Behavior of Plain and High Performance Polypropylene Fiber Concrete Subjected to Elevated Temperatures

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Abstract

The aim of this work is to determine the residual compressive strength and splitting tensile strength after exposure to an elevated temperature (between100 to 500 C°) of plain and polypropylene fiber reinforced concrete (PPFRC) in comparison with specimens exposed to ordinary temperature 25C° . High – performance concrete mixes were produced by using high rang reducing agent superplasticizer (SP) and 10% high reactivity metakaoline (HRM) as a partial replacement by weight of cement (350)Kg/m^3 . A single concrete mix with HRM, SP and four PPF contents of (0.25, o.5, o.75 and 1%) by volume were adopted. The workability of the concrete was kept constant (slump 100 ± 5mm).Each group of specimens (plain and PPFRC) was heated to a specified temperature and kept at the temperature for one hour before being gradually cooled to room temperature and then they were tested .

The results show at ordinary temperatures 25 C°, the addition of fiber volume fraction (VF%) of (0.25%) increases the compressive (20.6%) comparable to HPC without fiber . While the addition of (0.5 , 0.75 and 1%) of polymer fibers , the compressive strength decreased (12.6 , 19 and 33%) respectively comparable to HPC without fiber . On the other hand the addition of (VF%) of (0.25) increased splitting tensile strength (15%) comparable to HPC without fiber . while the addition of fiber volume fraction (VF%) of (0.5) increased splitting tensile strength by a percentage which is lower than that in specimens with VF% of 0.25 , the increase in splitting tensile strength was (6%) comparable to HPC without fiber at ordinary temperatures

The results also shows that , when (1%) fibers was used , the splitting tensile strength decreased (10.8%) in comparable to HPC without fiber

At elevated temperature the results show an appreciable decrease in compressive strength and splitting tensile strength after exposure to temperature higher than 300 C° of both plain and PPFRC

Specimens containing PPF (0.25 , 0.5 , and 0.75 %) the percentage of reduction in splitting tensile strength is lower than that in HPC specimens (without fibers) after exposure to a temperature (500 ,300 and 100 C°) comparable to normal temperature 25C° .While specimen containing PPF (1%) the percentage of reduction in splitting tensile strength was higher than specimen without PPF after exposure to a similar temperature .

On the other hand , specimens containing PPF (0.25 , 0.5 , 0.75 and 1 %) the percentage of reduction in compressive strength is higher than that in HPC specimens (without fibers) after exposure to a temperature (500 ,300 and 100 C°). comparable to normal temperature 25C°

Keywords: High Performance concrete, polypropylene Fiber, elevated temperature, compressive strength , splitting tensile strength

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سلوك الخرسانة العلية الاداء و المعززة بالياف البوليبروبلين تحت تاثير الحرارة المتزايدة

الخلاصة

الهدف من هذا العمل هو تحديد التغيرات الحاصلة في مقاومتي الانضغاط و الشد الانشطاري بعد التعرض لدرجات متزايدة من الحرارة بين 100 -500 مْ للخرسانة الغير مسلحة و الخرسانة المسلحة بالياف البوليبروبلين بالمقارنة مع درجات الحرارة الاعتيادية 25 مْ

في هذه الدراسة تم انتاج خرسانة عالية الاداء باستعمال الملدن المتفوق و باستعمال الملدن مع الميتاكاوؤلين بنسبة 10% كاحلال جرئي من السمنت (350) كغم/م^3 و للخرسانة المسلحة بالياف البوليبروبلين تم استخدام خلطة موحدة من الميتاكاؤولين و الملدن مع اربعة نسب من الياف البوليبروبلين (0.25 ، 0.5 ، 0.75 و1) . سخنت كل مجموعة من النماذج (المسلحة و غير المسلحة) الى درجة الحرارة المحددة و ثم تم الابقاء على هذه الدرجة لفترة ساعة واحدة قبل تبريدها تدريجيا الى درجة الحرارة الاعتيادية ثم اجريت الفحوصات المختلفة على النماذج .

اظهرت النتائج عند الدرجات الحرارة الاعتيادية 25 مْ ، ان اضافة (% 0.25) من الالياف ادى الى زيادة في مقاومة الانضغاط حوالي 20.6% من ناحية اخرى ، عند اضافة نسبة الالياف (0.5 ، 0.75 و 1%) ادى الى انخفاض في مقاومة الانضغاط حوالي (12 ، 19، و 33%) على التوالي مقارنة" مع خرسانة HPC و الخالية من الالياف . بينما اضافة نسبة الالياف (0.25%) ادى الى زيادة الشد الانشطاري حوالي (15 %) مقارنة" مع خرسانة HPC و الخالية من الالياف . ، بينما اضافة نسبة الالياف (0.5%) ادى الى زيادة الشد الانشطاري بنسبة اقل حيث كانت حوالي (6 %) مقارنة" مع خرسانة HPC و الخالية من الالياف . ، من ناحية اخرى اضافة نسبة الالياف 1% ادى الى انخفاض في مقاومة الشد الانشطاري حوالي 10.8% مقارنة" مع خرسانة HPC و الخالية من الالياف

