Study of the effect adding the polypropylene fibers and chemical additives on the behavior of Ultra-High-Performance Concrete

Ammar Oudah. AL-Mwanes¹, Dr. Reza Aghayari²
¹ Ammar Oudah AL-Mwanes is a Ph.D. Studies at the Department of Structure, Civil Engineering, University of Tabriz, Iran. ammarouda7@gmail.com

² Reza Aghayari is an Associate Professor at the Department of Civil Engineering Razi University, Iran. draghayarireza@gmail.com

ABSTRACT

Ultra-High-Performance Fiber-reinforced concrete (UHPFRC) is an improved best of types of concrete containing fibers randomly distributed inside it, and high resistance give. The mechanical properties of concrete have been developed namely, compressive, flexural, and tensile strength by adding the fibers, and some chemical additives (superplasticizers) to reduce the percentage of water, and to ensure suitable workability. Also, the fiber makes the concrete very durable, tougher, and lower permeability. This paper aims to enhance the concrete mechanical properties by adding polypropylene fibers in combination with superplasticizers as a partial cement replacement. Test results give a good improvement by using both polypropylene fibers and superplasticizers. The split tensile strength and the flexural strength are increased significantly from 14.1 to 18.3 MPa, and from 14.28 to 20.85 MPa, respectively. While concrete strength of compression increased from 124.05 MPa to 145.87 MPa due to the inclusion of polypropylene fibers and superplasticizers. This will be seen as the experimental results showed a big improvement within the residual mechanical properties of the UHPFRC which contain the fibers compared to concrete mixes without fibers.

Keywords: Polypropylene Fibers; chemical additives; Ultra High Performance Concrete

1. INTRODUCTION

Exciting new developments have been in the concrete materials such as the recent advances in high strength concrete (HSC), high-performance concrete (HPC), and ultra-high-strength performance concrete (UHPC). These high-tech materials provide great application potential for the construction sector with the development of these concrete technologies. Which has limited applications in the construction sector recorded so far [1]. Ultra-high Performance Concrete (UHPC) is a very dense structured fine or coarse aggregated concrete with a low water/cement ratio smaller than 0.30, high cement content and mineral admixtures, which are selected to increase the bond between the
aggregates and the cement paste, this type of concrete is named Ultra-High-Performance Concrete [2]. The high-strength properties of UHPC allow for the design of thinner structures that reduce the weight of the structure less material used in the normal concrete. This also reduces the amount of waste that will need to be dismantled in the future, thereby reducing transportation requirements and mitigating environmental impacts [3].

Paste Cracks are formed when the acceleration of water evaporation is greater than the movement of concrete emulsion to the surface. The cracks caused by the contraction of the paste into the concrete are formed in the first hours, after pouring the concrete into the frames and before the concrete reaches its initial strength. These cracks establish critical points in the concrete susceptibility for adding harmful materials to internal concrete pieces which can eventually lead to corrosion and damage to the concrete material. Consequently, the concrete structures are reduced in efficiency, servicing or profitability, length, aesthetics, and weight. Controlling the paste contraction tracks in the concrete is of great importance in the shortest period of structural use for more length and resistivity of the concrete. The use of polypropylene fibers can improve concrete spalling behavior [4,5]. Fiber-reinforced concrete contains fibrous material which enhances its structural integrity. Fibers include synthetic fibers such as steel fibers, polypropylene fibers, glass fibers,.....etc., and natural fibers, and each of which lends varying properties to the normal or Ultra High Performance Concrete. UHPFRC contains short discrete fibers that are uniformly distributed or randomly oriented [6]. m against wetting with cement paste. Polypropylene's hydrophobic nature doesn't affect the amount of water needed for concrete. The addition of polypropylene fibers could therefore significantly enhance the flexural, tensile, and compressive strength of concrete [7]. As well the amount of chemical additives in Ultra High Performance Concrete and water-cement ratio influences both the freshly mixed and hardened properties of Ultra High Performance Concrete [8]. Well established that its resistance to cracking and crack propagation is one of the key properties of fiber reinforced concrete (FRC). As a result of this ability to arrest cracks both initially and eventually, particularly under flexural loading, fiber has increased extensibility and tensile strength and thus the fibers can keep the matrix together even after extensive cracking [9].

