the propagation and progression of cracks by a stitching effect.

## Conclusion

The results obtained after these tests on the various specimens enabled us to draw the following conclusions:

- The length parameter of the Sisal fibers influences the resistance of these mortars.
- The maximum tensile strength by bending is higher for mortars with 10 cm long fibers than for the reference mortar (without fibres).
- The mortars with fibers 10 cm in length presented better performances, in tractions by bending, compared to the mortar of fibers of 7 cm. There is a difference of 17%.
- The best resistances for the 7 cm fiber are recorded for a dosage of 1%, on the other hand for the 10 cm fiber the best performance is recorded for a dosage of 1.5%..

## Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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