Resistance of polypropylene fibered mortar to elevated temperature under different cooling regimes

Resistencia del mortero con fibra de polipropileno a temperatura elevada bajo diferentes regímenes de enfriamiento

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Abstract
Behaviour of construction materials i.e. steel, concrete and mortar under elevated temperature is important. In the study, the variations in mass loss, and strengths of polypropylene fiber reinforced mortar subjected to elevated temperatures were examined. Mortar was made with CEM I 42.5R Portland cement, monofilament polypropylene fiber, fine aggregate and drinkable water. The sand-cement and water-cement ratio were chosen 3:1 and 1:2 for all mixtures, respectively. Mixes containing 0, 0.1, 0.2 and 0.3% polypropylene fiber in volume of solid matter of mixture were prepared. Mortars were exposed to 100, 200, 400, 600 and 800°C temperatures and cooled down 23±2°C in air and water. There was a difference between the temperatures at which the important reductions observed for flexural tensile and compressive strength. Significant reduction was observed at 400°C for compressive strength and while it was 200°C for flexural strength. No difference was observed between air cooling and water cooling regimes up to 600°C; however, at 800°C the residual compressive and flexural strength of water cooled mortar was about 40% of the air cooled mortar. Mortar containing polypropylene fiber presented better behaviour to elevated temperature in terms of relative residual strengths up to 400°C.

Keywords: Compressive strength, flexural strength, mortar, polypropylene fiber, high temperatura.

Resumen
El comportamiento de los materiales de construcción, por ejemplo, acero, hormigón y mortero a temperatura elevada es importante. En el estudio, se examinaron las variaciones en la pérdida de masa y las resistencias del mortero reforzado con fibra de polipropileno sometido a temperaturas elevadas. El mortero se hizo con cemento Portland CEM I 42.5R, fibra de polipropileno monofilamento, agregado fino y agua potable. La relación arena-cemento y agua-cemento se eligió como 3: 1 y 1: 2 para todas las mezclas, respectivamente. Se prepararon mezclas que contenían 0, 0.1, 0.2 y 0.3% de fibra de polipropileno, en volumen de materia sólida de la mezcla. Los morteros se expusieron a temperaturas de 100, 200, 400, 600 y 800°C y se enfriaron 23 ± 2 °C en aire y agua. Hubo una diferencia entre las temperaturas a las que se observaron reducciones importantes para la tracción a la flexión y resistencia a la compresión. Se observó una reducción significativa a 400°C para la resistencia a la compresión y mientras que fue de 200°C para la resistencia a la flexion No se observaron diferencias entre los regímenes de enfriamiento por aire y agua hasta 600°C; sin embargo, a 800°C, la resistencia residual a la compresión y a la flexión del mortero enfriado por agua era aproximadamente el 40% del mortero enfriado por aire. El mortero que contiene fibra de polipropileno presentó un mejor comportamiento a temperaturas elevadas en términos de resistencias residuales relativas hasta 400°C.

Palabras clave: Resistencia a la compresión, resistencia a la flexión, mortero, fibra de polipropileno, alta temperatura.

High temperature is one of the important physical deterioration parameters that effect the durability of concrete structures (Aydin, 2008). With exposure to elevated temperature, for instance during fire, concrete subjects to change in its chemical composition, physical structure, and water content (Haddad & Shannis, 2004).

These changes take place mainly in the hardened cement paste starting from the alteration of calcium hydroxide at 400°C and continue till thorough decomposition of calcium-silicate-hydrate gel at about 900°C (Chi Sun Poon, Azhar, Anson, & Wong, 2001b). During the last decade, extensive research has been conducted on fire resistance of concrete, and most studies emphasize on aspects such as types of aggregate, fiber addition, heating rate and maximum temperature level, testing methods, etc. (Chi Sun Poon, Azhar, Anson, & Wong, 2001a).

Many studies indicated incorporating polypropylene fiber is an effective solution to reduce the risk of spalling of concrete or mortar subjected to high temperature (Aydin, Yazici, & Baradan, 2008; Kalifa, Chéné, & Gallé, 2001; Peng et al., 2006; Xiao & Falkner, 2006; Zeiml, Leithner, Lackner, & Mang, 2006). In case of fire, the polypropylene fibers will sublime at around 170°C and, create a network of micro-channels in the concrete which serve as a way to release water vapour to the atmosphere, which, will consequently prevent the types of failures referred to above (Rodrigues, Laím, & Correia, 2010). Introducing polypropylene fiber into mixture increases the spalling resistance of concrete and mortar. However, polypropylene fibers had a negative effect on concrete's remaining mechanical properties, since they reduced the remaining compressive strength, modulus of elasticity and tensile strength of fired concrete (Sideris, Manita, & Chaniotakis, 2009).