The interest in the use of fibers and chemical additives for the reinforcement of concrete has increased during the last several years. In this paper, the main objective is to investigate the effects of adding polypropylene fibers and chemical additives (superplasticizers) on quality, behavior, and mechanical properties to the Ultra-High-Performance Concrete. Different percentages of polypropylene fibers and superplasticizers were used. The compressive, tensile, and flexural tests were carried out for each concrete mix from Ultra-High-Performance Fiber-reinforced concrete (UHPFRC).

2. EXPERIMENTAL TESTING

The influence of the test procedures, details, the properties of different constituent materials and equipment used to assess concrete properties are illustrated in the following sections:-

2.1 Materials

Portland cement: is the most active component of UHPC and usually has the greatest unit cost and the test results comply with the requirements of the Iraqi Standard Specification IQS (No. 5/1984) (Portland cement) and with the requirements of (ASTM C150) [10] specifications for comparison purposes.

Quartz Sand: it is comparatively inexpensive for producing UHPC. The nominal size ranges from (0.15 to 0.6)mm. It is important to ensure that the aggregates are clean, since a layer of silt or clay reduce the cement aggregate bond strength, in addition to increasing the water demand, results of the sand, the limits of the Iraqi Specification (No.45/1984), and British Standards (B.S.) 882:1983) [11].

Silica fume: It is a byproduct coming from the reduction of quartz with coke and wood chips in an electrical arc furnace during the production of silicon metal or ferrosilicon alloys. The silica fume,
which condenses from the gases escaping from the furnaces, has a very high content of amorphous silicon dioxide and consists of very fine spherical particles (ACI-234R-96). It is extremely fine with a particle size of 0.1 μm, and it exists in a grey powder form that contains latently reactive silicon dioxide and no chlorides or other potentially corrosive substances. The silica fume used in this investigation conforms to the requirements of (ASTM C1240-05) specifications.

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

**Chemical Admixtures** (Superplasticizer): the chemical admixture used is superplasticizer which is manufactured to conform to (ASTM -C-494) [12] specification types G and F. When added to the concrete blend, it improves the properties of fresh and hardened concrete, and this plasticizing impact can be used to increase the workability of fresh concrete, making it extremely powerful; and the water reduces to a great degree, resulting in high density, strength, and excellent flowing ability. Some technical data for the "Sika ViscoCrete - 5930" are shown in Table (1) Shawn below.

**Table 1.** The technical data for the (Sika Visco Crete – 5930)

| NO. | Property | Appearance |
|-----|----------|------------|
| 1-  | Property | Turbid liquid |
| 2-  | Density  | (kg/l) 1.08 kg/Lt. ± 0.005 |
| 3-  | Basis    | Aqueous solution of modified polycarboxylate |
| 4-  | Toxicity | Non-Toxic under relevant health and safety codes |

**Polypropylene fibers**: Polypropylene being a raw material is effective on diffusion in concrete it belongs to the poly-Avllynhast family. It is a plastic polymer used in the construction industry to enhance the resistance of concrete. It is not hydrophilic- polypropylene fibers do not absorb water as a result of malicious. These fibers are resistant to alkalis, chemicals, chloride, and heat transfer properties. Among the properties of polypropylene is that it does not absorb water, that is, polypropylene fibers do not need to bother to mix cement with water. Table (1) show the property of the used polypropylene in this research work. ASTM C-1116-1997, Type [13].

**Table 2.** properties of polypropylene fibers

| NO. | Property          | Polypropylene |
|-----|-------------------|---------------|
| 1-  | Specific gravity  | 0.91          |
| 2-  | Sulfate content   | Nil           |
| 3-  | Chloride content  | Nil           |
| 4-  | Alkali content    | Nil           |
| 5-  | Fiber diameter    | 38 µm         |
| 6-  | Fiber length      | 12mm          |
| 7-  | Tensile strength  | 320-400 MPa   |
| 8-  | Melting point     | 160-170 °C    |

**Figure 1. Polypropylene Fibers.**

2.2 Testing program

The effect of polypropylene fibers and a superplasticizer amounts on the UHPC properties were studied by preparing several concrete mixes table 3. Also, we discussed the details of the test's procedure to produce UHPC. Proportions of these constituent materials have been chosen carefully to optimize the properties of the mixture, according to many studies.
Table 3 UHPFRC Mixes Used in This Research /Cement content percentage.

