

# EFFECT OF COMBINATION OF PYROPHYLLITE AND POLYPROPYLENE FIBERS ON THE MECHANICAL BEHAVIOUR OF REINFORCED CONCRETE

M. S. MANSOUR<sup>1</sup>, R. CHAID<sup>2</sup>

<sup>1,2</sup>Department Materials/ University M'Hamed Bougara UMBB, Algeria

## Abstract

This work investigates the use of pyrophyllite admixture as a partial replacement of cement of hydraulic concrete elaborated with Portland cement, water, silica sand, pyrophyllite and a rate of polypropylene (PP) fibers set at 1% vol. Effect of pyrophyllite with a rate of replacement ranging from 10%, 20%, to 30% by mass of cement on the physical-mechanical properties of fiber reinforced concretes is studied. In the fresh and hardened state, the density of concrete decreased with increasing the rate of pyrophyllite. Moreover, regarding reference concrete without pyrophyllite, their compressive, splitting and bending tensile strength is very high and increase significantly over time. In addition, the pyrophyllite improves the mechanical strengths of concrete especially with the rate of 10% approaching without exceeding that of the reference concrete up to 28 days.

**Mots clefs :** *Fiber reinforced Concrete, Poly-propylene, Mechanical strength, Pyrophyllite.*

## 1. Introduction

Recently, natural pyrophyllite was found in large amount in Algeria. Being finely ground, becomes a pozzolanic material. Pyrophyllite is a soft, white or pale colored silicate mineral. Hydrated aluminum silicate  $Al_2Si_4O_{10}(OH)_2$ , comprised as the main constituent of some schistose rocks. Much research is going to get a better understanding of its properties. Pérez - Rodriguez et al [1] studied its determination in mixtures of minerals and Maqueda and al [2, 3] discussed the analytical problems associated with its incomplete dissolution in acids. Also, researches of Lauw and Besari [4] showed that the calcined pyrophyllite decreased strength of lightweight concrete. Otherwise substitute cement by an addition leads to a brittle behavior of the resulting concrete ie its resistance to bending and tensile strength is low. To compensate this brittleness [5] and to overcome its low tensile strength and contain a stable macro cracking in tensile areas, the concrete must be reinforced with fibers [6] such as polypropylene limiting the opening and propagation of the first micro cracks cracking [7, 8]. In this work, the effects of pyrophyllite utilized as partial cement replacement as well as filler material at the rate

of 0%, 10%, 20% and 30% on the physical-mechanical properties of polypropylene fiber reinforced concrete is studied.

## 2. Materials and Experimental

### 2.1 Materials

The cement used in this study is a CPJ-CEM II/ A 52.5 ordinary Portland cement according to standard AN 442, with a 4028 cm<sup>2</sup>/g specific surface area and 3,38 g/cm<sup>3</sup> specific gravity. A 0/4 mm sand used is siliceous (EN 196-1) with a specific gravity and a water absorption of 1.6g/cm<sup>3</sup> and 14%, respectively. The pyrophyllite Pry incorporating in cement is obtained by grinding pyrophyllitic rock rich in silica (51,02%) and alumina (27,87%) given from southwest Algerian region and sieving at 80 µm (6300 cm<sup>2</sup>/g). A high range water reducer superplasticizer having a specific gravity of 1.06 was used. The ratio water to binder W/B is 0.27. Moreover, the 12 mm Polypropylene fibers were added directly to the mixer with the dry components of the concrete. Their embedded dosage in the concrete mix is set at 1kg/m<sup>3</sup>.

### 2.2 Specimen preparation

For polypropylene fiber reinforced concrete mix, four formulations were performed with water to binder ratio of 0.27 and by varying the pyrophyllite rate ranging from 0%, 10%, and 20% to 30%. The composition of concretes is shown in TABLE 1. Moreover, for mechanical tests, for each mixture, three prismatic samples (40x40x160 mm) and three cylindrical samples (110x220mm) were cast into steel molds according to standard NF P 18-404. The molds are kept in a room at ambient temperature, after 24 hours demolded. To ensure proper curing of concrete PFRC, the specimens were placed in a tank of water at a temperature of 20° C±2°C. The concretes were then tested in compression (NF P 18-406) and tensile bending and splitting (NF P 18-408) at maturities 2d, 7d and 28 days.