عند التعرض الى درجات حرارة متزايدة ، اظهرت نتائج الفحوصات انخفاض واضح في مقاومتي الانضغاط و الشد الانشطاري بعد التعرض لدرجات حرارة تزيد على 300 مْ للحرسانة المسلحة و غير المسلحة . كذلك اظهرت النتائج ان الفقدان الحاصل في مقاومة الشد الانشطاري للخرسانة المسلحة بالياف البوليبروبلين كان اقل بشكل واضح بالمقارنة مع الخرسانة الغير مسلحة بالياف البوليبروبلين بعد التعرض الى درجات الحرارة (500 ،300 و100) مقارنة مع الدرجات الحرارة الاعتيادية 25 مْ (، ومن ناحية اخرى ، العينات الحاوية على الياف 1% ، نسبة الانخفاض في مقاومة الشد الانشطاري كانت اعلى من العينات الخالية من الالياف بعد التعرض الى درجات حرارة مشابهة ومن ناحية اخرى ، العينات الحاوية على الياف (0.25 ، 0.5 ، 0.75 و 1%) ، نسبة الانخفاض في مقاومة الانضغاط كانت اعلى من العينات HPC (الخالية من الالياف) بعد التعرض الى درجات الحرارة (500 ،300 و100) مقارنة مع الدرجات الحرارة الاعتيادية 25مْ

Abbreviations:PPFRC : Polypropylene fiber reinforced concrete

NC : Normal concrete

SHPC : High – performance concrete with superplasticizer

SHHPC : High – performance concrete with superplasticizer and 10% high reactivity metakaoline

SHHPC$_{0.25}$: High – performance concrete with superplasticizer , 10% high reactivity metakaoline and polypropylene fiber content of (0.25%) by volume

$SHHPC_{0.5}$: High – performance concrete with superplasticizer , 10% high reactivity metakaoline and polypropylene fiber content of (o.5%) by volume

$SHHPC_{0.75}$: High – performance concrete with superplasticizer , 10% high reactivity metakaoline and polypropylene fiber content of (o.75 %) by volume

$SHHPC_{1}$.: High – performance concrete with superplasticizer , 10% high reactivity metakaoline and polypropylene fiber content of (1%) by volume

Introduction

The terminology "High – Performance Concrete "(HPC) has been introduced in to the construction industry . Due to their high compactness and their low permeability (HPC) are used more and more in construction (high rise building , tunnels , bridges) .However , when they are subjected to high temperatures, such as during a fire , these compact concrete , unlike ordinary concretes , may behave in a brittle way [1] .

High temperature influences the behavior of concrete at different structural levels . At the micro and meso levels , concrete sustains physical and chemical changes. Physically , thermal dilations , thermal shrinkage , and creep associated with water loss cause large volume changes that result in large internal stresses and strains leading to microcracking and fractures. Chemically, high temperature increases dehydration and cause decomposition of hardened cement paste and aggregates .[2]

Poon el at. [3] studies the effect of PPF fiber and steel reinforcement on the compressive behavior of HPC when it was subjected

To elevated temperatures . The results showed that after exposure to 600 and 800̊ C, the concrete mixes retained, respectively , 45% and 23% of their compressive strength , on average . The results also showed that after the concrete was exposed to the elevated temperature, the loss of stiffness was much quicker than the loss in compressive strength, but the loss of energy absorption capacity was relatively slower.

Al – Rubiy [4] studied the effect of PPF reinforcement on the engineering properties of concrete when (0 to 6)% by volume of PPF was added . Test results showed that the addition of PPF decreases workability by about (74 , 84 and 100) % by using (0.75 , 1.5 and 6) % by volume of PPF respectively . The poor workability makes the concrete has higher bleeding , non – homogeneous and also increases porosity .Test results also indicate that compressive strength does not increase when the percentage of fiber is increased more than 1% by volume fraction

Research Significance

Concrete structures may be exposed to high temperatures at which deterioration of concrete occurs. Exposing concrete to high temperature causes strength deterioration, increase in drying shrinkage, reduction in bond strength with reinforcement . Little investigations have been noticed to provide experimental result about the effect of PPF on the properties of concrete at elevated temperature , so it became necessary to make additional studies on the effect of elevated temperature on properties of PPFRC

In this study an investigation is carried out on the effect of elevated temperature on the compressive strength and splitting tensile strength.

Experimental Program:

Materials:

Cement:

Ordinary Portland cement (Type 1) manufactured by Taasloja cement factory used throughout this study. The chemical and physical properties of this cement are was shown in Tables (1) and (2) respectively, which comply with the Iraqi Standard Specification I.Q.S. No.5, 1984 requirements[5].

Fine Aggregate

Natural siliceous sand of Al-Ukhaider region with fineness modulus, specific gravity , SO3% and absorption of 3.18, 2.7 , 0.32% and 1.5 % respectively was used in this work. Results indicate that the used fine aggregate was within zone 2 according to the requirements of the Iraqi standard specification No.45/1984 [6].

Coarse Aggregate:

Crushed gravel was used as a course aggregate, it was from Al-Niba'ee region with 14 mm . The specific gravity and absorption of the used coarse aggregate was 2.64 and 0.57 %, respectively. The sulfate content (SO3%) was 0.09% of the used coarse aggregate , while the maximum limit specified by I.Q.S. No.45, 1984. [6] is.1%.

High Range Water Reducer Agent(HRWRA): -

For the production of the HPC concrete, high water reducing agent (HRWRA) based on polycarboxylic ether is used. Glenium 51 is considered one of a new generation of copolymer -based superplasticizer ASTM C494-Types A and F designed for the production of HPC is used in this study. Table (3) shows the typical properties of this admixture.