Poon, Shui, & Lam (2004) concluded that using a 0.11% of polypropylene fibers by volume of mortar which increased the residual strength of concrete after exposure to 600°C had negative effects on the compressive strength of concrete at 800°C. Komonen & Penttala (2003) stated that polypropylene fiber result with a finer residual capillary pore structure in concrete reduced compressive strengths, and improved residual flexural strengths at low temperatures. Suhaendi & Horiguchi (2006) indicated that with the melting and vaporization of its fiber constituents at 160-170°C and 340°C, respectively, polypropylene fiber reinforced high strength concrete loses its mechanical and permeability performance.

On the contrary, Kalifa et al. (2001) concluded that polypropylene fibers demonstrated beneficial influence to the residual strength of concrete after exposure to high temperature. Xiao & Falkner (2006) stated that polypropylene fiber increases the relative residual compressive strength, but decrease the residual flexural strength. Chan, Luo, & Sun (2000) reported that the inclusion of polypropylene fiber did not cause a significant decrease in residual strength compared to without fibers. Behnood & Ghandehari (2009) concluded that the splitting tensile strength of concrete was more sensitive to high temperatures than the compressive strength, and the presence of polypropylene fiber was more effective for compressive strength than splitting tensile strength above 200ºC. Also, they concluded that the addition of polypropylene fibers could significantly promote the residual mechanical properties of high strength concrete during heating. Noumowe (2005) stated that the addition of polypropylene fibers (0.2%) may cause small changes in remaining compressive strength, elasticity module and splitting tensile strength owing to fibers melting during heating up to 200°C. Tanyildizi (2009) attributed the reduction in compressive and flexural strength to the drying out free water and fraction water of hydration of concrete due to high temperatures.

Yermak, Pliya, Beaucour, Simon, & Noumowé (2017) studied on effect of steel and polypropylene fibers on the behaviour of concrete subjected to elevated temperature in terms of spalling, transfer and mechanical properties of concrete. Strength grade of concrete was 70 MPa. They reported that high strength concrete containing 60 kg/m^3 of steel fiber showed spalling however control concrete and concrete made with combination of polypropylene fiber (0.75 kg/m^3) and stell fiber (60 kg/m^3) did not spall. They concluded that using polypropylene fiber increase the porosity and permeability of concretes thus resulting with higher spalling resistance.

Hiremath & Yaragal (2018) carried out laboratory study to investigate and evaluate the performance of reactive concrete containing polypropylene fibers subject to high temperatures from 200 °C to 800 °C. Fiber dosages were from 0.1% to 0.9%. Residual compressive strength of reactive powder concrete and concrete containing fiber were measured. In addition, ultrasonic pulse velocity and water absorption and sorptivity of samples were measured. Based on their experimental result, they concluded that inclusion of 0.1% fiber dosage was adequate to control spalling of RPC up to 800°C. They recommended that utilization of 0.5% fiber in reactive powder concrete to enhance the residual properties. They also evaluated microstructural properties (formation of pores and cracks) of reactive powder concrete. This assessment of reactive powder concrete show that quantity of hydrated products increase and microstructural formation of reactive powder concrete gets denser up to 400°C. However, when exposure temperature reaches to 600°C, concrete starts to deteriorate while its hydrated products decompose.

Li, Pimienta, Pinoteau, & Tan (2019) researched the individual and combined influence of polypropylene fibers, steel fibers, and size of aggregate on spalling behavior and pore pressure development of very-high-performance concrete subjected to high temperature. They measured compressive, tensile, and permeability properties of specimens to asses spalling behavior. It is reported that inclusion of polypropylene fibers in mixture prevented spalling, and they found to be more effective in increasing permeability than steel fibers and larger aggregates. However, combined effect of using polypropylene fibers and steel fibers, and polypropylene fibers and larger aggregates result with higher permeability than that of inclusion of individual polypropylene fibers.

Amancio, De Carvalho Rafael, De Oliveira Dias, & Bezerra Cabral (2018) exposed concrete reinforced with polypropylene fibers to elevated temperature from 200 C to 800°C. They produced 30 MPa concrete grade with the inclusion of three different fiber amounts (1.2, 1.8 and 2.4 k/m^3). The properties measured were compressive strength, ultrasonic pulse velocity, and mass reduction. In comparison to mixture without fiber, spalling resistance of concrete was increased when polypropylene fiber included in the mixture up to exposure temperature of 600°C. They noted that residual strength of the concrete is not influenced by the inclusion of fibers when concrete is exposed to elevated temperature.

The literature survey indicated that conflict still exists regarding the use of polypropylene and its influence on fire resistance of concrete or mortar. Also, few studies have examined the cooling regimes of concrete or mortar subjected to elevated temperatures. Therefore, the aims of this study were to investigate the influence of elevated temperature and cooling regimes on compressive and particularly flexural strength of mortar containing polypropylene fiber. This was achieved by measuring mass loss, residual flexural and compressive strength of mortar made with and without polypropylene fiber, after elevated temperature followed by air and water cooling.

Materials and methods

The binding material used throughout this study was ordinary Portland Cement CEM I 42.5R complying with TS EN 197-1 (TS EN 197-1, 2012). The chemical composition of the cement is shown in Table 1.

