Study of mechanical and elastic properties of reactive powder concrete

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Abstract

The current trend in the world is to find new materials at a lower cost which can guarantee better performance during their incorporation into concrete. The present study is part of the valalorization of such local materials. Recently very high performance concrete has become the main objective of several researcher works. This has encouraged the investigation of the effect of metal fibers on mechanical and elastic properties of reactive powder concrete (RPC) and the use of materials existing on the Algerian market like three mineral such as crushed slag, crushed quartz and silica fume to be incorporated into a cement of various contents (15%, 5% and 17%).

Keywords: *Reactive powder concrete (RPC), Formulation, Mechanical properties, Fibers, Elastic properties.*

I. Introduction

Ultra-high-performance fiber-reinforced concretes UBFUP are materials with very high compactness and high resistance. It is of the order of more than 100 MPa for very high performance concretes, or even more (150 to 200 MPa for ultra high performance fiber-reinforced concrete, UHPC. High performance also means ease of implementation and flexibility of adaptation construction constraints According to Toutlemonde et al, very high performance concretes have extremely reduced porosity, are more resistant to aggressive agents and, in general, have increased durability [1].

We can see that a majority of studies have been carried out with volume dosages of fibers of 2 or 2.5%, with compressive strengths varying between 119 MPa and 261 MPa. These dosages are considered to be a good compromise between the desired mechanical performance and the price. Recent studies [2,3,4] have shown that it is possible to obtain a compressive strength of 180 MPa without adding fibers by improving the compactness of the mixture.

The mechanical resistance and deformation are important characteristics of concrete, because they play a big role not only for the stability, but also for the durability of the structures. Concrete is an evolving material: its properties constantly change during its existence, the hydration of the cement continues for a long time, thus increasing the mechanical strengths and the deformation moduli. Concrete subjected to the action of a fairly low load undergoes almost instantaneous elastic deformation, reversible [5].

Three lengths of steel fibers were used (6, 12 and 20) mm and an aspect ratio of (37.5, 75 and 125) respectively studied the effect of the length of the fibers on the resistance to compression and toughness of reactive powder concrete. The test results show that the RPC with 150 MPa and reinforced with long steel fibers, it had the highest compressive strength, maximum strength and toughness due to the higher bond between the fibers and the Very high strength RPC matrix. While for RPC with a compressive strength of 270 MPa, reinforcement using short steel fibers is more effective. However, for compressive strength of

(RPC) was less affected by the length of the steel fibers [6].

The results of tensile strength and maximum deformation after cracking are significantly improved by using deformed steel fibers instead of smooth fibers. In addition, the stress strain curve path of UHPFRC reinforced with hooked steel fibers and UHPFRC reinforced with twisted steel fibers is similar up to the peak load of UHPFRC reinforced with hooked steel fibers. While UHPFRC reinforced with hooked steel fibers begins to soften at post-cracking strain $\varepsilon tp = 0.46\%$, UHPFRC reinforced with twisted steel fibers continues to increase tensile stress up to 'to the post-cracking strain $\varepsilon tp \approx 0.6\%$ [7].

The compressive strength test, cylindrical specimens were used with a height of 200 mm and a diameter of 100 mm. While for the bending tests, prismatic beams with a cross section of 100 × 100 mm^2 were fabricated [8].

The effect of fiber length, shape and aspect ratio on the bending behavior of ultra-high performance fiber-reinforced cement composites using straight steel fibers , hooked and twisted. The results show that at a fiber volume fraction greater than 1%, the hooked end fibers offered lower flexural strength and toughness than straight fibers. For straight fibers, in most cases, the short-length fibers provided better bending results with respect to higher flexural strength, deflection capacity and tenacity compared to the short-length fibers in because of their greater form ratio [9].

The main objective of this article is to study the effect of metal fibers on mechanical and elastic properties such as compressive strength, deformability, modulus of elasticity. Concrete cubes of (100xl00x100) mm^3 and (100xl00x400) mm^3 were made to conduct this study the immersion time in water was 28 days. The results obtained for the mechanical and elastic properties were compared with the same properties obtained from the published literature.

