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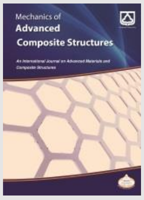

Experimental Investigating to Increases the Fire Resistance of the Ultra-High-Performance Concrete by using Hybrid Fibers

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KEYWORDS

Hybrid fibers;
Fire resistance;
Ultra-High-Performance concrete.

ABSTRACT

Nowadays fire has become one of the large prominent threats to buildings and concrete structures in the world. In this research, an experimental study was performed to examine the spalling phenomenon and residual mechanical properties of fiber toughened Ultra-High-Performance Concrete (polypropylene (PPF) and steel fibers (SF)). Moreover, the effect of high temperatures, namely, 250 ºC and 500 ºC for 2.5 hours and 5 hours has been studied for each mix of samples. This research discussed the results of compressive strength, flexural tensile strength, and splitting strength. Weight loss of the specimens and the effect of hybrid fibers incorporation (PPF and SF) behavior Ultra-High-Performance Concrete at high temperature were studied. The study concludes that the residual resistance of UHPC decreases as the temperature increases. Also, increasing the heating time resulted in lowering the residual concrete strength. The addition of the optimum percentage of PPF (0.8%) results in a remarkable effect on decreasing the risk of spalling in the UHPFRC. Polypropylene fibers provide channels in the concrete for this reduced pore pressures and the risk of spalling. Incorporating hybrid fiber seems to enhance the resistance of UHPFRC to explosive spalling due to the significant increase of permeability in UHPFRC. In addition to that, the steel fibers will increase the ductility of the UHPFRC and render it more able to withstand the high internal pressures which were experimentally confirmed by this work.

1. Introduction

Advances in concrete technology have resulted in the development of new types of cementation composites such as self-compacting concrete, self-healing concrete, high-performance concrete (HPC), ultra-high performance concrete (UHPC), etc. UHPC characterized demonstrates excellent workability, high mechanical, and good durability properties. These and other properties mainly depend on particle size distribution, optimal w/c ratio, and packing density [1][2]. Because of the growing need for high-rise buildings, buildings are being constructed worldwide over 200 m high. So become now one of the main technical elements for constructing these ultra-high-rise structures is the production of high resistance concrete with greater allowable stress and smaller cross-sections. High-rise buildings with compressive strength of more than 100 MPa were recently built using high-strength concrete [3]. The advancement of concrete technology and the demand for high-strength building materials give impetus to the advancement of UHPC [4]. This type of concrete with good properties, more commonly known as UHPC differs from high-performance concrete (HPC). The UHPC appears to have superior properties such as resilience, ductility, and increased compressive resistance to more than 150 MPa [5]. The Compressive performance in the concrete after the high temperature is important for the post-fire evaluation and repair of concrete structures. Studies show the mechanical properties of NC, HSC, and HPC gradually decline with increasing temperature and explosive spalling occurs in the concrete heating process [6].