Table 1. Chemical composition of cement. Source:Self-Elaboration.

Oxide	(%)	Oxide	(%)
CaO	62.1	SO_3	3.4
SiO_2	21.2	Cl	0.01
Al_2O_3	5.6	Na_2O	0.4
Fe_2O_3	3.2	K_2O	0.9
MgO	1.6	F.CaO	0.8

In preparation of mortar mixture, natural river sand was used. The sand used was quartzite sand. Maximum size of the sand was 4 mm. Absorption value was 1.9%. Relative density of sand at saturated surface dry (SSD) condition was 2.63. The fine aggregate had fineness modulus of 2.61. The gradation of sand obtained in accordance with TS EN 933-1 (TS EN 933-1, 2012) is presented in Table 2.

Table 2. Grading of fine aggregate. Source: Self-Elaboration.

Sieve size (mm)	4	2	1	0.5	0.25
Passing (%)	99.4	64.7	37.6	23.7	13.8

Polypropylene fibers used were fire (type M6) monofilament fibers with a length of 6 mm and diameter of 18 µm. The characteristic properties of polypropylene fiber are presented in Table 3.

Table 3. Characteristic of polypropylene fiber. Source: Self-Elaboration.

Density (kg/dm^3)	Length (mm)	Diameter (µm)	Aspect ratio	Tensile strength (N/mm^2)	E-module (N/mm^2)
0.91	6	18	3000	300	3500

Four types of mixtures were prepared. Mortar mixtures were proportioned according to the TS EN 196-1 (TS EN 196-1, 2016) mix design procedure for mortar at a sand/cement ratio 3:1 and water/cement ratio 1:2 with fine aggregate, Portland cement, and natural spring water. Fresh fiber reinforced mortars containing 0% (M0), 0.1% (M1), 0.2% (M2) and 0.3% (M3) polypropylene fiber in volume of solid matter of mixture were prepared. The ingredients of mixtures for three 40×40×160 mm^3 prismatic specimens are presented in Table 4.

All mortar mixtures were produced in a Hobart mixer. The mixing procedures for mortar involved the following steps. The water, cement and polypropylene fiber was put in a mixer and mixed in slow mode for 30 seconds. The sand was introduced in 30 seconds, whilst mixing was in slow mode. Then, the mixture was mixed in fast mode for 30 seconds. The mixture was waited for 15 seconds without mixing. The mixture was mixed for a further one minute in fast mode (TS EN 196-1, 2016).

Table 4. Mix design of all mixtures. Source: Self-Elaboration.

Mix	Fiber (g)	Cement (g)	Sand (g)	Water (g)	Flow (mm)	Unit Weight (g/cm^3)
M0	0	450	1350	225	168	2.06
M1	0.8	450	1350	225	161	2.04
M2	1.6	450	1350	225	154	2.00
M3	2.4	450	1350	225	143	1.99

After mixing, mortar workability was measured as an indicator of mixture consistency with mortar flow test. Fresh mixture was poured into a small frustum cone on its vibrating table according to description made in TS EN 1015-3 (TS EN 1015-3, 2000), and the cone was taken off. Fresh mortar was jolted from 12.5 mm height for 15 times in 15 seconds onto the vibrating table. Afterward, the mortar spread, and the maximum spread was measured. The average of two values of spread diameter was recorded. The hardened unit weight of polypropylene fiber reinforced mortar was between 1.99-2.04 g/cm^3. The results of unit weight and consistency of fresh mortar by flow table are presented in Table 4. It shows that as the polypropylene fiber's content increased in mortar, unit weight and workability of mixture decreased.

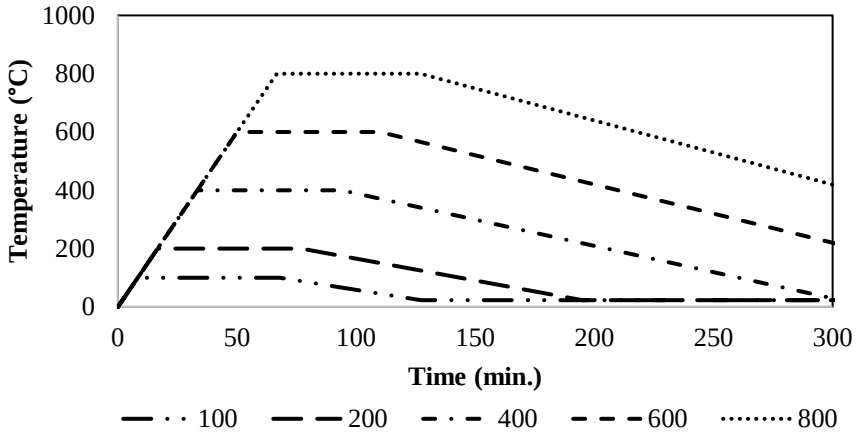
Then mortars were cast into three-cell prismatic 40×40×160 mm^3 steel moulds and vibrated for compaction. Three prismatic specimens per mixture were cast in steel moulds. The specimens were kept in the moulds for 24 hours at 23±2°C temperature. After demoulding, the specimens were stored in water at 21±1°C for 28 days. Table 5 shows the detail of the variables used in the experiment.