II. Material and methods

2.1 Cement: the cement used is CPA-CEM I / 42.5, (Algerian).

2.2 Aggregates: this is sand from a 0.6 mm sieve pass from the region of Djamaa, Wilaya of El Oued, Algeria. Figure 1 shows the grain size curve of dune sand according to (Norme NF EN 933-8).

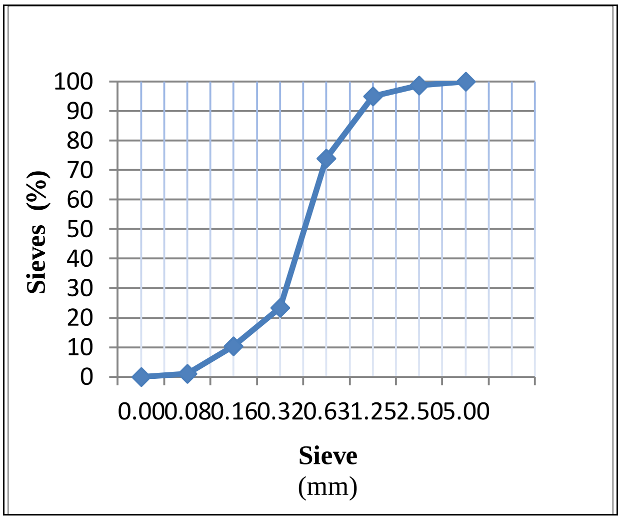

Figure. 1. Sand grain size curve

2.3 Additive: the additive used is a SIKA VISCOCRETE TEMPO 12 superplasticizer with a density of 1.06.

2.4 Charges: three additions were used:

2.4.1. The granulated slag from the blast furnace: comes from the metallurgical complex (El-hadjar) of Annaba, It has a specific surface area of 7277cm2 / g and a density of (2.60).

2.4.2. Crushed quartz: it is a powder, with an average diameter between 10 and 15 µm, resulting from the grinding of a sand very rich in silica. It has a specific surface area of 5714cm2 / g and a density of (2.63).

2.4.3 Silica fume: (Condensil S95 DP) (Sika Company) with a density equal to 1.56.

2.5 Metal fibers: Crimped metal fibres of 50mm length with a dia of 1.05mm, Number of fiber are 2800 fiber/kg and Tensile strength is 1000 MPA/line of fiber were used throughout the experimental program.

2.6 Water: Water used for both mixing and curing should be free from harmful amounts of harmful materials. In the present work drinkable tap water was mixed directly with concrete.

III. Concrete formulations

First, all of the basic constituents of RPC were dry blended. In the second step, half the water with half the amount of plasticizer was added to the dry mixture. Fibers were added in the third step (in the case of fiber-reinforced RPCs) with half the water and plasticizer. The first mixing stage lasted 4 minutes at mixing speed and the second and third stages lasted 8 minutes each. The mixing speed was increased in the third step. The total mixing time was 20 min.

The different formulations of the concretes studied are given in Table 1 (RPCC: concrete without fibers; RPCF: with metal fibers). The percentages of fibers have been calculated in order to have good workability. Because according to [10] by increasing the volume and length of the fibers, there may be workability problems.

Table 1: Final compositions of the concretes used (kg/m^3).

	C	S/C	SF/C	CQ/C	GS/C	SP/C	W/C	**MF (%)**
RPCC	945	1,1	0,17	0,05	0,15	0,018	0,16	0
RPCF	945	1,1	0,17	0,05	0,15	0,018	0,16	2,5

The specimens were produced in accordance with the standards in force (mixing, clamping), are of various geometries depending on the test carried out (l00xl00 ×100) mm^3 and (100xl00x400) mm^3, they are kept after leaving the mold in water at 20 ° C .

IV. Results and discussion

IV.1 Mechanical resistance to compression

IV.1.1 Effect of metal fibers on the mechanical resistance to compression

Figure 2 gives an example of results obtained at room temperature at the age of 28 days. It can be read, that for an W/ C ratio equal to 0.16, the concrete based on CPA42.5 cement which closes at 17% of the silica fume, 15% of granulated slag and 5% of the crushed quartez has powerful properties. . Examination of the compressive strength at 28 days shows that an addition of 2.5% of metallic fiber causes an increase in compressive strength of 18.12% over that of non-fiber. According to the results obtained from [11].