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In (HPC) and, (UHPC) is prone to explosive spalling when exposed to high temperatures, which may lead to changes in concrete properties dramatically and deterioration of mechanical properties of concrete and hence the failure of the concrete elements [7]. In the high-strength concrete tests during the heating, it can be seen that it has two major weaknesses: first, the resistance decreases with increasing temperature, and, secondly, it leads the spalling to emerge quicker in concrete. Due to the loss of continuity between aggregate and cement paste, cracks resulted in the separation of the cement paste from the aggregate [8]. Recently, there has been increasing use of 'high-strength' or (high-performance) concrete. It is sometimes argued that high-strength concrete is more prone to spalling, due to its lower porosity and hence the increased likelihood of high pressure developing within the concrete structure because hard to exit water vapor during heating [9]. The hardened concrete matrix of Ultra-High Performance Fire Resistance Concrete (UHPFRC) shows extraordinary strength, durability properties and improves the ability of concrete to withstand elevated temperature or fire and that these features are the result of using very low amounts of water, high amounts of cement, fine aggregates, steel and polypropylene fibers and micro-fine powders [10]. The mechanical properties of concrete during fire containing different percentages of PPF and SF are significantly improved compared to concrete without fibers[11]. The increase of concrete permeability in the fire situation in case of dense and tight concretes is vital for limiting concrete spalling propensity. Polypropylene fibers are a proven solution enabling to increase permeability in an effective way. PP fibers provide a supplementary pore network at a temperature lower than spalling occurrence, enabling gas pore pressure to be reduced. Therefore, the appropriate concrete mix design is of high importance, especially when designing high-performance concretes for concrete structures with the risk of fire occurrence [12]. As the temperature increases up to above 200, water vaporizes and increases the porosity of the UHPC. As well as, the polypropylene fibers melted at high temperatures, creating channels that led to reduced internal vapor pressure in UHPC and retain some residual resistance. But the optimal volume of polypropylene fiber needs to be discussed further [13][14]. Because of the importance of concrete as a structural material in the building and the importance of preserving its stability during the fire, progress has become very important in researching materials and systems that improve their behavior, because fire reduces concrete resistance and rigidity and causes deformation in the concrete [15]. Spalling can greatly reduce or even remove the concrete cover layer at the reinforcement bars, thereby exposing the reinforcement to high temperatures directly, which leads to a reduction of the steel's strength in the concrete. It is commonly held that steel reinforcement bars effect by temperatures above 200 °C so they must be covered from temperature exposure exceeding 250-300 °C [9]. A positive influence on the explosive spalling of concrete specimens can be observed when adding fibers so that the spalling threshold was moved to higher temperature levels. The proposed relationships and models are compared to experimental results at elevated temperatures [16].

Because of the importance of concrete in building as a structural material and the importance of maintaining its stability at the high temperature, it has become extremely important to advance the research of materials and systems that enhance their efficiency as high temperature decreases concrete resistance and rigidity and creates deformations during and after the fire. Many researchers have performed UHPC studies but there is still little knowledge of UHPC's materials and structural properties. This work studies UHPC's properties after heating and investigates the effect of PPF and SF on the fire resistance of a UHPC. As well as determine the optimum amount of PPF and SF on improving fire resistance of Ultra-High-Performance Concrete (UHPC), and increasing the time of exposure before the occurrence of failure, and suggest some potential research needs.

2. Methodology

2.1. Materials

The equipment and materials listed below were used:

Ordinary Portland Cement(OPC): The test results comply with the requirements of (ASTM C150) [17], and It is the most active component of concrete and usually has a high unit cost.

Quartz Sand: aggregate is relatively inexpensive for producing UHPFRC. The nominal size ranges from (0.15mm to 0.6mm). It is important to ensure that the aggregates are clean, since a layer of silt or clay reduces the cement aggregate bond strength, in addition to increasing the water demand, and complies with the British Standards (B.S.) 882:1983) [18]. The silica fume (SF): SF exists in a grey powder form that contains silicon dioxide and no chlorides or other potentially corrosive substances. The SF used in this research work conforms to the requirements specifications of the (ASTM C1240-5).

Water: tap water was used in all concrete mixtures and in curing all of the tests' Specimens.

Superplasticizer: It is a superplasticizer that is produced (kinds F and G) to conform to requirements specifications (ASTM C494) [19]. Superplasticizer improves fresh concrete properties when added to the blend of UHPC, and this plasticizing impact might be utilized to improve the fresh concrete workability, and water minimizes to a high extent and rendering it powerful extremely; leading to strength, and high density.

Polypropylene fibers (PPF): It is a plastic polymer that was developed in the middle of the 20th century where it became widely used in the construction industry. These fibers are resistant to alkalis, chemicals, chloride, and heat transfer properties. Among the properties of PP is that it does not absorb water. Table 1 shows the property of the polypropylene used.

Table 1. polypropylene fibers properties used

Polypropylene	Property
0.91	Specific gravity
Nil	Sulfate content
38 µm	Fiber diameter
12mm	Fiber length
320-400 MPa	Tensile strength
160-170 °C	Melting point

Steel fibers (SF): these have high tensile strength and good formability; they are considered as one of the best and most economical fiber types. The steel fibers used in UHPC, exhibit high tensile strength, as well as the effect of using it in improving resistance for the UHPC, shown in Table 2.