Table 1 Concrete compositions (by weight) (Kg/m<sup>3</sup>)

Constitu ant	PFRC 1	PFRC 2	PFRC 3	PFRC 4
Cement	800	710	640	560
Sand	1253	1163	1208	1187
Pyr	0	80	160	240
Polypro fibres	01	01	01	01
Effective water	205.2	203.68	202	199.7
Super- plasticizer	13.45	16.60	18.86	21.88

PFRC1= reference concrete, PFRC2, PFRC3, PFRC4 = concrete containing 10%, 20%, 30% of pyrophyllite.

### 3. Results

#### 3.1 Effect of pyrophyllite on normal consistency and setting times of cement pastes

The results of TABLE 2 show that the normal consistency of the cement pastes increases with increasing the pyrophyllite replacement rate. This is due to the increase in the water absorption of pyrophyllite caused by its fineness. Moreover, the setting times are determined with the Vicat needle on a cementitious paste of normal consistency placed in a tapered mold. The beginning and the end setting times increase when the rate of pyrophyllite increases. There is a delay in the hydration of the cement mixtures containing pyrophyllite which causes a delay in their setting.

TABLE 2 Setting times and normal consistency of cement pastes

Concrete	PFRC1	PFRC2	PFRC3	PFRC4
Beginning setting	150	154	160	168
End setting	238	245	252	254
Normal consistency	0.27	0.29	0.31	0.33

#### 3.2 Effect of pyrophyllite Pyr on the density of concrete

The results show that at fresh state (Fig. 1) and hardened state (Fig. 2), the density of fibre reinforced concrete decreases with increasing the replacement rate of pyrophyllite; this is due to the fact that the density of the pyrophyllite is smaller than that of the cement and from the nature of the material component. In addition, the densities at fresh state are bigger than those at hardened state.

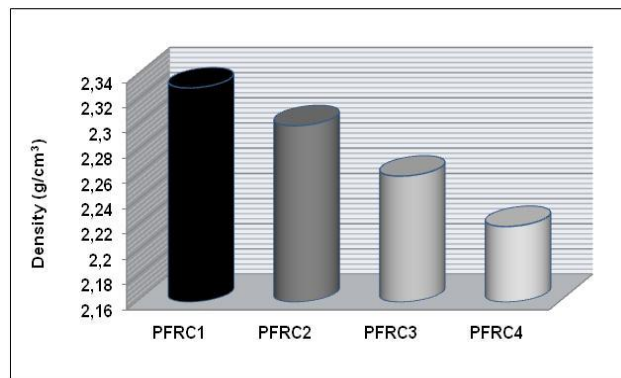


Fig. 1 Density of fresh polypropylene fiber reinforced concrete

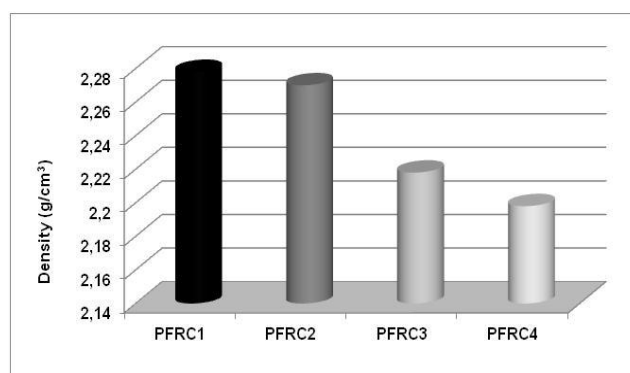


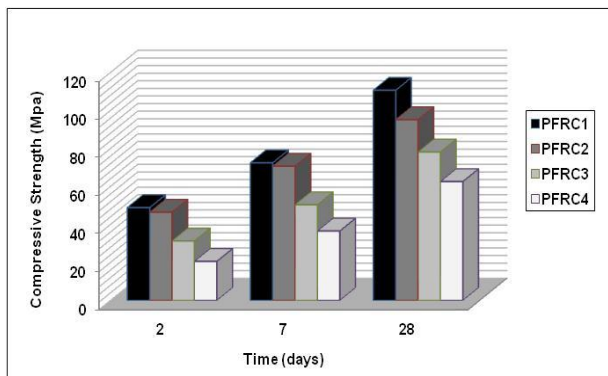
Fig. 2 Density of hardened polypropylene fiber reinforced concrete