Table 5. Testing variables used in the experiments. Source: Self-Elaboration.

Heating degree (°C)	Polypropylene (%)	Cooling regime
20, 100, 200, 400, 600, 800	0, 0.1, 0.2, 0.3	In air, In water

The elevated temperature test was carried out in a Protherm electric oven (Figure 2). At 28 days, the specimens were taken out curing tank, and dried at 105°C for 24 hours for avoiding undesirable explosive spalling of concrete while subjected to high temperatures above 100°C (Peng et al., 2006). Dried specimens were placed in an electrical furnace with heat applied at a rate of 12°C/min until the desired temperature was reached. Target desired temperatures were set at five values, 100, 200, 400, 600 and 800°C. After having reached a target temperature, the temperature was maintained for 1 hour. Then, mortar samples subjected to high temperature were cooled down in two regimes. Some specimens were remained in laboratory conditions for ambient cooling untill cool down room temperature. Temperature variations versus time were plotted and presented in Figure 1. Other group of samples was shockly cooled by exposing to water at 23±2°C for one hour. After cooling, mass loss of samples, flexural tensile strength and compressive strength were measured. Mass of specimens were weighed before and after exposure to elevated temperatures.

Figure 1. Time-temperature relationship. Source: Self Elaboration.



Compressive and flexural tensile strengths were measured according to TS EN 1015-11 (TS EN 1015-11, 2000). Using 40×40×160 mm^3 sized prism samples, flexural strength test was made, whereas compressive strength test was measured on broken prismatic specimens. Test results were compared with results of mortar specimens tested for other mixes, temperatures and cooling regimes.

Figure 2. Furnace. Source: Self-Elaboration.

Results and discussion

The effect of polypropylene dosage at elevated temperature on behaviour of mortars for both air and water cooling were investigated using mortar specimens containing 0, 0.1, 0.2 and 0.3% polypropylene fiber. The hardened mortar samples were tested at 28 days.

The results of specimens exposed to elevated temperatures were compared with an unheated control specimen. The measured properties of mortar were mass loss, flexural tensile and compressive strength. Figure 3. illustrates the mortars (with and without polypropylene fiber) surfaces after exposure to 800ºC temperatures in water cooling (Karahan, 2010).

The mass of hardened mortar samples were determined before and after heating at target temperatures. Standard deviation for each mass loss results data point is calculated and average standard deviations are found to be in the order of 2% and 4%, for air and water cooled specimens, respectively. The relative mass losses of all the investigated mixtures are shown in Figure 4 and Figure 5 as an average of three specimens. Mass loss increases as target heating temperature increases. Figure 4 and Figure 5 show that the mass loss of mortar containing polypropylene fiber tends to increase in comparison to mortar made without polypropylene fiber.

Figure 3. Specimens exposed to 800ºC and stored for 1 hour in water cooling. Source: Self-Elaboration.

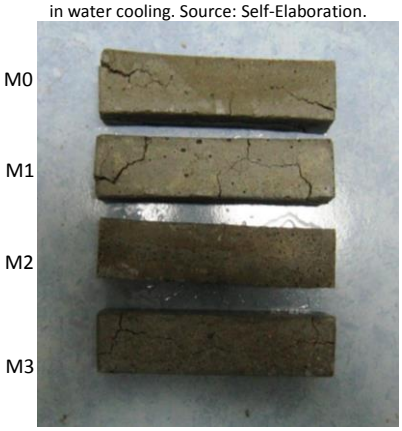


Figure 4. Relative mass loss of air-cooled mortar: Source: Self-Elaboration.