Table 2. Steel fibers properties used

Steel fibers	Properties
13 mm	Length (mm)
0.20 mm	Diameter (mm)
7.8 g/cm3	Density (gm/cm3)
655 MPa	Tensile strength
Straight	Shape

2.2. Experimental Study

2.2.1. The Program of Tests

The effect of SF and PPF amounts on the UHPFRC properties that are subjected to high temperatures was studied by preparing several concrete mixes. Properties of the different constituent materials used to produce UHPFRC have also discussed the details of the test's procedure. UHPFRC constituent materials used in this research included ordinary Portland cement, quartz sand, silica fume, polypropylene, and steel fibers. Also, a superplasticizer was used to ensure suitable workability. Proportions of these mixture constituent materials were carefully selected to optimize the properties of the mixture concrete according to numerous studies, shown in Table 3. The tests for hardened concrete include the compressive, splitting strength, and flexural strengths before heating and after heating the concrete.

2.2.2. Specimens

A total of 120 cubes 10 × 10 × 10 cm, 72 prisms 10 × 10 cm cross-section and 40 cm in length, and 72 cylindrical specimens with a diameter of 15 cm and a height of 30 cm of UHPFRC specimens were cast and tested in this research. These UHPFRC specimens were arranged into eight groups shown as shown in Table (3). These eight group cubes of UHPC, in the beginning, tested the compressive strength, splitting strength test, and flexural strength without heating. All these eight group specimens tested the effect of heating samples to 250 ºC and 500 ºC for 2.5 hours and 5 hours were studied for each mix and compared the compressive, splitting strength, and tensile strength among the specimen mixes consecutively.

2.2.3 Experimental Process

Take out specimens UHPFRC used for testing from water, the specimens that completed the age of testing, were moved to the climatic

Table 3. UHPFRC mixture as a % from cement content.

The mixture Material	M.00. 1	M.P0. 2	M.P0. 3	M.P0. 4	M.0S. 5	M.PS. 6	M.PS. 7	M.PS. 8
Cement (PC)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Quartz Sand (QS)	125%	125%	125%	125%	125%	125%	125%	125%
Silica Fume (SF)	15%	15%	15%	15%	15%	15%	15%	15%
Superplasticizer	3%	3%	3%	3%	3%	3%	3%	3%
W/C	24%	24%	24%	24%	24%	24%	24%	24%
Polypropylene	0.0%	0.4%	0.8%	1.2%	0.0%	0.4%	0.8%	1.2%
Steel Fibers(by volume of concrete)	0.0%	0.0%	0.0%	0.0%	2%	2%	2%	2%

chamber, where the temperature was 20±2 ºC and the humidity of 60±5%, until testing age. Laboratory testing was conducted as follows:

2.2.3.1 The Compression Test:

The compressive strength test is one of the most important tests for concrete. This test was done according to the [ASTM C109/C109M, 2008]. Various trial mixtures were prepared.100x100x100 mm cubes of concrete for each batch of UHPFRC. For each group, three samples with a temperature ware 20±2 ºC and humidity of 60±5 %, before heating was prepared and tested in order to obtain the averaged value. The compressive strength machine was utilized for determining the greatest compressive loads carried by concrete cube samples. Additionally, all the samples were heated in the laboratory ovens for the required high temperatures and required periods. Temperatures were set at two values, 250 °C & 500 °C. After reaching the target temperature, the temperature was maintained for about 2.5 hours and 5 hours [Eurocode 2, (2002), part 1-2], and the samples were cooled down to room temperature. Also, all surface changes (color and cracks of the samples after the temperature exposure) were observed in Figure (1). The compressive strength machine was used for determining the maximum compressive loads carried by concrete cube samples.

The compressive strength for the samples σ *comp*. In (MPa) can be calculated by dividing the maximum compressive load by the area loaded:

$$\sigma com\, p = P/A \tag{1}$$

where P = maximum load carried by the cube sample and, A = the cross-sectional area of the sample.