The factors most responsible for this increase would of course be the choice of the types of additive, the great fineness of the additions used and another very important factor is the reduction of the W / C ratio, this parameter is favored by the formation of internal hydration products which are characterized by a very fine texture and which resemble a compact phase with an amorphous appearance.[12].

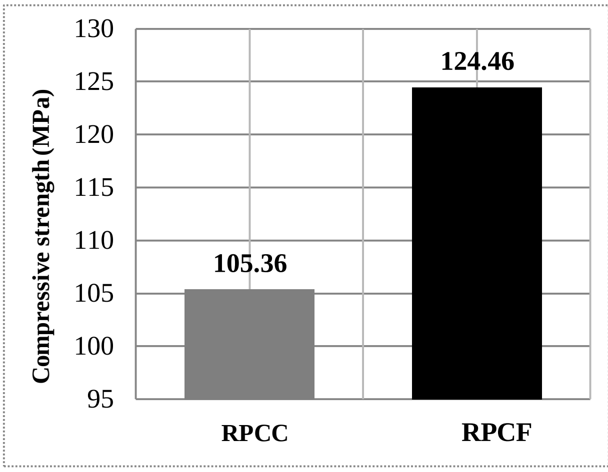

Figure. 2. The compressive strength at 28 days

IV.2 Deformability

To study the influence of fibers on the deformability of reactive powder concretes, we have developed two reactive powder concrete formulations, one is fiber-reinforced and the other non-fiber (RPCC, RPCF) dimension (100 × 100 × 400) mm^3.

The compression tests are carried out after 28 days of natural hardening (these specimens are stored in water), using a press.

Concrete subjected to the action of a relatively weak load undergoes an almost instantaneous elastic deformation, reversible. It follows the well-known Hooke's law: $\sigma c = \varepsilon c \times Ec$.

The deformation was measured by means of indicators with dial having the value of a division of 0.01 which are installed using suitable frames over an area of 200 mm^2 and 100 mm in the transverse and longitudinal directions, comprising measuring pads (20 cm apart).

The total evolution of the deflection elastic - total longitudinal and instantaneous transverse of the concrete, modulus of deformability and modulus of elasticity of the concrete as a function of the relative stresses for the series of prisms: RPCC, RPCF will be presented in the figures (3 , 4, 5 and 6).

IV.2.1 Curve longitudinal stress-strain

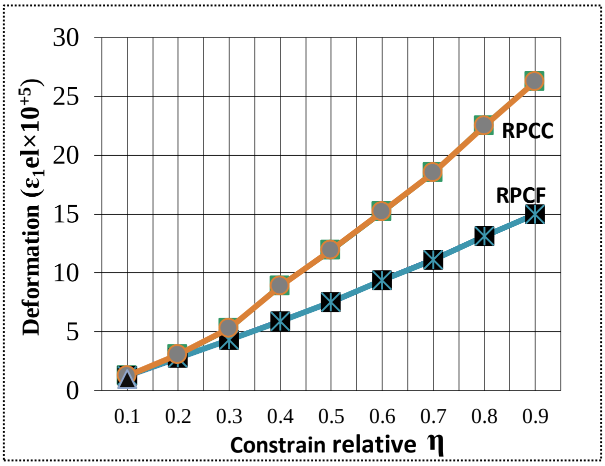

Figure . 3. Longitudinal elasto-instantaneous deformation of concrete ε1el as a function of the relative stresses η for the series of prisms RPCC and RPCF.