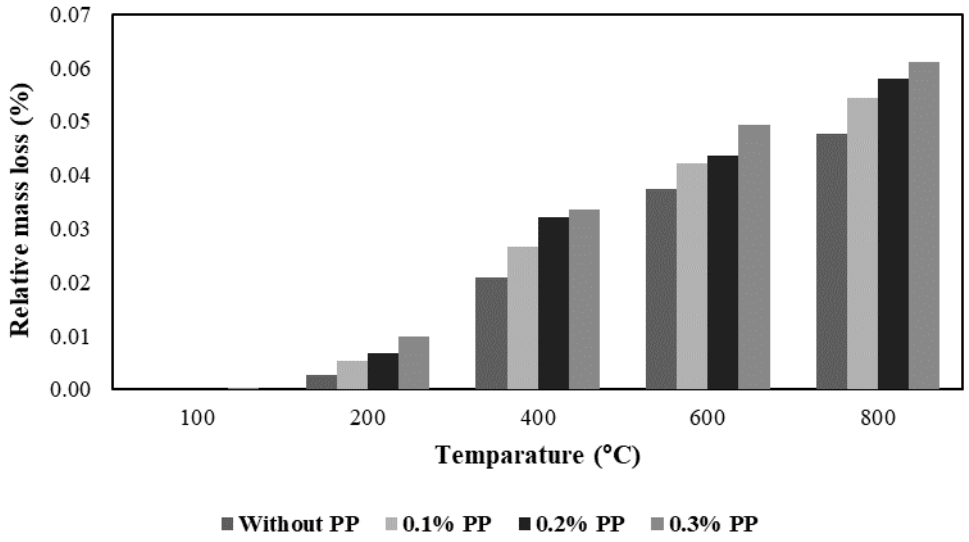
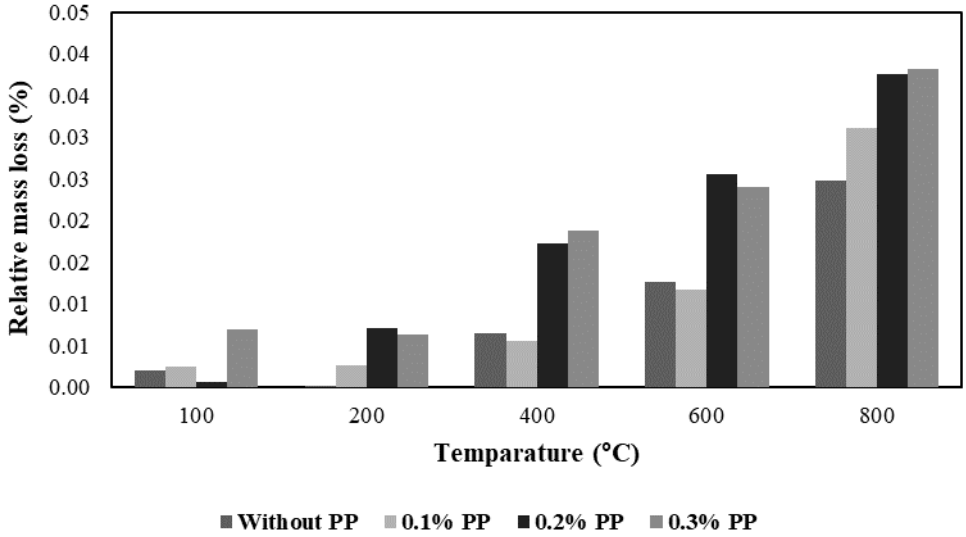


Figure 5. Relative mass loss of water-cooled mortar. Source: Self-Elaboration.



From both figures, it can be concluded that increasing polypropylene content in mortar increases mass loss of mortar. For both cooling regimes, mass loss of mortar is insignificant when exposure temperature was 200ºC or below. The percentages of mass losses were about 2 -3 and 4 - 5 and 5 - 6 for air cooling at 400, 600 and 800°C, respectively. The

percentages of mass losses were about 1 - 2 and 1 - 2 and 2 - 4 for water cooling at 400, 600 and 800°C, respectively. It was observed that the mass loss of air cooling was found to be higher than the mass loss of water cooling. This was attributed to rehydration of CaO which was formed due to dehydration of $Ca(OH)_2$ in mortar after heating, thus, this CaO hydrates with water when the mortar was cooled down in water. Rehydration of CaO bounds water and increases the mass of sample. It should be noted that the mass loss of mortar measured in this study was total mass loss which is caused by released water and melted polypropylene fiber. This results was in agreement with the published results of Xiao & Falkner (2006), Rodrigues et al. (2010), Arioz (2007) who concluded that the mass of the specimens reduced significantly as the temperature increased.

Compressive strength results for reference control unheated mortar and mortar subjected to elevated temperature are presented in Table 6. In general, it can be observed from Table 6 that the higher peak temperature results in higher reduction in compressive strength. The decrease in the compressive strength of heated mortar was found to be insignificant up to 200°C, when compared to unheated control mortar regardless of polypropylene content and cooling regimes. However, the decrease in the compressive strength of mortars were found to be significant at 400°C elevated temperature, and the reduction seemed to be dramatic at 600°C. This is explained by the well known fact that $Ca(OH)_2$ decomposes to CaO above 400-600°C. The order of the reduction in compressive strength was found to be at about 50% at 600°C. The comparison made between cooling regimes showed that there was no difference between the cooling regimes in terms of residual compressive strength of mortar regardless of polypropylene fiber content, up to 600°C elevated temperature. Therefore, water cooling or extinguishing fire with water can be performed for a small-scale fire.

Table 6. Compressive strength of hardened mortar (MPa). Source: Self-Elaboration.

Mix	Cooling Regime	20°C	100°C	200°C	400°C	600°C	800°C
M0	Air	64.7	64.5	65.7	54.2	33.5	15.2
M1	Air	56.7	56.1	59.9	53.0	31.3	14.1
M2	Air	57.2	59.8	61.1	50.3	27.3	13.4
M3	Air	59.1	58.8	60.5	49.0	28.9	11.0
M0	Water	64.7	65.7	60.0	49.8	31.1	6.4
M1	Water	56.7	60.7	60.5	52.2	30.9	5.0
M2	Water	57.2	57.7	59.1	47.5	30.0	4.5
M3	Water	59.1	60.9	58.1	49.2	29.9	4.3

Figure 6 and 7 compare the relative residual compressive strengths corresponding to mortar with polypropylene content to exposure temperatures with cooling regimes. The relative residual strength is defined as the ratio of compressive strength at high temperature to its initial compressive strength at ambient temperature. Obviously regardless of the presence of polypropylene fibers, water cooling resulted higher strength reduction when compared to air cooling regime. The influence of water cooling on the reduction of compressive strength becomes more marked at 800°C.