Results of the compressive strength tests are shown in Table (3) for different percentages of polypropylene (0%, 0.4%, 08%, and 1.2%), and different percentages of steel fibers (0% and 16%), for the heating durations (0, 2.5, and 5 hours) and different heating temperatures (Room temperature, 250°C, and 500°C.

Fig 1. The oven used for heating the specimens

2.2.3.2 The Flexural Test:

The flexural resistance of UHPC samples was determined by the use of a simple beam with center-point loading in accordance with [ASTM C293, ASTM C293/C293M, 2010 [20]. Various trial mixtures were prepared. For each group, three specimens were prepared and tested in order to obtain an average value. The sample is a beam of 10 x 10 x 40 cm. The mold is filled in one layer of concrete and after 24 hours then immersed in water at 25ºC. The concrete samples are tested and turned on their sides with respect to their position as molded. This should provide smooth, plane, and parallel faces for loading so any loose sand grains or incrustations are removed from the faces that will be in contact with the bearing surfaces of the points of support and the load application. Results of the Flexural strength tests are shown in Table (5) for different percentages of polypropylene (0%, 0.4, 0.8%, and 1.2%), different percentages of steel fibers (0% and 16%), different heating temperatures (Room temperature and 250°C), and heating durations (0, 2.5 and 5 hours). The flexural resistance of the beam, (Fr) in (MPa), is calculated as follows:

$$Fr = 3PL/2BD2 \tag{2}$$

where P = maximum load, and L = span length, B = average width at the point of fracture and, D = average depth at the point of fracture.

2.2.3.3 Splitting Tensile Strength:

UHPFRC splitting strength tensile was calculated according to (ASTM C496. 2004), for cylindrical specimens with a diameter of 15 cm and a height of 30 cm of UHPFRC specimens the test as a standard procedure for cylindrical specimens measures tensile resistance. The tensile concrete strength is measured indirectly via cylinder compressing at width. Normally, the shear resistance given by concrete components is measured using a splitting tensile strength test. Results of the Splitting strength tests are shown in Table (6) for different percentages of polypropylene (0%, 0.4, 0.8%, and 1.2%), different percentages of steel fibers (0% and 25 by volume of concrete), different heating temperatures (Room temperature and 250°C), and heating durations (0, 2.5 and 5 hours). The splitting strength of the beam, (Fsp) in (MPa), is calculated as follows:

$$Fsp = 2P/\pi\, DL \tag{3}$$

3. Results and Discussion

3.1. Compressive Strengths:

The results (as shown in Table 4 and Figure 2) show that for the specimens without PPF and SF, the decrease of compressive strengths is larger than those specimens with PPF and FS after a fire. As well as, noticed that the duration of exposure to fire for 5 hours gets more reduction in the compressive strength in UHPFRC than in the case of exposure to fire heating duration of 2.5 hours in the temperatures 250 °C and 500 °C. Such as notes the percentage of strength loss for samples with 0.0% polypropylene and 0.0% steel fibers (Mix.001) heated at 250°C for 2.5 hours was 18.5%, and when heated at 500°C for 2.5 hours was 70.1%. While the percentage of compressive strength loss for specimens with 0.0% polypropylene and 0.0% steel fibers (Mix.001), heated at 250°C for 5 hours was 31.8%, and when heated at 500°C for 5 hours was 83.5%. And For specimens with (0.4%,0.8%, and 1.2%) polypropylene and without steel fibers (0%) heated at 250°C for 5 hours the loss was (14.9%,13.7%, and 17.9%), and when heated to 500°C for 5 hours, the loss was (76.4%,74.3, and77.8), respectively. While the loss for samples with (0.4%, 0.8%, and 1.2%) polypropylene and (16%) steel fibers heated at 250°C for 5 hours was (10.5%, 8.5%, and 12.2%) and when heated at 500°C for 5 hours the loss was (70.6%, 67.2%, and 73.7%), respectively.