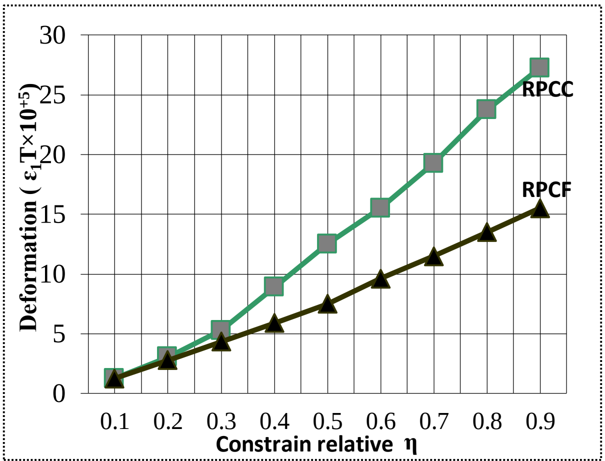

Figure. 4. Total longitudinal elasto-instantaneous deformation of the concrete ε1el according to the relative stresses η for the series of prisms RPCC and RPCF.

In the figures above, we notice that:

-The relation between the relative value and the longitudinal elasto-instantaneous deformations of the reactive powder concrete has a linear character in all the ranges of relative stress (η = 0.1−0.9) whatever the fiber formulation or not.

-The longitudinal elasto-instantaneous deformations developed in a non-fiber reactive powder concrete formulation is lower than that of a fiber formulation and for the same relative stresses η. thus for the total longitudinal elasto-instantaneous deformations. According to the results obtained from [13].

IV.2.2 Curve Stress- Transverse strain

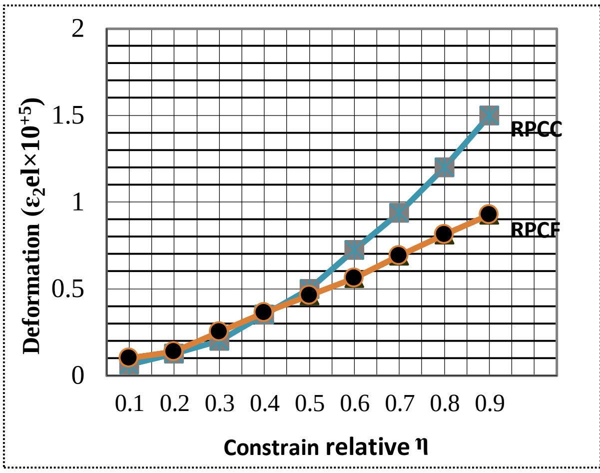

Figure. 5. Elasto-instantaneous transverse deformation of concrete ε2el according to the relative stresses η for the series of prisms RPCC and RPCF

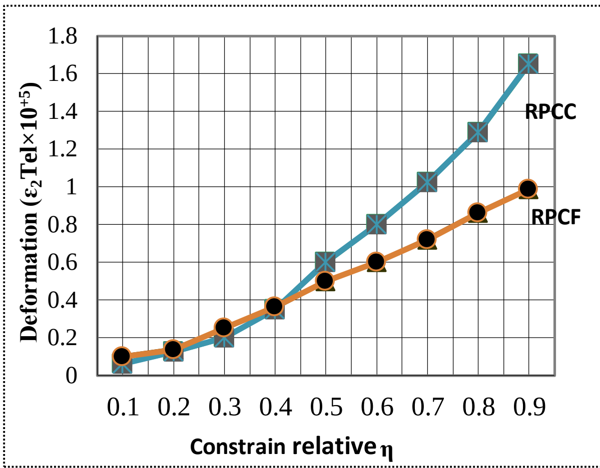

Figure. 6. Total transverse elasto-instantaneous deformation of concrete ε2Tel as a function of the relative stresses η for the series of prisms RPCC and RPCF.

Conversely to what was found for the elasto-instantaneous longiditunal and total deformations, the total transverse and transverse elasto-instantaneous deformations of a non-fiber-reinforced reactive powder concrete are greater than those of fiber-reinforced concretes and this within a range of relative stresses (η = 0.1 to 0.4) moreover for high relative stress values (greater than 0.4) the transverse elasto-instantaneous and total transverse deformations of RPCC exceed that of RPCF. According to the results obtained from [13,14].

