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HIGH TEMPERATURE BEHAVIOR ON THE PROPERTIES OF FIBER CONCRETE

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Abstract – Despite the fact that concrete has a good behavior at ambient temperature, this is not true under fire conditions, as it can exhibit thermal instability which may occur in several forms. The introduction of polypropylene fibers into the concrete composition has been proved to be an effective technique to overcome the risk of thermal instability and possible bursting perils.

The objective of the present manuscript is to describe the impact of polypropylene fibers on the behavior of heated concrete subjected to heating and cooling cycles at temperatures of 200, 450 and 600 °C respectively for six hours,through a series of experimental tests on mass loss, porosity, compressive and tensile strength. For this purpose, mixes were prepared with a water/cement ratio with the incorporation of polypropylene fibers with a rate varying from 0.5 to 1.5%. These fibers were added in order to improve the thermal stability and to prevent the concrete from splitting. The results show that a considerable loss of strength was noticed for all tested specimens. The relative compressive strengths of the concretes containing polypropylene fibers were higher than those of the concretes without fibers. Also, a greater loss of mass of the polypropylene fibers compared to those without fibers was noticed whenincreasing the temperature. The flexural tensile strength of the concrete was more sensitive to elevated temperatures than the compressive strength and a rapid increase in porosity was observed for the fiber-reinforced concrete compared to the reference concrete.

Keywords – Concrete; Temperature; Polypropylene Fibers; Mechanical Properties; Physical Properties;.

I. INTRODUCTION

Despite the fact that concrete has a good behavior at ambient temperature, this is not true under fire conditions, as it can exhibit thermal instability which may occur in several forms. Through the outcomes of this research make it possible to explain the observed phenomena on the behavior of concrete at high temperature. The introduction of polypropylene fibers into the concrete composition has been proved to be an effective technique to overcome the risk of thermal instability and possible bursting perils. Several researchers had carried out full experimental studies on the mechanical behavior of concrete and fibrous concrete subjected to high temperatures, particularly in terms of porosity, mass loss,. compression resistance, ultrasonic tests and tensile strength. As far as porosity is concerned, [1] quantified the effect of polypropylene fibers on the behavior of concrete at high temperatures to determine how the fibers contribute to the creation of a network that is much more permeable than the ordinary matrix [2, 3]. Have experimentally studied the effect of polypropylene and metallic fibers on the behavior of concrete subjected to high temperature and have resulted in the formulation of improved concretes with high temperature stability and mechanical behavior after cooling, [4, 5] have shown an increase in temperature either for ordinary concrete or high-performance concrete with or without fibers. [2] confirms that low fiber-free concrete damages are more than high concrete. On the other hand, [6, 7] found that in the presence

of fibers an additional porosity occurs and increases with the fiber dosage.

This study focuses on the effect of the inclusion of polypropylene fibers in improving the mechanical performance of the concrete and preventing its spalling. Since the heating rate and experimental conditions are not identical. The authors differ on the analysis of the mechanical properties of concrete heated with polypropylene fibers. For this purpose, the present study was carried out by varying several parameters such as temperature (T°c), fiber content (%) keeping constant the ratio (water/cement) and the heating cycle time (t) which represents the novelty of the present study.

II. MATERIAL PROPERTIES

A. *Cement*

The type of cement used for both ordinary concrete and polypropylene fiber concrete is made by is Djebel Rsass cement company (Tunisia).

B. *Aggregates*

All the concrete was made with aggregates (sand and gravel).

Identification of aggregates intended for the manufacture of concrete

Quarry sand from Sotramat (Boulhafdir) Tebessa, Algeria.

Gravel: 3/8– 8/15 from the quarry of Sotramat (Boulhafdir) Tebessa, Algeria

C. *Superplasticizer*

The superplasticizer used in this testing program is the VISCOCRETE TEMPO 12 type high water reducer, marketed by the Algerian company Sika El-DJAZAIR, and complies with NF EN 934-2, French standardization, with a recommended range of use from 0.2 to 3% of binder or cement weight depending on fluidity.

D. *Water*

The mixing water used in this study is potable water from the laboratory tap. The conditions imposed on this mixing water are subject to the NF EN 1008 standard, once again a French standardization. This water must be clean and free from organic substances.

E. *Polypropylene Fibers*

The fibers used are polypropylene fibers marketed by the company Algerian GRANITEX see Figure . They are used in the concrete to improve the fire resistance of the structures; they are cylindrical and are delivered in the form of a cluster.