| Name MIX | C. 0.1 | C. p.2 | C. p.3 | C. p.4 | C. 0.5 | C. p.6 | C. p.7 | C. p.8 |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|
| Material|        |        |        |        |        |        |        |        |
| Cement  | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   |
| Quartz Sand | 125%  | 125%  | 125%  | 125%  | 125%  | 125%  | 125%  | 125%  |
| Silica Fume | 15%  | 15%  | 15%  | 15%  | 15%  | 15%  | 15%  | 15%  |
| Superplasticizer | 1.5%  | 1.5%  | 1.5%  | 1.5%  | 3%  | 3%  | 3%  | 3%  |
| water    | 28%   | 28%   | 28%   | 28%   | 24%   | 24%   | 24%   | 24%   |
| Polypropylene | 0.0% | 0.5%  | 0.1%  | 1.5%  | 0.0%  | 0.5%  | 0.1%  | 1.5%  |

2.3 Specimens A total of (48) cubes 100 × 100 × 100 mm, and 24 prisms 100 × 100 mm cross-section and 400 mm length and (24) cylinders 300mm length and 150 mm Diameter cylinders 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 flexural strength and tensile stresses strength.

3. TESTING PROCEDURE FOR (UHPFRC)

As stated before, this research aims to study the effects of adding polypropylene fibers and a superplasticizer on-resistance of Ultra-High-Performance Concrete (UHPC) using locally available materials. The tests for hardened concrete included compressive flexural strengths and splitting tensile the concrete.

3.1 Compression test of UHPFRC

One of the most important tests for concrete is the compressive strength; this test was done according to the [ASTM C109, 2008 ASTM C109/C109M, 2008]. Numerous trial mixtures were prepared For each batch of UHPFRC made, (100x100x100) mm, cubes of concrete were prepared. For each group, three samples were prepared and tested to obtain the averaged value.

The compressive strength machine the materials were used for determining the maximum compressive loads carried by concrete cube specimens.

The compressive strength for the specimen $\sigma_{\text{comp}}$ in MPa can be calculated by dividing the maximum compressive load by the area loaded:

$$\sigma_{\text{comp}} = \frac{P}{A} \quad \text{Eq. (1)}$$

Where: $P =$ maximum load carried by the cube specimen during the test.

$A =$ the cross-sectional area of the specimen.

3.2. Splitting cylinder test of UHPFRC

The splitting tensile strength of UHPFRC was measured based on (ASTM C496. 2004)[14] Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. Indirectly measures the tensile strength of concrete by compressing a cylinder through a line load applied along its length.
Specimen induces tensile and shear stresses on the aggregate particles inside the specimen, generating the bond failure between the aggregate particles and the cement paste. Usually, a splitting tensile strength test is used to evaluate the shear resistance provided by concrete elements.

The maximum fracture strength can be calculated based on the following equation.

\[
F_{sp} = \frac{2P}{\pi DL} \quad \text{Eq. (2)}
\]

Where:
- \( P \): is the fracture compression force acting along the cylinder,
- \( D \): is the cylinder diameter,
- \( \pi \) = 3.14,
- \( L \): is the cylinder length.

### 3.3 Flexural test of UHPFRC

The flexural strengths of concrete specimens were determined by the use of a simple beam with center-point loading in accordance with [ASTM C293, ASTM C293/C293M, 2010][15] Numerous trial mixtures were prepared. For each batch of UHPFRC made, (100x100x400) mm, prisms of concrete were prepared. For each group, three samples were prepared and tested to obtain the averaged value.

The specimen is a beam (100 x 100 x 400) mm, the mold is filled in one layer, without any compacting or rodding, and then immersed in water at 25ºC. The cast beam specimens are tested turned on their sides with respect to their position as molded. This should provide smooth, plane and parallel faces for loading if 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.

The pedestal on the base plate of the machine is centered directly below the center of the upper spherical head, and the bearing plate and support edge assembly are placed on the pedestal. The center point loading device is attached to the spherical head. The test specimen is turned on its side with respect to its position as molded and it is placed on the supports of the testing device. This provides smooth, plane, and parallel faces for loading. The longitudinal centerline of the specimen is set directly above the midpoint of both supports. If full contact is not obtained between the specimen and the load applying or the support blocks so that there is a gap, the contact surfaces of the specimen are ground. The specimen is loaded continuously and without shock until rupture occurs.

Finally, the maximum load indicated by the testing machine is recorded.

The flexural strength of the beam, \( F_r \) (in MPa), is calculated as follows:

\[
F_r = \frac{3PL}{2BD^2} \quad \text{Eq. (3)}
\]

Where:
- \( P \) = maximum applied load indicated by the testing machine,
- \( L \) = span length, \( B \) = average width of the specimen, at the point of fracture,
- \( D \) = average depth of specimen at the point of fracture.