A comparison between air cooling and water cooling regimes at 800°C showed that remaining compressive strength of water cooled mortar was lower than half of the compressive strength of air cooled mortar (at average 40%). Therefore, the water cooling method or fire extinguishing with water sprinkling is not suitable for fire with longer duration or a large-scale fire. Yüzer, Aköz, & Öztürk (2004) made a similar recommendation stating that alternative extinguishers should be used instead of water.

Figure 6. Relative compressive strength of air cooled mortar. Source: Self-Elaboration.

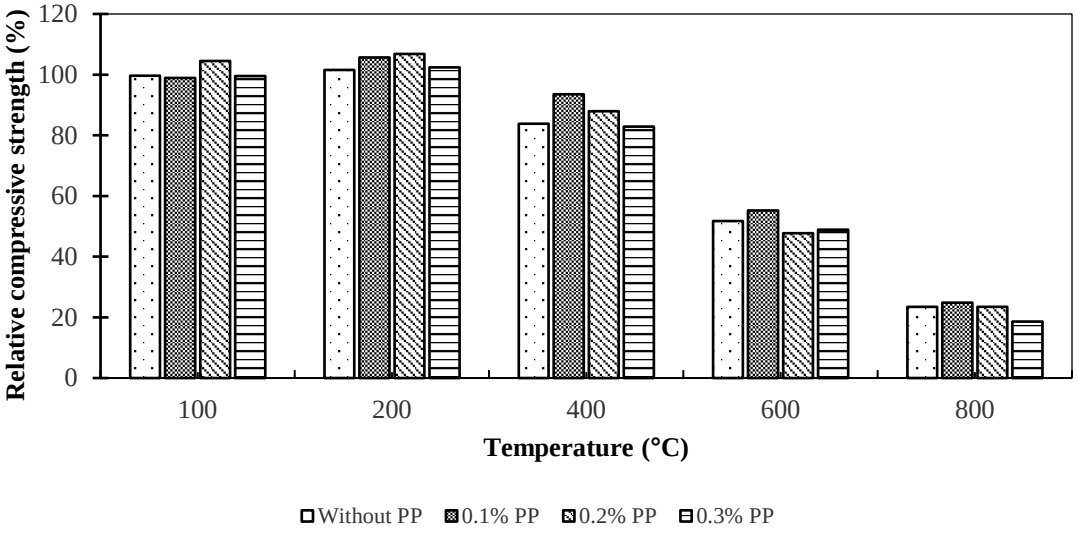
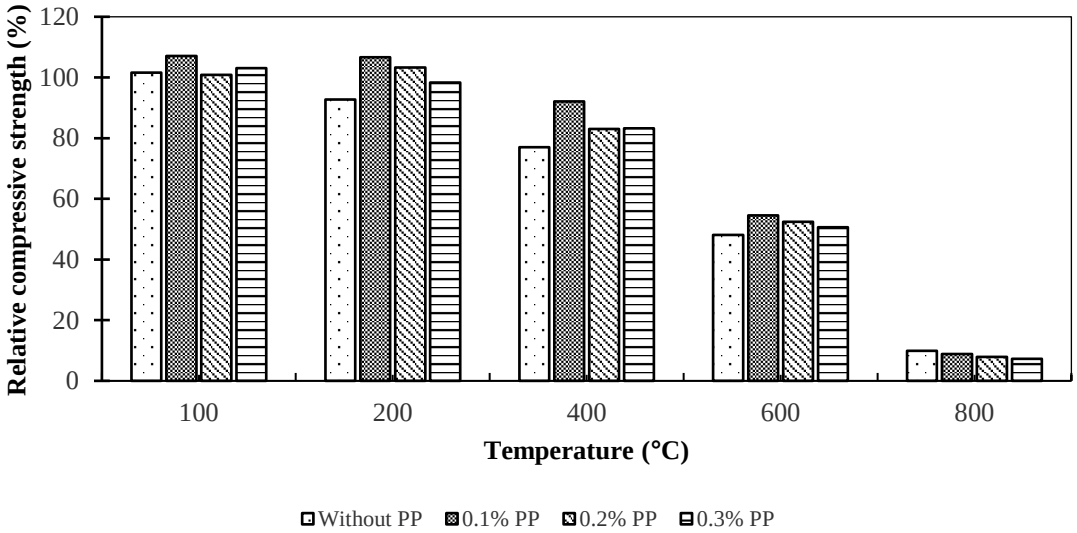


Figure 7. Relative compressive strength of water cooled mortar. Source: Self-Elaboration.



