

# NANOCOMPOSITE FIBER REINFORCED MORTARS

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## Introduction

The use of fibers to reinforce a brittle material is an extensively studied application. In the field of cementitious materials a wide range of fibers have been investigated, from natural to synthetic fiber (wood, cellulose, carbon, glass, polypropylene) in order to achieve several purposes [1-2].

Nowadays there is a continuing effort to take advantage of recent advances in nanotechnology, in the polymer and fiber industry [3]. Nanoclays are some of the most affordable materials that have shown promising results in nanocomposite polymers. They are characterized by a “platelet” structure with average dimension of 1 nm thick and 70 to 150 nm wide.

This work is aimed at studying the different behavior of fiber reinforced mortars, containing nanocomposite polymeric fibers.

## Materials

Three different fibers have been used: commercial PP fibers (referred as CPP) (provided by MAPEI), pure PP (referred as PP) and PP nanocomposite fibers (PPNC) (both produced by a laboratory scale extrusion apparatus). DELLITE 43B (provided by LAVIOSA CHIMICA MINERARIA S.P.A.) that is a nanoclay deriving from a natural montmorillonite was used as nanometric filler. In order to manufacture fibers, PP nanocomposite has been first obtained by melt compounding of pure PP matrix and the layered silicate in a twin-screw extruder. Nanocomposite fibers were then

**Table 2:** Results of the tensile test on fibers

	E [MPa]	$s_y$ [MPa]	$e_y$ [%]	$s_b$ [MPa]	$e_b$ [%]
PP	2762 ± 457	24 ± 2	0.71 ± 0.11	177 ± 20	243 ± 61
PP NC	3706 ± 987	24 ± 5	0.62 ± 0.11	240 ± 40	17 ± 2

produced by fiber spinning, carried out using a single-screw extruder. The geometrical characteristics of fibers are listed in Table 1. In order to produce composite mortars, the fibers have been cut into filaments of 12 mm length. All the mortar specimens were prepared employing one part of cement, three parts of sands and half part of water (1:3:0.5), using an Ordinary Portland Cement (CEM I 52.5 N MF) produced by HOLCIM and a CEN standard sand according to UNI EN 196-1. All the mixes contain fibers at a volume fraction of 0.1%. In the following, mortars samples and are referred as UNRM (unreinforced) and RM (reinforced).

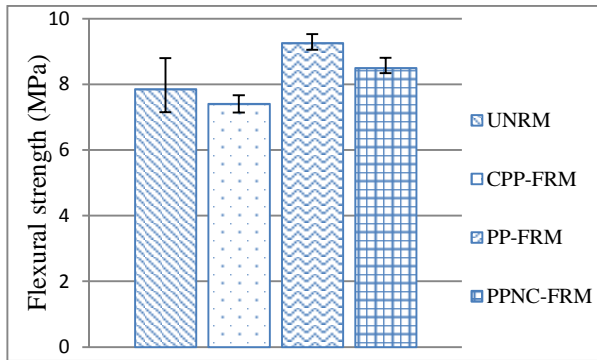
**Table 1:** geometrical characteristics of the fibers

Property	Mapecibre NS12	Pure PP	PP NC
Diameter (mm)	0.034	0.150	0.250
Length (mm)	12	12	12

## Performed Tests and Results Discussion

According to ASTM C 1557-03 tensile tests were carried out on fibers. Results are shown in Table 2. The flexural strength of the hardened mortar was determined by three point loading of a prismatic specimen (40x40x160 mm) while the compressive strength was determined on each half of the specimen after its failure under flexural test. Three specimens for each mix at 28 days have been tested. Results are shown in Figure 1.

Observations of the rupture mechanism clearly show a difference between samples with and without fibers. Specimens without fibers offer the so-called “hourglass” shape where the lateral sides get spalled. When fibers are added to the mix, a less brittle rupture of specimens is induced and failure is less clear and reproducible.



**Figure 1:** Flexural strength of mortars at 28 days.

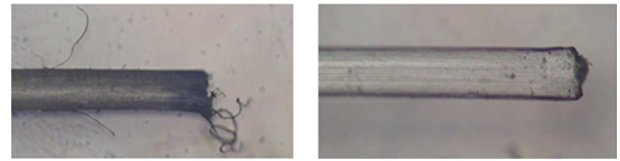
It is well known that the natural action of CO<sub>2</sub> on concrete structures lead to a dangerous phenomenon, that is carbonation. According to UNI EN 13295, carbonation resistance can be estimated by depth of carbonation. Table 3 shows the variation of carbonation depth over 3 months. Fiber reinforced mortars present higher values of carbonation depth, particularly PP-FRM which is carbonatated 1 mm deeper than UNRM.

**Table 3:** Depth of carbonation [mm]

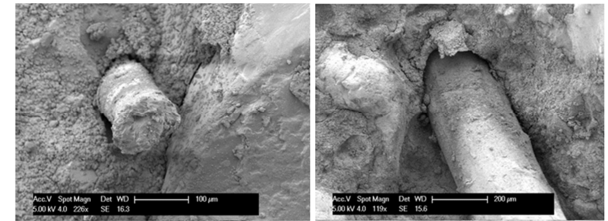
	Month		
	1	2	3
UNRM	1.96	2.54	3.46
CPP-FRM	1.88	2.79	3.63
PP-FRM	2.46	3.00	4.46
PPNC-FRM	2.60	3.13	4.04

The mechanical bond strength between fibers and matrix plays an important role in cement-based composites. In the mechanical bond test, the strength of PP NC fiber was slightly higher; its mechanical bond strength was 0.28 MPa, whereas those of PP fibers was 0.15 MPa. The lower increase of pull-out stress (112.25 MPa for PPNC fibers instead of 98.46 MPa for PP fibers, corresponding an increase of 14%) is not due to a better adhesion of PPNC fibers, as demonstrated by ESEM observations (Figure 3), but it could be correlated to a greater friction during pull-out.

This was caused by fibrils formation that increase the surface energy of the fiber due to the friction resistance during pull-out. After pull-out test the fiber surface was observed by means of an optical microscope (magnification 10x) and the different behavior of the two fibers is showed in Figure 2. Through ESEM observations (Figure 3) further information about fibers shape and their bond with cement paste has been investigated. The adhesion of pure PP fibers seems to be better than PPNC fibers.



**Figure 2:** Images of fibers after pull-out test. a) PPNC fiber; b) PP fiber



**Figure 3:** a) Bond between pure PP fiber and cement paste; b) Bond between PPNC fiber and cement paste

## Conclusions

The addition of nanoclays to a PP matrix increases the elastic modulus and the tensile strength of about 35%. However, nanoclays addition lead to a decrease of fibers ductility. This statement is strictly correlated also to results of flexural test on mortars: the increase in flexural strength for the mix containing NC fibers is only 5% while the presence of pure PP fibers increases flexural strength of about 18%. Further studies are necessary to improve bond between fibers and cement paste.

## References

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