Based on this investigation, the optimum percentage of PPF and SF for improving the concrete resistance against fire is 0.8% polypropylene and 16% steel fibers by weight of the cement in the UHPFRC. Based on the results it was concluded that the relative compressive strengths of concretes containing polypropylene fibers were higher than those without polypropylene fibers. Furthermore, adding steel fiber to UHPC can change the crack patterns, delay the crack appearance and restrain the crack expansion in the concrete specimen, the steel will increase the ductility of the concrete and render it more able to withstand the high internal pressures. As well as, incorporating hybrid fiber (polypropylene and steel fibers) In Specific proportions seems to be a promising way to increase the resistance of concrete to thermally induced explosive spalling, due to a significant increase of permeability in UHPFRC which was experimentally confirmed by this investigation.

Table 4. Compressive strength results at 28 days.

Name Mix	Unit weight	Compressive strength, (MPa)				
		Room temp.° C	2.5 hours heating		5 hours heating	
			250 °C	500 °C	250 °C	500 °C
M.00. 1	2335.3	140.05	114.15	41.89	95.42	23.13
M.P0.2	2326.1	150.25	146.33	65.75	127.75	35.42
M.P0.3	2321.4	154.75	149.56	69.55	133.5	39.76
M.P0.4	2316.5	160.45	155.76	62.25	131.66	35.57
M.0S.5	2396.2	163.75	160.67	70.50	135.49	40.85
M.PS.6	2378.7	167.49	159.54	91.30	149.82	49.2
M.PS.7	2366.3	170.32	163.75	97.46	155.88	55.77
M.PS.8	2348.4	161.95	157.30	80.97	142.27	42.61

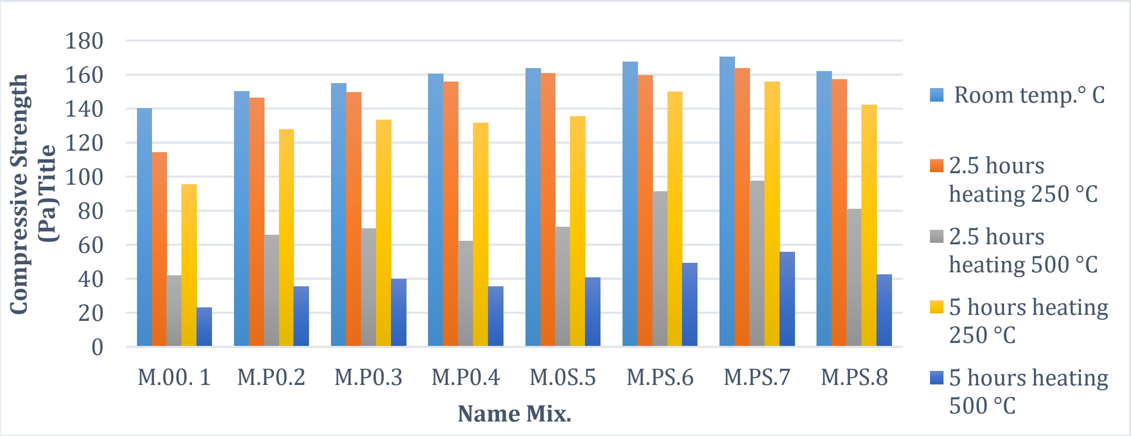

Fig 2. The compressive strength before and after firing samples.

3.2. The Flexural Strengths:

The results (as shown in Table 5 and Figure 3) show that the specimens without polypropylene and steel fibers, and specimens that contain only polypropylene reduce the flexural tensile strengths larger than those specimens with polypropylene and steel fibers. Such as notes the percentage of strength losses for samples with 00% PP and 00% steel fibers (Mix.001) heated at 250°C for 2.5 hours was 34.7%. But when heated for 5 hours at the same temperature was 64.9%, and the percentage of strength losses for samples with (0.4%, 0.8 and 1.2) polypropylene, and 0.0% steel fibers heated at 250°c for 2.5 hours was (35.3%,36.1%, and 38.9%). When heated for 5 hours at the same temperature was (64.9%, 65.2%, and 65.9%), respectively. Moreover, the loss in flexural strength of specimens with 0.0% polypropylene and 16% steel fibers heated at 250°C for 2.5 hours was 16.6% and when heated at 250°C for 5 hours the loss was 47.7%. While the loss in tensile strength for specimens with (0.4%,0.8%, and 1.2%) polypropylene and 16% steel fibers heated at 250°C for 2.5 hours was (17.1%,18.6%, and 24.5%) and when heated at 250°C for 5 hours the loss was (57.3%, 58.3%, and 63.1%), respectively.