Fig.1 Polypropylene fibers

III. MIX PROPORTIONS

Fiber-free concrete composition is obtained using the Dreux-Gorisse formulation method [12]. The adjuvant dosage is adjusted by execution of preliminary tests to get a mixture that ensures good handling. The consistency class of the concrete obtained is characterized by a subsidence to the Abrams cone Between 75 and 50mm for concrete reinforced with polypropylene fibers, the percentage of fibers relative to the total weight of the concrete was set at three values: 0.055–0.11 and 0.17%. The composition detail is shown in Table 1:

Table 1 . Concrete composition

Matériels	**Poids en (Kg/m^3)**			
Cement	400	400	400	400
Polypropylene fiber	0.00	0.5	1	1,5
Water	180	180	180	180
Superplasticize (%)	1	2	2,1	2,2
Superplasticizer kg	4	8	8,40	8,80
Coarse aggregate	1131	1131	1131	1131
Fine aggregate	654	654	654	654

IV. MIXING, CASTING AND CURING PROCEDURES

The tests are carried out on twelve (10×10×10) cm cubic specimens to determine the compressive strength at 28 days. The ends of the test tubes are rectified by surfacing with Sulphur.

Table 2 . Number of test tubes details

PP Fiber Content	200 C°	6 hrs
0% PP		03
0,5% PP		03
1% PP		03
1,5% PP		03
	450 C°	6 hrs
0% PP		03
0,5% PP		03
1% PP		03
1,5% PP		03
	600 C°	6 hrs
0% PP		03
0,5% PP		03
1% PP		03
1,5% PP		03

V. RESULTS AND DISCUSSION

F. *Mass Loss*

As it can be seen from the Figure, with the rise in temperature, consequently the concrete its mass. This loss of mass is due essentially to the water departure which occurs with temperature less than 600°C and taking place usually throughout three stages. These stages can be summarized as follows:

For the case of ambient temperature ranging between 100-150 °C, a low mass loss is observed due to free water in the concrete. With a temperature ranging between 150 and 300°C: a rapid increase in mass loss due to water contained in hydrates and mainly from hydrated calcium silicategel. According [13], at 300 °C, concrete can lose approximately 65 to 80% of the total water mass. Beyond 300°C: Small mass loss corresponding to the dehydroxylation of the portlandite (450-550 °C), the decomposition of silanols (Sioh), flint (400 to 570 °C) and Caco3 limestone decarbonization (600 to 800 °C). It is can be observed from Figure that for polypropylene fiber concretes, an increase in kinetics mass loss is noticeable and the three domains characterizing the evolution of mass loss in terms of temperatures can also be remarked.

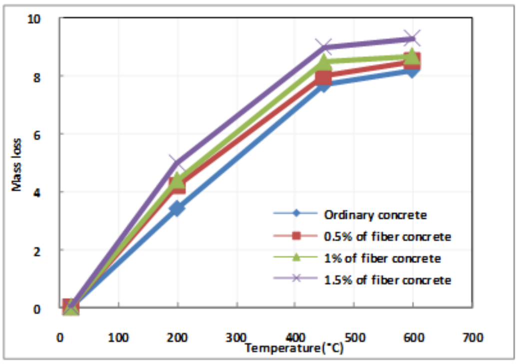

Fig. 2 Variation of mass loss (%) vs. Temperature (°C)

G. *Porosity Evolution*

The results of the experimental tests carried out by the various authors showed an increase in porosity with temperature for both ordinary and high-performance concretes in the presence or in absence of fibers [4, 5]. From the results presented

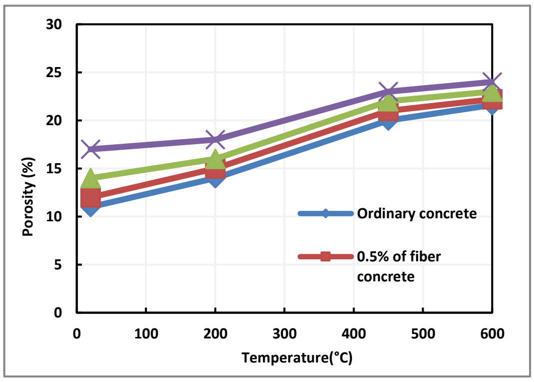

Fig. 3 Variation of Porosity (%) vs. Temperature (°C)