Overall, a comparison was made whether the polypropylene influenced the compressive strength of mortar before and after elevated temperature, little decrease in compressive strength was observed when the polypropylene fiber content of mortar increased for both cooling regimes irrespective of heating temperature. However, when comparison was made interms of relative changes in compressive strength to control mortar, influence of fiber addition in mortar show that better behaviour at 200℃ and 400℃ regardless of cooling method. Moreover, at 600℃ and 800℃, mortar containing polypropylene was behaved similar to control mortar. Xiao & König (2004) reported that the compressive strength of high strength concrete made with and without polypropylene fiber was almost the same after high temperature, regardless of the elevated temperatures. Aydin et al. (2008) reported that using polypropylene fiber decreased the compressive strength due to melting of polypropylene. Karahan (2010) studied on residual compressive strength of damaged mortar after elevated temperature, he concluded that slow cooling method either in air or in oven represented almost no difference in terms of compressive strength reduction for all exposure temperatures, however, quick cooling in water created important decrease in compressive strength in comparison to other gradual air cooling and furnace cooling method.

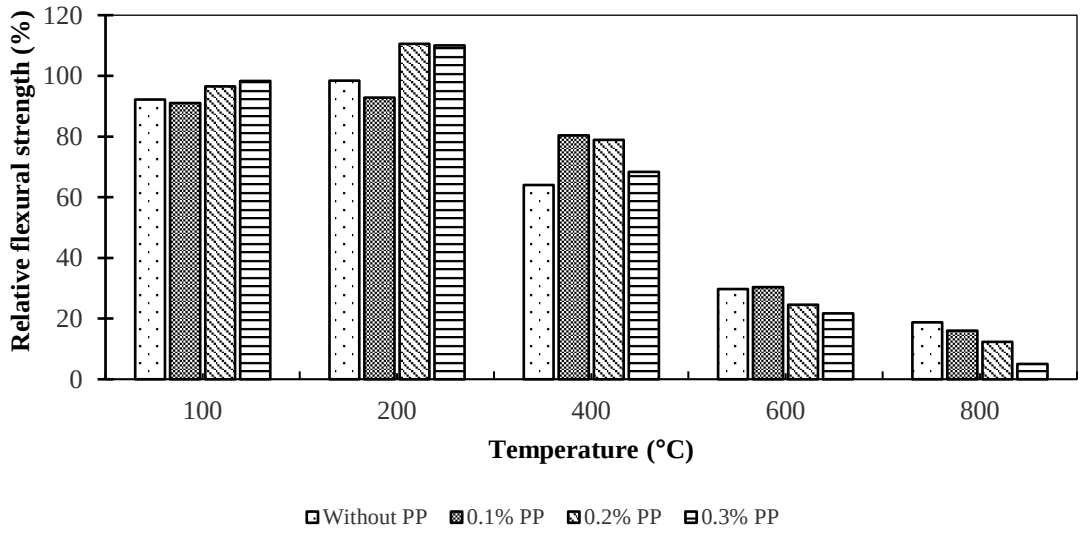
Flexural tensile strength results for reference control, unheated mortar and mortar subjected to elevated temperature are presented in Table 7. In general, similar to the compressive strength results, it can be observed from Table 7 that the higher peak temperature results in a higher reduction in flexural strength. The variations of relative remaining flexural tensile strength ratio of mortar samples after exposure to high temperature are shown in Figure 8 and 9.

It can be seen from Figure 8 and 9, as opposed to compressive strength, the strength reduction becomes significant at 200°C for flexural tensile strength when a specimen was cooled in water; (this may be due to formation of cracks when heated specimens introduced to water for shock cooling) in an air cooled specimen the strength reduction was insignificant. In addition, the reduction in the flexural strength of mortar was about 21-36% for air cooling, 45-62% for water cooling at 400°C. It was about 70-78% for air cooling, 72-87% for water cooling at 600°C. A comparison between air cooling and water cooling regimes at 800°C shows that residual flexural tensile strength of water cooled mortar was found to be half of the flexural tensile strength value of air cooled mortar.

Table 7. Flexural tensile strength of hardened mortar (MPa). Source: Self-Elaboration.