One may conclude that the addition of PPF and SF highly decreases the loss of concrete tensile strength when it was heated up to 2.5 hours at 250°C and when the specimens were heated to 250°C for 5 hours, and the flexural tensile strengths were highly improved to resist high temperatures for 2.5 and 5 hours of heating. Based on this investigation, the optimum percentage of PPF and SF recommended to be used for improving the concrete resistance against fire is 0.8% and 16% from the cement. The steel fibers to concrete systems, because the fibers will increase the ductility of the concrete and render it more able to withstand the high internal pressures and hence an increase in the flexural tensile strengths.

Table 5. The flexural resistance for samples after firing to 250 °C.

Name Mix	Polypropylene %	Steel Fibers %	Flexural tensile strength(MPa)		
			Room Temp.	2.5 hour	5 hours
M.00.1	0.0%	0.0%	14.28	9.32	5.01
M.P0.2	0.4%	0.0%	15.62	10.11	5.44
M.P0.3	0.8%	0.0%	16.82	10.75	5.73
M.P0.4	1.2%	0.0%	19.01	11.61	6.21
M.0S.5	0.0%	16%	21.65	18.05	11.33
M.PS.6	0.4%	16%	22.86	18.95	9.04
M.PS.7	0.8%	16%	23.54	19.15	9.78
M.PS.8	1.2%	16%	22.01	16.61	8.13

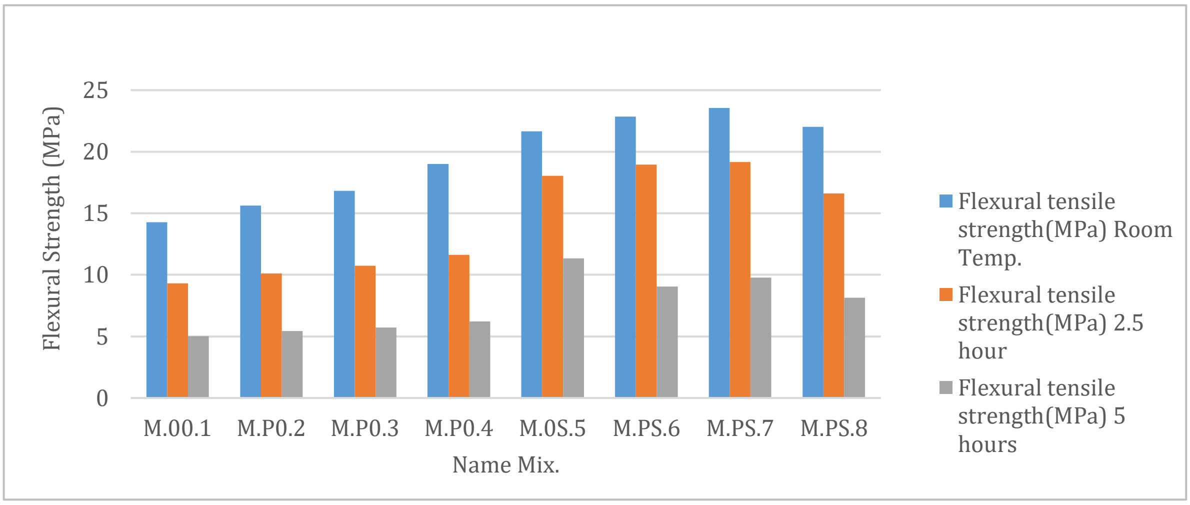

Fig. 3. The flexural resistance results in 250 C°.