High Reactivity Metakaolin (HRM):-

Metakaolin is a pozzolanic material produced by calcining chin clay at temperature of 700-900 °C. In this study, the locally available china clay (Kaoline) clinks in laboratory using a burning kiln with clinkering ability up to 1000°C. The china clay (kaolin) is burned at 700°C for whole one hour then left to cool down gradually. The strength activity index (**S.A.I**) of HRM with Portland cement was determined according to ASTM C311-03 . The chemical and physical properties of HRM are listed in Table (4).

Polypropylene Fiber (PPF)

High performance short 19 mm polypropylene fiber was used in this investigation, it was brought from Fosroc Company Table (5) indicates the physical properties of PPF used throughout this work.

Preparation of Concrete Specimens

Concrete Mixes

Concrete mix was designed according to Building Research Establishment Method. The mixes are divided in two groups as follows:-

Group 1:- includes reference NC , SP and HRM – SP. The reference concrete mix designed to have a 28 days characteristic compressive strength of about (25) MPa and slump 100 ± 5 mm . According to the mix design procedure, concrete mix with a weight proportions of (1: 2.1 : 3) and water /cement ratio of (0.6) was used as a reference mixes .The high performance mixes were produced by using superplasticizer and mineral admixtures (metakaolin) as a partial replacement by wt. of cement 10%

Group 2 :- includes high performance using SP , HRM and polymer fibers contain (Vf % = 0) as a reference , and four other high performance concrete mixes with four polymer fiber content Vf % of (0.25 , 0.5 , o.75 and 1)

Table (6) shows the details of reference and high performance concrete with and without polymer fibers mixes used throughout this work . Because of the effects of HRM and polymer fibers contents on workability of concrete, the water/cement ratio , and SP of mixes were changed to maintain the desired workability constant , (slump 100 ± 5 mm) .

From Table (6) the Superplasticizer dosage is raised due to increased the fiber volume fraction , when (0.75 or 1%) was added , the workability problems arise and become severe at (1%) by volume friction . This finding is also confirmed by Patrick [7] , he also reported that the use of superplasticizers reduces this problem. therefore , it is necessary increasing Superplasticizer dosage to reduce the problem of workability and to maintain the desired workability constant , (slump 100 ± 5 mm) .

Mixing Procedure

A standard mixer of rotating drum was used to mix concrete to obtain the required workability and homogeneity . The interior surface of the mixer cleaned and moistened before placing the materials .

For reference concrete the dry constituents , were placed in the mixer such that cement is placed between two layers of gravel and sand . The dry materials were well mixed for about 1.5 minutes to attain uniform mix . The required quantity of tap water was then added and the whole constituents were mixed for other two minutes .

To mix the materials for HPC , the above procedure was used expect that the metakaolin be mixed with the quantity of cement and the superplasticizer was thoroughly mixed with water and the liquid component was added to the dry material mixture , this wet composition was allowed to mix for another four minutes. During the process, PPF (if any) was sprinkled uniformly in the wet mixture. Care has been taken in allowing all the materials to get mixed up uniformly avoiding the materials to get stuck up to the walls of the mixer.

Details of the Tests

After 24 hours of casting , the specimens were de-moulded and placed in water for curing . After 28 days of curing the specimens were exposed to air to be air dried.

An electric furnace was used for heating the specimens ; the maximum furnace temperature was 1200 ̊ C. The temperatures was controlled by an electronic controller. The specimens were exposed to different temperatures of 100 , 300 and 500 ̊ C in order to find the residual compressive and splitting tensile strengths . They were heated to the test temperatures , allowed to remain at final elevated temperature for one hour then allowed to cool gradually in air at room temperature for a period of 24 hours before being tested . The following tests at each temperature level were carried out :

1. three 100 mm cubes were heated to evaluate the residual compressive strength.
2. three cylinders of 100 × 200 mm were heated to evaluate the residual splitting tensile strengths

Results and Discussion

Compressive strength of mixes at ordinary temperature 25 C̊

The Building Research Establishment (2000) citd by Alan [8] reported that " strength tests on specimens found the cube compressive strength of concrete containing polypropylene fibers to be significantly reduced because of the resulting lower density " . Gold (2000) citd by Alan [8] " Fibers actually entrain small amounts of air as a result of the surface treatment they receive in the manufacturing process " , this provides a plausible reason for the lower density and subsequent compressive strength .

Different result have been reported on the compressive strength of materials when PPF are added . Zollo indicated a negative effect of fibers in the strength resistance of concrete . Some other findings by Alhzaimy et al . showed that at volume fractions from 0.05 to 0.3 % of PPF fibers have no statistically significant effect on the compressive strength. Other studies by Altoubat et al. showed a small decrease in the compressive strength when fibers were added at a dosage of o.32 and 0.48% [9].

In this study , the addition of fiber volume fraction (VF%) of (0.25%) increases the compressive from (31.5 to 38MPa) . This is due to the fact that the presence of fibers increases strainability in compressive failure [10] and hence the compressive strength increases as reported by Khalil [11] .While the addition of (0.5 , 0.75 and 1%) of polymer fibers , the compressive strength decreased from (31.5 to 27.5 , 25.5 and 21 MPa) respectively . This could be attributed to , the increase of air voids in concrete due to an increase in fiber content and water – cement ratio , which is required to maintain a given workability (slump 100 ± 5 mm), where the compressive strength is very sensitive to the presence of these voids. This finding is also confirmed by other researchers[8][9]

Table (7) shows the result of compressive strength for all concrete specimens exposed to ordinary temperature 25 C̊ . Fig. (1) shows a comparison between normal and HPC concrete . It shows that the use of SP and HRM increase the compressive strength from (25.5 to 31.5MPa) Fig. (2) shows a comparison between plain and fiber reinforced HPC concrete .