#### 3.3 Effect of pyrophyllite Pyr on compressive strength of PFRC

In Fig. 3, it is clearly shown that the use of pyrophyllite decrease the strength at early ages of polypropylene fiber reinforced concrete. However at later ages all concretes reached strengths which are lower than those of the reference reinforced concrete (0% Pyr). This phenomenon is explained by the slow pozzolanic reaction. The intensity of pozzolanic reactivity usually depends on several factors such as silica content, degree of crystallinity or amorphousness and particle size or specific surface area. At 28 days, the strength of concrete PFRC2 containing 10% Pyr is 99 Mpa compared to 110 Mpa of the reference concrete. It seems that the rate of 10% Pyr is the most efficient compared to 20% and 30% Pyr.

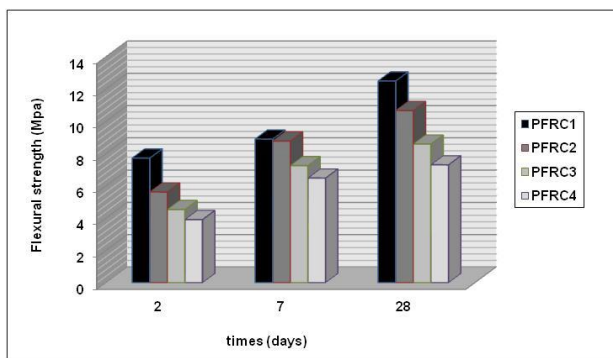
#### 3.4 Effect of pyrophyllite Pyr on flexural strength of PFRC

Fig. 4 shows the increase of flexural strength by bending as function as the maturities for the four compositions of the reinforced concrete. The strengths of concretes containing the pyrophyllite at maturities 7d, 14d and 28 days do not reach those of the reference concrete PFRC1. The strengths of PFRC2 with 10% are the closest that



**Fig. 3 Compressive strength of Polypropylene fiber reinforced concrete PFRC**

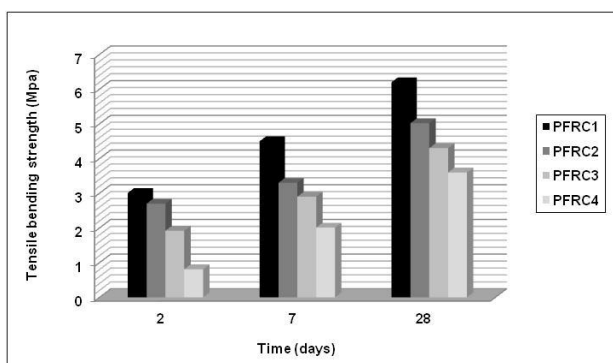
those of the reference PRFC. Moreover, the flexural strength of the reference concrete PFRC1 are very high and increase considerably over time, this is due to the positive effect of polypropylene fibres whose characteristics are good.



**Fig. 4 Flexural strengths of Polypropylene fiber reinforced concrete PFRC**

### 3.5 Effect of pyrophyllite Pyr on tensile bending strength of PFRC

Fig. 5 shows that incorporation of the pyrophyllite decreases the tensile bending strengths of reinforced concretes PFRC2, PFRC3 and PFRC4 with increase with times until 28 days. Also, the 10% Pyr is the best rate which generates strengths that approach those of the reference concrete.



**Fig. 5 Tensile bending strength of Polypropylene fiber reinforced concrete PFRC**

## 4. Conclusion

The combination of pyrophyllite as mineral admixture, synthetic fibers and binder creates an unusual fiber reinforced concrete; new composite, which offers a wide field of possible use in construction industry. The Polypropylene fiber reinforced concrete containing pyrophyllite represents a new step forward for concrete construction as it offers many advantages both economically and ecologically. The experimental results showed that:

The use of pyrophyllite as substitution to cement slows down the hardening process of PFRC concrete, consequently producing lower strengths concretes at early ages approaching without exceeding those that the reference reinforced concrete. It seems that the rate of 10 % of pyrophyllite gives the reinforced concrete, the best physical- mechanical performances compared to 20% Pyr and 30% Pyr.

The application of this composite material is ensured by the synthetic fibers, which along with the other components constitutes the tough structure of the composite favorable especially under tensile loading due to its high ductility.

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