All beam specimens were tested after 28 days from casting. Three beams were tested for each batch, the mean values of the specimens were considered as flexural strength of the beam. All concrete samples were placed in the curing basin after 24 hours from the casing. All samples remained in the curing basin up to the time of testing at the specified age. The curing condition of the lab basin followed the (ASTM C192, 2008). Curing water temperature is around 25C.

### 4. EXPERIMENTAL RESULTS TESTS AND DISCUSSION

Laboratory tests were conducted to evaluate and study the hardened properties of Ultra- High-Performance Fiber Reinforced Concrete (UHPFRC). Mean results for concrete mixtures at ages 28 days are the unit weight, compressive strength, Flexural strength, and splitting tensile strength tests. are summarized in the tables and figures are below:-
4.1 Compressive strengths for samples

The results showed Compressive strengths for samples of Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC) as in Table (4) and Figure (2) shown below:-

Table 4. Compressive strengths for samples

| Name Mix | Polypropylene Fibers | Superplasticizer | Compressive Strength (MPa) 7 days | Compressive Strength (MPa) 28 days |
|----------|----------------------|------------------|----------------------------------|----------------------------------|
| C.0.1    | 0.0%                 | 1.5%             | 72.34                            | 124.05                           |
| C.P.2    | 0.5%                 | 1.5%             | 83.55                            | 135.25                           |
| C.P.3    | 1%                   | 1.5%             | 86.75                            | 139.75                           |
| C.P.4    | 1.5%                 | 1.5%             | 84.66                            | 137.15                           |
| C.0.5    | 0.0%                 | 3%               | 77.43                            | 133.65                           |
| C.P.6    | 0.5%                 | 3%               | 86.56                            | 141.6                            |
| C.P.7    | 1%                   | 3%               | 89.98                            | 148.13                           |
| C.p.8    | 1.5%                 | 3%               | 87.81                            | 145.87                           |

Figure 2. Compressive strengths for samples (7 and 28 days)

Results are shown in Table (4) and Figure (2) demonstrates that it is possible to develop Ultra-High Performance Concrete (UHPC) with different polypropylene fibers amounts in the 7 and 28 days age. It can be observed that increasing the polypropylene content from (0.5% to 1% and, 1.5%) and 3% superplasticizer, and decreased (w/c) to 24% partial cement replacement effectively increases the compressive strength of UHPC more than when UHPC used alone without fibers polypropylene.

It is noticed the compressive strength for a mix without fibers and 1.5% superplasticizer only such as (C.0.1) were increased by 24.08% when polypropylene fiber 1% and 3% superplasticizer is used such as (C.P.7). From the above It was observed that adding the optimum percentage of polypropylene fiber (1%) increases effect the polypropylene fibers on the compressive strength of UHPFRC, it gives the best results in the compression-resistant Ultra-High Performance Fiber Reinforced Concrete. polypropylene fibers prevent the formation of cracks in the (UHPFRC), during the process of stiffening. It manifests binding properties between aggregates in the concrete mix so as to prevent micro-cracks in the concrete from growing. Specimens without polypropylene fibers ended with
sudden brittle failure, while specimens made of UHPFRC containing fibers exhibit ductile behavior, and hence improving compressive strength the main factor in reducing the compressive strength with increased polypropylene fibers to 1.5% can be in increased porosity in proportion to the increase in the amount of polypropylene fibers. Also, Superplasticizer when added to the concrete blend, it improves the properties of fresh and hardened concrete, and this plasticizing impact can be used to increase the workability of fresh concrete, making it extremely powerful; and the water reduces to a great degree, resulting in high density, strength, and excellent flowing ability.

The optimum percentage of polypropylene fibers and Superplasticizer recommended to be used based on this investigation for improving the Ultra-High-Performance concrete resistance is 1%, and of a 3% percentage of the cement content is used respectively.