H. *Compressive Strength*

For different temperatures cases and as shown in the Figure , the compressive strength of concrete having 0.5, 1, and 1.5% polypropylene fiber ratios increases, due to effect of heating and beyond 200°C the liquid water converts to steam and the improvement of strength is a consequence of the departure of this water allowing a re-increase of the tension forces and reconciliation of the sheets of hydrated calcium silicate which was found to decrease significantly at 600°C because of the partial or total melting of polypropylene fibers creating channels within the cement matrix. It is worth noting that the evolution of the compressive strength of ordinary concrete is similar to that of fiber concrete but remains lower than this one. Similar results were observed by other researchers [8, 9].

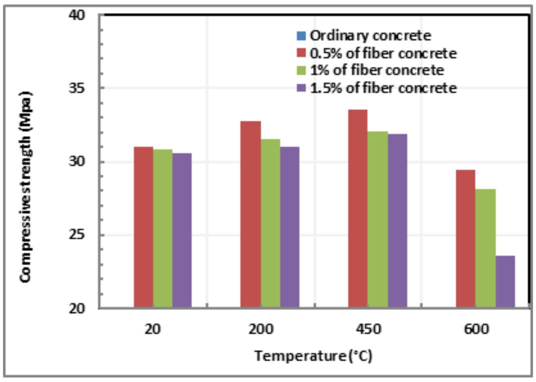

Fig. 4 Variation of compressive vs. Temperature (°C)

in Figure , the inclusion of polypropylene fibers in heated concrete leads to an increase in pore volume and changes the kinetics of porosity development. Moreover, the polypropylene fibers show the appearance of an additional porosity. This porosity is related to the micro cracking generated by the expansion of the polypropylene

i. *Tensile Strength*

Based on the previous studies such as [10,11], there is a decrease in tensile strength due to temperature. Figure involving the flexural tensile strengths of polypropylene fiber concretes for different heating-cooling cycles reveals a progressive decrease in the flexural strength of concrete with polypropylene fibers as the heating temperature increases. This strength decreases with increasing temperature for all the concretes studied; With the exception or then above 300°C, the decrease in tensile strength becomes more important, all concretes losing more than half of their initial flexural strength due to the degradation of the cementitious matrix (decomposition of the portlandite).

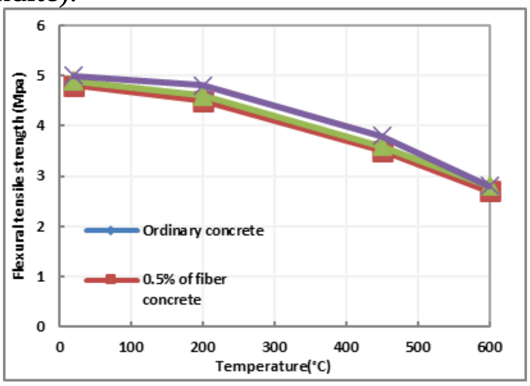

Fig. 5 Variation of Flexuel tensil strength (MPa) vs. Temperature (°C)

VI. Conclusions

According to the obtained results in tests carried out in this study on ordinary concrete specimens, the following concluding remarks can be drawn:

A reduction in the concrete mass (or mass loss) with the increase in temperature was observed by weighing the test tubes before and after each single heating cycle.

An increase of porosity increases when the temperature rises to 450°C and then slowing down under 600°C.

The mechanical behavior relative to the compression strength is divided into two areas. The first, ranging from ambient temperature up to 450°Cwhich is marked by a slight decrease or improvement in resistance. The second one, when the ambient temperature is higher than 450°C, resulting in a significant loss of strength.

The obtained results from tensile tests are characterized by a drop in the tensile strength.

The obtained results from the tests carried out on the polypropylene fiber-containing concretes show that:

It was observed that a concrete mass loss increases with temperature, with an additional loss of mass on polypropylene fiber concretes.

It was observed that the porosity measurements show a rapid increase in porosity for concrete reinforced with fiber than unreinforced concrete.

The addition of polypropylene fibers in the concrete results in an increase in resistance up to 450°C and a remarkable fall to 600 °C due to the melting and vaporization of the fibers.

The influence of the fibers on the tensile behavior is negative because the melting of the fibers causing a loss of their tensile strength. Among the dosages of polypropylene fibers studied the dosage of 0.5% leads to better mechanical performance particularly for compressive strength.

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