Splitting tensile strength of mixes at ordinary temperature 25 C̊

Table (7) shows the result of splitting tensile strength for all concrete specimens exposed to ordinary temperature 25 C̊ .Fig. (3) shows a comparison between normal and HPC concrete for plain concrete . It show that the use of SP and HRM increases the splitting tensile strength from (2.6 to 4.6 MPa) . Fig. (4) shows the effect of addition of polymer fiber on concrete splitting tensile strength in comparison with HPC without fiber . It is shown that the addition of fiber volume fraction (VF%) of (0.25) increased splitting tensile strength (15%) comparable to HPC without fiber . This increase in tensile strength is expected , since polymer fibers work as a spread reinforcing elements in the matrix, which means that fibers inhibit crack propagation in the matrix , and consequently enhance the behavior and the strength of concrete . On the other hand the addition of fiber volume fraction (VF%) of (0.5) increased splitting tensile strength by a percentage which is lower than that in specimens with VF% of 0.25 , the increases in splitting tensile strength was (6%) in comparison with HPC without fiber Also, it was found that workability problems arise when fiber volume reaches about 0.5% this leads to increase the w/c ratio which is required to maintain a give workability (slump 100 ± 5 mm) that leads to decreased splitting tensile strength in comparison with (VF%) of (0.25) .

When (0.75%) by volume of fiber was added , there was no gain in splitting tensile strength of concrete comparable to HPC without fiber , while when (1%) fibers was used , the splitting tensile strength decreased from (4.6 to 4.1 MPa) in comparable to HPC without fiber . This could be attributed to the increase of air voids in concrete due to an increase in water – cement ratio , which is required to maintain a give workability (slump 100 ± 5 mm) . This finding is also confirmed by Patrick [7] he studied the influence of PPF on the mechanical properties, using different percentages of PPF (0.1 to 2.0) % by volume. The test results indicated that PPF at dosage rate of 0.1 % by volume or less has no significant effect on compressive and tensile strengths , Also, it was found that workability problems arise when fiber volume reaches about 0.3% and become severe at 1% by volume, therefore, the use of superplasticizers reduces this problem. Also, the inclusion of PPF limits the extent of cracking in the plastic state but it does not enhance the tensile strength of the concrete, therefore, PPF cannot be used as a substitute for steel reinforcement. [7]

In this study , When (1%) by volume of fiber was added , the splitting tensile strength decreased to (10.8%) in comparison with HPC without fibers. This is not similar to the study done by Al-Owaisy [12] {he used steel fibers in spite of PPF , for mixes with steel fibers the increased in the volume fraction of fibers leads to higher density of the mix , this is because of the high density of steel fibers . On the other hand the increase in the polypropylene fibers leads to a lower density of the mix and this is because of the low density of such fibers which means replacement of some concrete content with a lighter material } also , the workability problems arise when PPF reaches 1% , This leads to an increase in water – cement ratio , which is required to maintain a give workability (slump 100 ± 5 mm) which leads to decreased splitting tensile strength in comparison with HPC without fibers

Concrete properties after high temperature exposure

After exposure to (100 , 300 and 500 ̊ C) , it was noticed that the investigated concrete properties for both plain concrete and polymer fibers reinforced concrete suffer some changes. These changes ranged from limited loss in strength up to extreme deterioration in strength over the original strength values in some cases . But, it can be recorded that the exposure to temperature above (300 ̊ C) causes a noticeable decrease in strength , for plain concrete and for polymer fibers reinforced concrete.

Effect of elevated temperature on compressive strength

Table(8) shows the result of compressive strength for all concrete specimens exposed to elevated temperature Fig. (5) and (6) show the relationship between temperature and the residual compressive strength in relation to the original strength prior to heating of plain concrete and PPFRC . Generally , it can be seen that all mixes either plain or polymer fiber mixes exhibited compressive strength loss as temperature increases . There is a considerable decrease in compressive strength as the temperature was increase above 300 ̊ C , this is due to the loss of cement paste plasticity at high temperatures [13] . Also the decrease in compressive strength of concrete is attributed to the breakdown of interfacial bond due to incompatible volume changes between cement paste and aggregate during heating and cooling [14] , and dehydration of calcium hydroxide occurs when temperature exceeds about (400 ̊ C) and causes shrinkage of the cement paste[15] .

For plain concrete of (NC , SHPC and SHHPC) the percentage of reduction in compressive strength was (36.5 ,28.6 and 20.6%) respectively at 500 C̊ comparable to normal temperature 25C̊ , but when the furnace is 300 C̊ the percentage of reduction in compressive strength was (17 , 21.4 and 14.3%) respectively compared to normal temperature 25C̊. At 100C̊ the percentage of reduction in compressive strength was (3.8, 5 and 6%) respectively. comparable to normal temperature 25C̊

For PPFRC of ($SHHPC_{0.25}$, $SHHPC_{0.5}$, $SHHPC_{0.75}$ and $SHHPC_{1}$) the percentage of reduction in compressive strength at 500 C̊ was (48 , 32 , 47 and 42.5%)respectively comparable to normal temperature 25C̊ While when the furnace is 300 C̊ the percentage of reduction in compressive strength was (26 , 21.4 ,35 and 3%) respectively compared to normal temperature 25C̊. At 100C̊ the percentage of reduction in compressive strength was (11.8, 10.7 , 21.5 and 12%) respectively compared to normal temperature 25C̊.