3.3. Splitting Strength:

The results (as shown in Tables 6, and Figure 4) show that the specimens without polypropylene and steel fibers and specimens that contain only polypropylene decreased the splitting strengths larger than those specimens with polypropylene and steel fibers. Such as the percentage of strength losses for samples with 0.0% PP and 0.0% steel fibers (Mix.001) heated at 250°C for 2.5 hours was 43.8%. But when heated for 5 hours at the same temperature was 73.2%. While the percentage of strength losses for samples with (0.4%, 0.8 and 1.2) polypropylene, and 0.0% steel fibers heated at 250°c for 2.5 hours was (38.2%,33.5%, and 30.6%). And when heated for 5 hours at the same temperature was (71.4%, 68.1%, and 66.2%) respectively. The loss in split strength of specimens with 0.0% polypropylene and 16% steel fibers heated at 250°C for 2.5 hours was 17.1%. But when heated at 250°C for 5 hours the loss was 59.3%, and the loss in tensile strength for specimens with (0.4%,0.8%, and 1.2%) polypropylene and 16% steel fibers heated at 250°C for 2.5 hours was (13.6%,12.2%, and 16.6%) and when heated at 250°C for 5 hours the loss was (53.5%, 52%, and 56.8%), respectively.

It is clear from the test results that the splitting tensile strength is more sensitive to elevated temperature than the concrete compressive strength. It can be observed that concrete deteriorates at a faster rate when tested in tension rather than in compressive. In a temperature range of 250, at 2.5 h, and 5 h, all UHPFRC specimens showed a reduction in splitting strength range, compared with the reference specimens. The reduction in splitting strength of concrete when exposed to a temperature of 250 °C is due to the fact that during initial heating the evaporable water present in the concrete vaporizes that causing triaxial tension within the concrete. When a tensile load is applied the tensile stresses due to the applied load become additive to the triaxial tension resulting in a drop in splitting strength. Also, this reduction is attributed to the dehydration phenomenon, large thermal incompatibilities among the constituents of concrete, and the significant loss in the bond between materials.

That the addition of PPF and SF only highly decreases the loss of concrete tensile strength when it was heated up to 2.5 hours at 250°C and when the specimens were heated to 250°C for 5 hours. The splitting tensile strengths were highly improved to resist high temperatures for 2.5 and 5 hours of heating. As well, it is obvious from these results that the addition of steel fibers inside the polypropylene fiber-reinforced concrete would increase the residual splitting tensile strength of heated concrete because the fibers will increase the ductility of the concrete and render it more able to withstand the high internal pressures and hence an increase in the splitting tensile strengths. Based on this investigation, the optimum percentage of PPF and SF fibers recommended to be used for improving the concrete resistance against fire is 0.8% and 16% from the cement.

3.4. Effects of PPF and SF on Concrete Unit Weight After Heating

The results (as shown in Table 7) show that the density of UHPC decreases when increasing the polypropylene fiber percentage in the mix, but it increases when the amount of SF increases. As for after the heating at 250 ºC and 500 ºC, the results show, that the density of UHPC after the heating at 250 ºC and 500 ºC, Generally, Concrete density decreases with increasing temperature and a period of exposure to temperature when it is with PP or with PPF and SF.

Table 6. Splitting strength for heated samples fired to 250 °C.

Name Mix	Polypropylene %	Steel Fibers %	Splitting Strength (MPa)		
			Room Temp.	2.5 hour	5 hours
M.00.1	0.0%	0.0%	11.26	6.32	3.01
M.P0.2	0.4%	0.0%	13.45	8.31	3.84
M.P0.3	0.8%	0.0%	14.82	9.85	4.73
M.P0.4	1.2%	0.0%	16.01	11.11	5.41
M.0S.5	0.0%	16%	18.05	14.95	7.33
M.PS.6	0.4%	16%	19.26	16.82	8.94
M.PS.7	0.8%	16%	19.84	17.85	9.52
M.PS.8	1.2%	16%	19.51	16.51	8.43