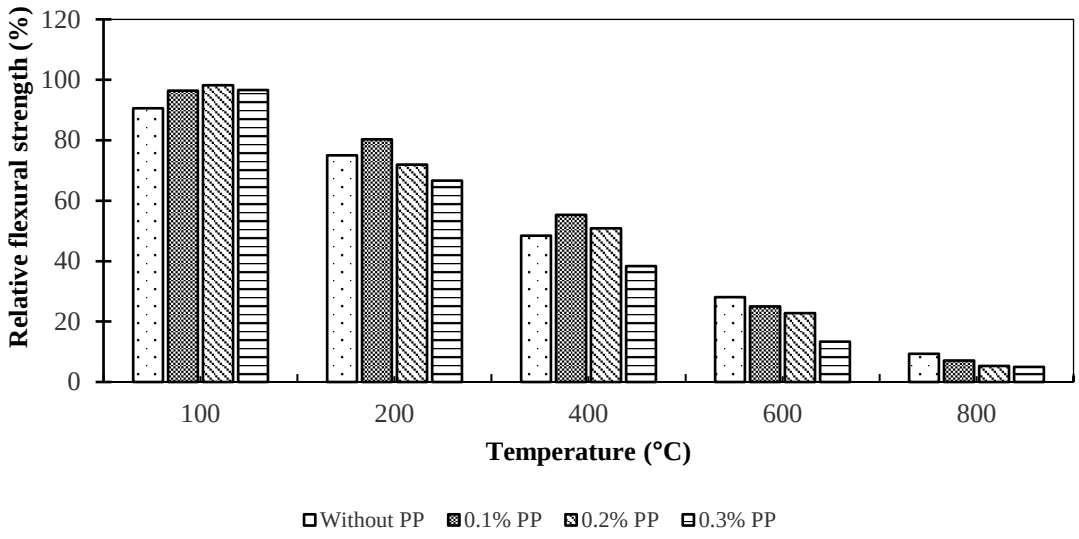
Mix	Cooling Regime	20°C	100°C	200°C	400°C	600°C	800°C
M0	Air	6.4	5.9	6.3	4.1	1.9	1.2
M1	Air	5.6	5.1	5.2	4.5	1.7	0.9
M2	Air	5.7	5.5	6.3	4.5	1.4	0.7
M3	Air	6.0	5.9	6.6	4.1	1.3	0.3
M0	Water	6.4	5.8	4.8	3.1	1.8	0.6
M1	Water	5.6	5.4	4.5	3.1	1.4	0.4
M2	Water	5.7	5.6	4.1	2.9	1.3	0.3
M3	Water	6.0	5.8	4.0	2.3	0.8	0.3

Figure 8. Relative flexural strength of air cooled mortar. Source: Self-Elaboration.



An overall observation showed that the inclusion of polypropylene in the mortar mixture did not increase the residual flexural strength of mortar made with type M6 polypropylene used at 0, 0.1, 0.2 and 0.3% fiber volume content. Flexural tensile strength was influenced more than that of the compressive strength, due to elevated temperature which was attributed to the fine cracks that occurred with the rapid heating and cooling period. Additional comparison was made in terms of tensile strength rate to compressive strength; the comparison showed that while temperature increases the strength rate reduces. However, this rate tends to reduce for mortar made with polypropylene fiber in comparison to control mortar. This result was found to be valid for both cooling methods.

Figure 9. Relative flexural strength of water cooled mortar. Source: Self-Elaboration.



This finding agrees with the published literature by Behnood & Ghandehari (2009) who concluded that the splitting tensile strength of concrete was more sensitive to high temperature than the compressive strength was. Furthermore, Xiao & Falkner (2006) concluded that the residual flexural strength of concrete with and without polypropylene fibers drops continuously under rising temperature. Aydin et al. (2008) reported that the deteriorating effect of elevated temperatures on flexural strength of mortar specimens was more extreme than compressive strength. Also, the other researches claimed that, the devastating effect of micro-cracks that form at elevated temperatures was more visible in the case of tensile stress created in flexural test (Cülfik & Özturan, 2002).

Conclusion

- The mass loss of air cooling was found to be higher than the mass loss of water cooling. This was attributed to rehydration of CaO which was formed due to dehydration of $Ca(OH)_2$ in mortar after elevated temperature, thus, this CaO hydrates with water when the mortar was cooled down in water. Rehydration of CaO bounds water and increases mass of sample.

- A small decrease in compressive strength was observed when the polypropylene fiber inclusion in mortar. The reduction in the compressive strength of heated mortar was insignificant up to 200°C. Besides that the decrease in the compressive strength of mortar was found to be significant at 400°C elevated temperature, and the reduction seemed to be dramatic at 600°C. The order of the reduction in compressive strength was found to be at about 50% at 600°C. In addition, interms of relative changes in compressive strength, polypropylene fiber mortar behaved better than control mortar mixture did at up to 400°C.

- Contrary to compressive strength, the flexural tensile strength reduction became significant at 200°C. In addition, the reduction in the flexural strength of mortar was about 21-36% for air cooling, 45-62% for water cooling at 400°C. It was about 70-78% for air cooling, 72-87% for water cooling at 600°C.

- Flexural tensile strength was influenced more than the compressive strength due to elevated temperature which was attributed to fine cracks. This may be owing to the fact that, the harmful effect of micro cracks that form at high temperatures was more apparent in the case of tensile stress.

- Based on laboratory work, addition of 0.1% polypropylene fiber in mixture was found to be optimum rate regardless of compressive or tensile strength, for both air and water cooling regimes.

- It was observed that water cooling result in more strength reduction when compared to an air cooling regime at 800°C. Therefore, the influence of water cooling in the reduction of compressive strength becomes more marked at higher temperatures.

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