IV.2.3 Modulus of deformation

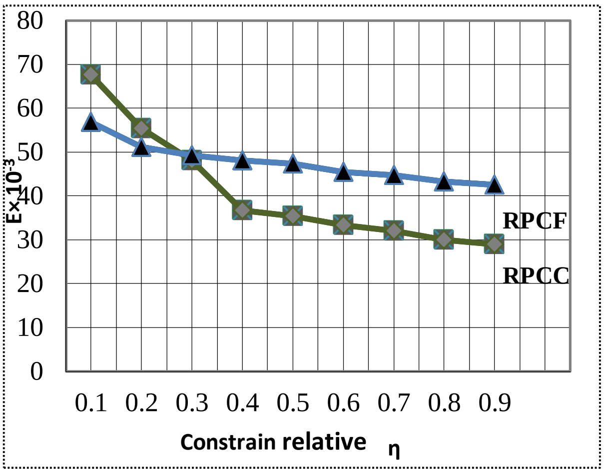

Figure. 7. Modulus of deformation E of concrete as a function of the relative stresses η for the series of prisms RPCC and RPCF.

The modulus of deformability of reactive powder concretes decreases with increasing relative stress. In a range of relative stress (0.1 to 0.3) the modulus of deformation of RPCF is greater than RPCC, this trend is reversed for values of relative stress greater than 0.4.
According to the results obtained from [13].

IV.2.4 Modulus of elasticity

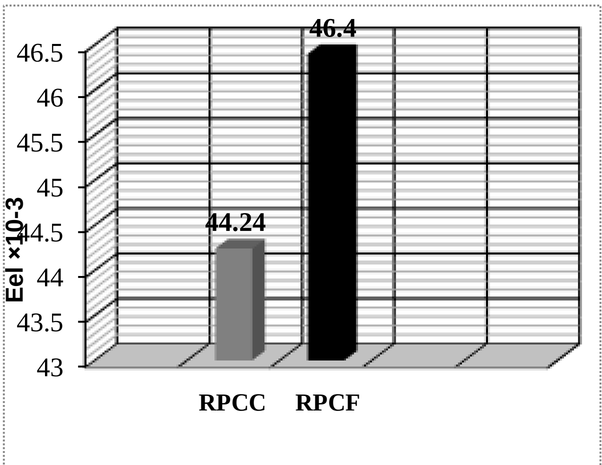

Figure. 8. Modulus of elasticity of RPCC and RPCF concretes

The modulus of elasticity of a fiber-reinforced reactive powder concrete is greater than that of non-fiber, which may be due to the presence of metal fibers, where an increase of 2.16 MPa has been recorded. there is no large significant difference between the modulus of elasticity of fiber-reinforced and non-fiber concrete because the modulus of elasticity represents a stable state of hardened concrete, even in the case of considerable increases in stress. According to the results obtained from [13,14].

V. Conclusions

In this paper, the effect of fibers on the characteristics of reactive powder concrete has been investigated. Major results of this research can be summarized as follows:
The incorporation of metal fibers in the formulation of a reactive powder concrete leads to a remarkable evolution of compressive strength comparable to that without fiber can have a concrete of 124 MPa in 28 days.
To obtain a high level of resistance, you must:
lower W/ C to environment from 0.16 to 0.20,
use a high quality superplasticizer.
all the ingredients in the concrete must be of very good quality.
The modulus of deformation decreases with increasing relative stress. The deformation modulus of concretes with the addition of 17% SF has a higher deformation modulus than the control concrete.
The modulus of elasticity of hardened concrete is a function of its mechanical strength. However, the factors acting on the modulus of elasticity are the same as those acting on the resistance.
The introduction of metal fibers is the most important parameter in the gain of compressive strengths (+ 17.20%). These improvements in strength are linked to the very high dosage of RPCs in metal fibers and are in agreement with the results obtained by other researchers such as [15,16].
The effect of mineral additions on the evolution of the modulus of elasticity is significant. Consequently, it is observed that the concrete containing an addition always has a higher modulus than that of the pilot concrete, which is linked to their great compactness.
The study of the deformability of reactive powder concrete shows that the relationship between the relative value and the longitudinal elasto-instantaneous deformations of reactive powder concrete has a linear character in all the ranges of relative stress and the modulus of elasticity developed for a fiber-reinforced reactive powder concrete is superior to that without fiber.

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