It is noticed that , for specimens containing PPF , the reduction percentage in compressive strength is higher than that in HPC specimens (without fibers) . This may be due to the combined effect of the temperature which affects the micro structure of concrete , and because of reaching PPF its melting point (especially after 160 ̊ C) which results in large of weak points between ingredients of concrete .

Effect of elevated temperature on splitting tensile strength

Table (9) shows the result of splitting tensile strength for all concrete specimens exposed to elevated temperature. The relationship between the temperature and the residual splitting tensile strength of plain concrete and PPFHPC is shown in Fig. (7 and 8) . The splitting tensile strength clearly decreases as the exposure temperature increase for all mixes and the rate of reduction increases as the temperature increase

For plain concrete of (NC ,SHPC and SHHPC) the percentage of reduction in splitting tensile strength was (27.6 , 31.8 and 30.4%) after exposed to a temperature (500 C̊) respectively in comparison with normal temperature , while when the furnace is 300 C̊ the percentage of reduction in splitting tensile strength was (17 ,27 and 17.4%) respectively. At 100C̊ the percentage of reduction in splitting tensile strength was (6 , 9 and 10.8%) respectively.

For PPFRC of ($SHHPC_{0.25}$, $SHHPC_{0.5}$ and $SHHPC_{0.75}$) the percentage of reduction in splitting tensile strength was (28.3 , 24 and 27.2%) after exposure to a temperature (500 C°) respectively comparable to normal temperature 25C°, while when the furnace is 300 C° the percentage of reduction in splitting tensile strength was (13 , 18 and 13.6%) respectively comparable to normal temperature 25C°. At 100C° the percentage of reduction in splitting tensile strength was (9 , 6 , and 6.8%) respectively comparable to normal temperature 25C°

For specimens containing PPF (0.25 , 0.5 , and 0.75 %) it is notice that the percentage of reduction in splitting tensile strength is lower than that in HPC specimens (without fibers) , This is attributed to the role of fibers in controlling crack propagation which begging only after matrix cracking [11] . On the other hand , specimen containing PPF (1%) the percentage of reduction in splitting tensile strength was higher than specimen without PPF ,the percentage of reduction in splitting tensile strength was (31.7 and 29 %) after exposed to a temperature (500 and 300 C°) respectively comparable to normal temperature 25C°

Modes of failure

Brown et al [15] study the behavior of PPF in a cement matrix , they reported that , plain concrete under loading cracks into two pieces when the structure is subjected to the peak tensile load and cannot withstand further load or deformation. The fiber reinforced concrete structure cracks at the same peak tensile load , but does not separate and can maintain a load to very large deformation . The behavior of PPF under loading can be understood from Figure (9). The area under the curve shows the energy absorbed by the PPF when subjected to tensile load. This can be termed as the post-cracking response of the PPF

In this study , the addition of polypropylene fibers helps to hold the specimens concrete together after reaching failure , preserving the whole member and integrity the connection . The modes of failure of concrete specimens are shown in Fig. (10)

Conclusions

1. The addition of PPF to concrete changes the mode of failure for all test , from sudden brittle to more ductile failure , both before and after exposure to elevated temperatures
2. Exposure to elevated temperatures affects concrete strength significantly . The strength decrease depends mainly on the temperature level and the type of concrete . And there is a considerable decreases in strength as the temperature increase above 300 C° .
3. At ordinary temperatures the addition of fiber volume fraction (VF%) of (0.25%) increases the compressive from (31.5 to 38MPa) ..While the addition of (0.5 , 0.75 and 1%) of polymer fibers , the compressive strength decreased from (31.5 to 27.5 , 25.5 and 21 MPa) respectively .
4. The addition of fiber volume fraction (VF%) of (0.25) increased splitting tensile strength (15%) comparable to HPC without fiber . On

the other hand the addition of fiber volume fraction (VF%) of (0.5) increased splitting tensile strength by a percentage is lower than that in specimens with VF% of 0.25 , the increase in splitting tensile strength was (6%) comparable to HPC without fiber at ordinary temperatures . When (1%) fibers was used , the splitting tensile strength decreased from (4.6 to 4.1 MPa) in comparable to HPC without fiber

5. Specimens containing PPF (0.25 , 0.5 , and 0.75 %) the percentage of reduction in splitting tensile strength is lower than that in HPC specimens (without fibers) after exposure to a temperature (500 ,300 and 100 C̊). comparable to normal temperature 25C̊
6. Specimen containing PPF (1%) the percentage of reduction in splitting tensile strength was higher than specimen without PPF after exposure to a temperature (500 ,300 and 100 C̊). comparable to normal temperature 25C̊
7. Specimens containing PPF (0.25 , 0.5 , 0.75 and 1 %) the percentage of reduction in compressive strength is higher than that in HPC specimens (without fibers) after exposure to a temperature (500 ,300 and 100 C̊). comparable to normal temperature 25C̊

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Table 1: Chemical Composition of Cement