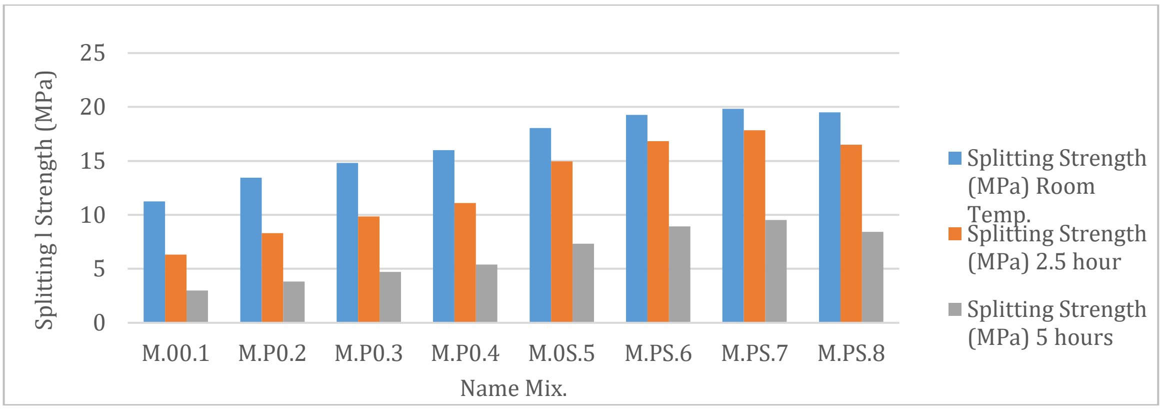

Fig 4. Splitting strength results for samples fired to 250 °C.

Table 7. Concrete unit weight for samples with and without heating.

Name Mix.	Polypropylene %	Steel Fibers %	Unit weight(kg/m3)		
			Room Temp.	2.5 hours at 250 °C	5 hours at 500 °C
M.00.1	0%	0%	2335.3	2321	2303.3
M.P0.2	0.4%	0%	2326.1	2306.6	2290.4
M.P0.3	0.8%	0%	2321.4	2301	2282.8
M.P0.4	1.2%	0%	2316.5	2290.6	2271.4
M.0S.5	0%	16%	2396.2	2389.9	2383.6
M.PS.6	0. 4%	16%	2378.7	2369.2	2366.8
M.PS.7	0.8%	16%	2366.3	2344	2342.1
M.PS.8	1.2%	16%	2348.4	2328.7	2326.4

4. Conclusion

In this Laboratory study, specimens of Ultra-High Performance Fire Resistance Concrete compositions were made and subjected to different heating periods and eight concrete groups were formulated without or with polypropylene and/or steel fibers. Concrete mass loss and residual mechanical properties were studied such as compressive, flexural tensile, and unit weight to the UHPFRC, and the following conclusions can be drawn from the former experimental results:

1. Experimental results show the significant improvement of the residual mechanical properties of UHPFRC containing the mix of fibers (polypropylene and steel fibers) compared to UHPC without fibers and the residual strength of UHPC decreases with the increase of temperature exposure and reduced the residual resistance of UHPC by increasing the heating time.
2. The addition of the optimum percentage of PPF (0.8%) results in a remarkable effect on decreasing the risk of spalling in the UHPFRC. where Polypropylene fibers melt at about 160-170 Cº and provide channels in the concrete for moisture to escape thus reducing pore pressures and the risk of spalling. Also, fine cracks around the fibers are contributed to pressure reduction, which subsequently reduced explosive spalling. However, the optimum volume of PP needs to be further studied.
3. From the analysis of the results, it can be concluded that UHPC with the addition of PPF and SF is a good alternative to traditional UHPC because both its strength and its behavior in case of fire are improved, delaying the appearance of fissures and explosive spalling concrete. Therefore hardened concrete matrix of (UHPFRC) shows extraordinary strength, and durability, and improves the ability of UHPC to withstand elevated temperatures or fire.
4. By using hybrid fibers (steel fibers＋ PP fibers), not only spalling under fire can be eliminated, but also mechanical properties after exposure to fire can be improved effectively, which may provide a necessary safe guarantee for rescue work and structure repair after a fire disaster.

5. Finally noted, after the heating at 250 ºC and 500 ºC Generally Concrete density decreases with increasing temperature and a period of exposure to temperature when it is with polypropylene or with polypropylene and steel fibers.

Conflicts of Interest:

The authors declare no conflict of interest.

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