Oxides		% #	IQS 5:1984 Limits
Calcium oxide	CaO	62.44	
Silicon oxide	SiO_2	20.25	
Aluminum oxide	Al_2O_3	4.73	
Ferric oxide	Fe_2O_3	4.32	
Magnesium oxide	MgO	2.19	5 max.
Sulphur trioxide	SO_3	1.88	2.8 max.
Loss on Ignition	L.O.I	3.5	4.00 max.
Insoluble residue	I.R	1.33	1.5 max
Lime saturated factor	L.S.F	0.66	0.66- 1.02
C3A		8.10	

Table 2: Physical Properties of Cement

Physical properties	Test result#	IQS 5:1984 limits
Fineness: specific surface, Blaine cm²/gm	3372	2300 min
Setting time, Vicat's method:- Initial (hrs: min.) Final (hrs :min)	 2:15 2:70	 45 minutes min. 10 hrs max.
Compressive strength of cement mortar cubes (70.7mm) MPa 3 days 7 days	 34.69 40.9	 15 min. 23 min.

Tests were made by National Center for Construction Laboratories and Research.

Table 3 : Typical properties of Glenium 51*

Form	Viscous liquid
Colour	Light brown
Relative density	1.1 @ 20 C^o
Viscosity	128 ∓ 30 CPS @ 20 ^{o}C
Transport	Not Classified as dangerous
Labeling	Not hazard label required
Chloride Content	Free from chlorides

* from manufacturer

Table 4: Chemical and physical properties of HRM

Oxide composition	**Oxide content %**
SiO_2	51.98
Al_2O_3	38.33
Fe_2O_3	1.77
Na_2O	0.38
K_2O	0.37
CaO	0.36
MgO	0.13
SO_3	0.12
L.O.I.	6.56
Physical properties of HRM	
S.A.I	131
Fineness (Blaine) cm^2/gm	17000

Table 5: Physical properties of polypropylene fibers (PPF)used in this investigation*

Form	Virgin Polypropylene Fiber
Specific gravity	0.91
Alkali content	Nil
Sulfate content	Nil
Chloride content	Nil
Air entrainment	Air content of concrete will not be significantly increased
Fiber thickness	(18 and 30) microns
Young modulus	(5500-7000) MPa
Tensile strength	350 MPa
Melting point	160 C^o
Fiber length	19 mm

* from manufacturer

Table : 6 Details of Concrete Mixes

Type of Concrete	Mix designation	Cement Kg/m^3	Gravel Kg/m^3	Sand Kg/m^3	HRM (%) By the wt. of cement	PPF content by volume (%)	w/c or w/cm to give slump 100 ± 5 (mm)	Superplasticizer (%) By the wt. of cement
Plain Concrete	NC	350	1050	725	0	0	0.6	0
	SHPC	350	1050	725	0	0	0.32	6
	SHHPC	350	1050	725	10	0	0,34	6
Fiber reinforced concrete	$SHHPC_0$	350	1050	725	10	0	0,34	6
	$SHHPC_{0.25}$	350	1050	725	10	0.25	0.36	6
	$SHHPC_{0.5}$	350	1050	725	10	0.5	0.43	8.5
	$SHHPC_{0.75}$	350	1050	725	10	0.75	0.48	10
	$SHHPC_1$	350	1050	725	10	1	0.58	12.8

Table: 7 Average test for compressive and splitting tensile strength results of concrete mixes exposed to ordinary temperature 25 C°

Mix designation	HRM (%)	PPF by volume (%)	w/c or w/cm to give slump 100 ± 5 (mm)	SP (%) By the wt. of cement	Compressive Strength @ 28 d (MPa)	Splitting Tensile Strength @ 28 d (MPa)
NC	0	0	0.6	0	25.5	2.9
SHPC	0	0	0.32	6	28	4.3
$SHHPC_0$	10	0	0,34	6	31.5	4.6
$SHHPC_{0.25}$	10	0.25	0.36	6	38	5.3
$SHHPC_{0.5}$	10	0.5	0.43	8.5	27.5	4.9
$SHHPC_{0.75}$	10	0.75	0.48	10	25.5	4.6
$SHHPC_1$	10	1	0.58	12.8	21	4.1

Table: 8 Average test for compressive strength results of concrete mixes exposed to elevated temperature

Mix designation	compressive strength MPa after exposure to different temperature			
	25 C°	100C°	300 C°	500 C°
NC	26	25	21.5	16.5
SHPC	28	26.5	22	20
$SHHPC_0$	31.5	29.5	27	25
$SHHPC_{0.25}$	38	33.5	28	20.5
$SHHPC_{0.5}$	28	25	22	19
$SHHPC_{0.75}$	25.5	20	16.5	13.5
$SHHPC_1$	20	17.5	14	11.5

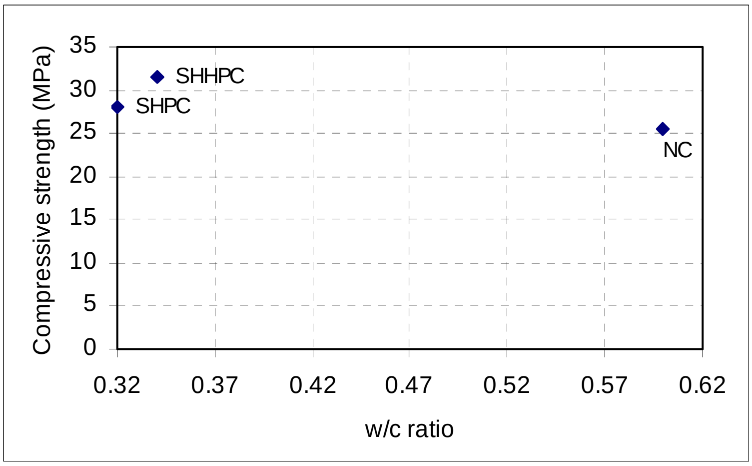

Figure (1) Compressive strength result for plain concrete exposed to ordinary temperature

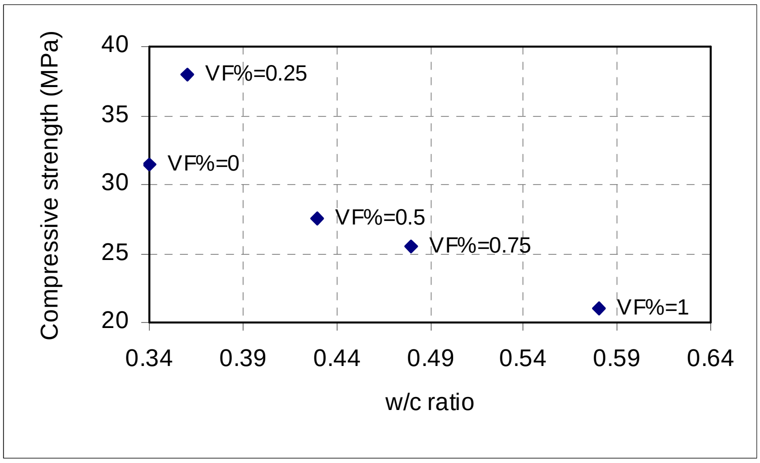

Figure (2) Compressive strength result for PPF reinforced concrete exposed to ordinary temperature

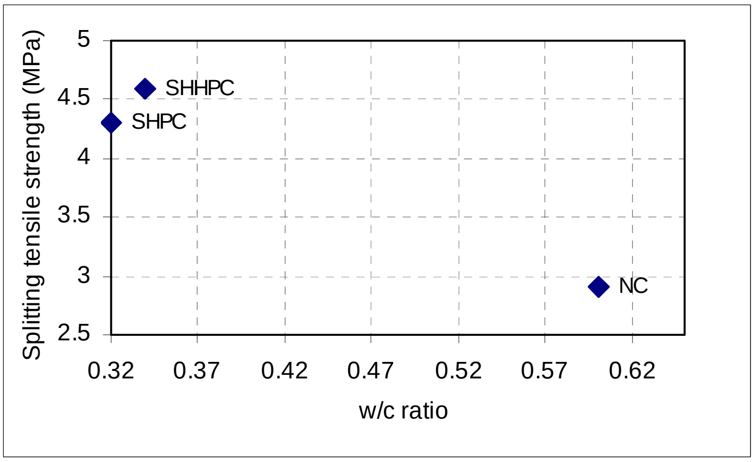

Figure (3) Splitting tensile strength result for plain concrete exposed to ordinary temperature

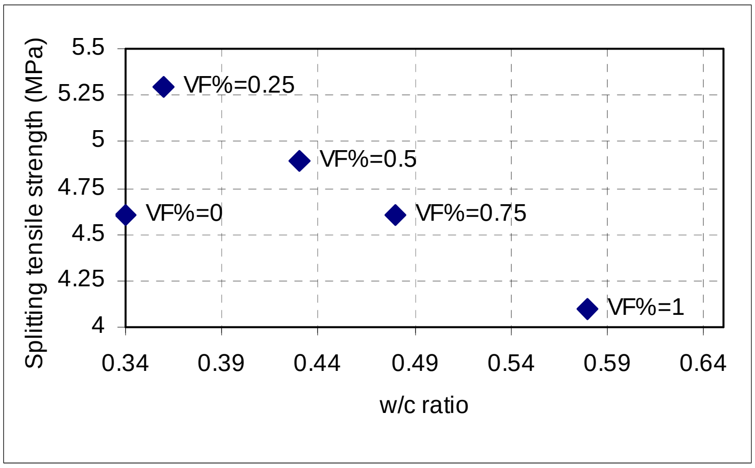

Figure (4) Splitting tensile strength result for PPF reinforced concrete exposed too rdinary temperature

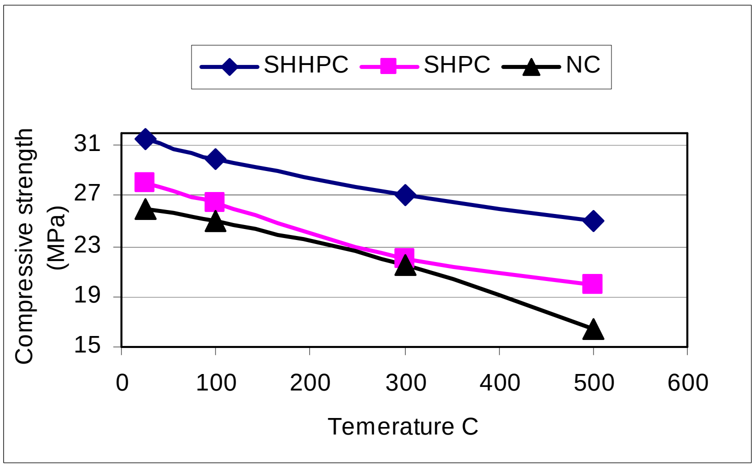

Figure (5) Compressive strength result for plain concrete exposed to different temperature

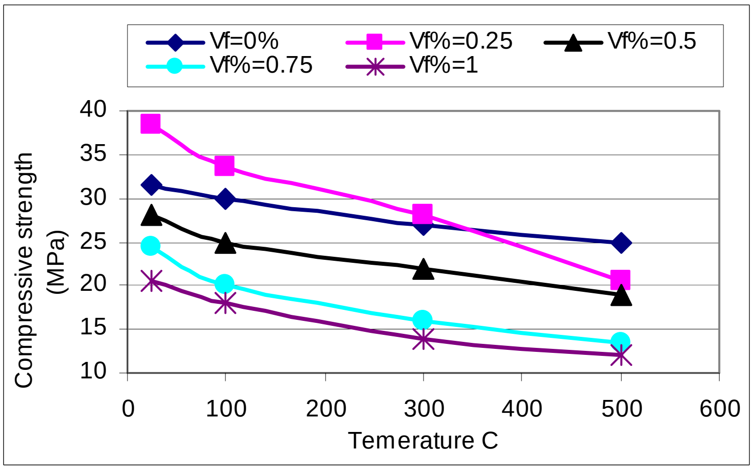

Figure (6) Compressive strength result for PPFRC exposed to different temperature

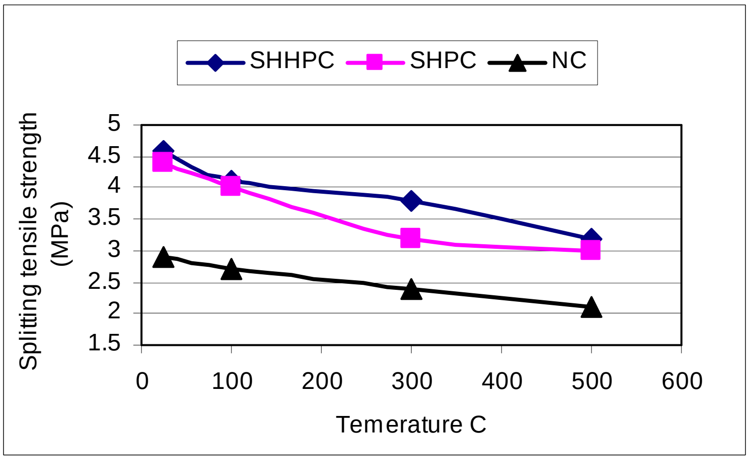

Figure (7) Splitting tensile strength result for plain concrete exposed to different temperature

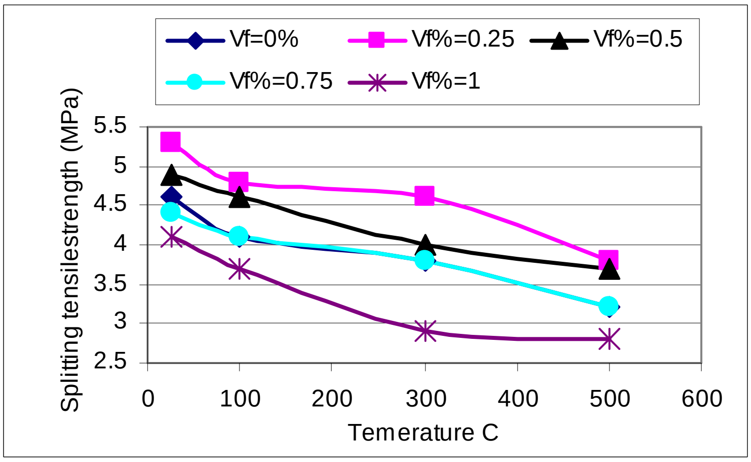

Figure (8) Splitting tensile strength result for PPFRC exposed to different temperature

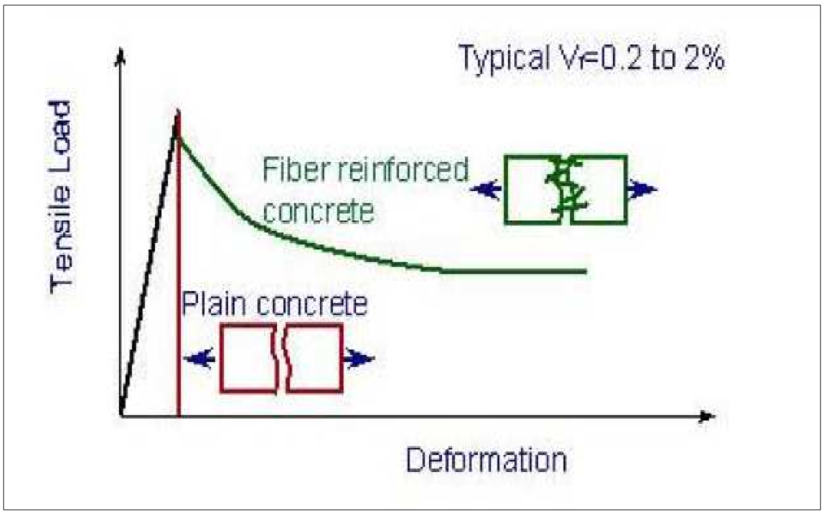

Figure (9): Tensile load versus deformation for plain and fiber reinforced concrete [15]

Figure (10) Modes of failure of concrete specimens with fiber content