4.2. Splitting Tensile strengths for samples

The results showed splitting Tensile strength of Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC) as in the Table (5) and Figure (3) shown below:

Table 5. splitting tensile strengths for samples

| Name Mix | Polypropylene Fibers % | Superplasticizer | Splitting tensile (MPa) 28 days |
|----------|------------------------|------------------|--------------------------------|
| C.0.1    | 0.0%                   | 1.5%             | 14.1                           |
| C.P.2    | 0.5%                   | 1.5%             | 14.7                           |
| C.P.3    | 1%                     | 1.5%             | 15.4                           |
| C.P.4    | 1.5%                   | 1.5%             | 16.2                           |
| C.0.5    | 0%                     | 3%               | 14.5                           |
| C.P.6    | 0.5%                   | 3%               | 16.6                           |
| C.P.7    | 1%                     | 3%               | 17.5                           |
| C.p.8    | 1.5%                   | 3%               | 18.3                           |

Figure 3. splitting tensile strengths for samples (28 days)

It is can be observed that increasing the polypropylene content from (0.5% to 1% and 1.5%) and Superplasticizer content from (1.5% to 3%) effectively increases the splitting tensile strengths of
Ultra-High-Performance Concrete (UHPC) when it was used alone without fibers polypropylene. It is noticed the splitting tensile strengths for a mix without fibers (C.0.1) were increased (29.7%). The tensile strength of concrete with fibers (UHPFRC) has a significant increase compared to non-fiber concrete and also with increasing the ratio of fibers to the perfect ratio the tensile strength increases. The obtained results can be justified as, the addition of Polypropylene Fibers with the tensile strength, distributed homogeneously within every batch will sustain the developed tensile stresses, thus increasing the splitting tensile strength of specimens. This indicates that the fibers at the microscopic level, it has been able to achieve acceptable adhesion and increase the tensile strength finally, the above results show that mixtures can achieve a mean splitting tensile strength of concrete specimens of 18.3 MPa at an age of 28 days, such as mix (C.P.8) is shown in table (5).

The optimum percentage of polypropylene fibers and Superplasticizer recommended to be used based on this investigation for improving the Ultra-High-Performance concrete resistance is 1.5%, and of a 3% percentage of the cement, content is used respectively.

4-3 Flexural strengths for samples

Results are shown below in Table (6) and Figure (4) demonstrates that it is possible to develop UHPFRC with different polypropylene amounts.

| Name Mix. | Polypropylene Fibers % | Superplasticizer | Flexural strengths ( MPa) 28 days |
|-----------|------------------------|------------------|-----------------------------------|
| C.0.1     | 0.0%                   | 1.5%             | 14.28                             |
| C.P.2     | 0.5%                   | 1.5%             | 15.62                             |
| C.P.3     | 1%                     | 1.5%             | 16.82                             |
| C.P.4     | 1.5%                   | 1.5%             | 19.01                             |
| C.0.5     | 0%                     | 3%               | 15.88                             |
| C.P.6     | 0.5%                   | 3%               | 17.94                             |
| C.P.7     | 1%                     | 3%               | 19.21                             |
| C.p.8     | 1.5%                   | 3%               | 20.85                             |

Figure 4. Flexural strengths for samples
It is can be observed that increasing the polypropylene content from (0.5% to 1% to1.5) and Superplasticizer content from (1.5% to 3%) effectively increases the flexural tensile strengths of concrete when it was used alone without fibers polypropylene. It is noticed the Flexural tensile strength for mix (C.p.8) was increased by (46%) when it has been mix 1.5% polypropylene fibers and 3% superplasticizer and decreased (w/c) to 24% partial cement replacement.

In general, the increase in bending strength can be considered proportional to the increase in tensile strength in UHPFRC. This is because, due to the elasticity of the bend, it controls the amount of sample load. In the experiments performed, it was observed that in single-point sample loading the fiber has been shown to increase the flexural strength of UHPFRC, due to increases the adhesion resistance, and can be a factor in controlling surface cracks and preventing the penetration of harmful substances into the concrete of the traverses.

The optimum percentage of polypropylene fibers and Superplasticizer recommended to be used based on this investigation for improving the flexural tensile strengths of Ultra-High-Performance concrete resistance is 1.5%, and of a 3% percentage of the cement, content is used respectively.

4.4 Effects of polypropylene on unit weight concrete

Table (7) and Figure (5) summarizes the effect of polypropylene fibers on the concrete unit weight. The results show that the density of concrete decreases when increasing the polypropylene fiber percentage in the mix, it is due to the increase in porosity in the sample.

| Name | Mix | Polypropylene % | Superplasticizer | Unit weight (kg/m3) |
|------|-----|-----------------|------------------|--------------------|
| C.0.1|     | 0%              | 1.5%             | 2335.3             |
| C.P.2|     | 0.5%            | 1.5%             | 2326.1             |
| C.P.3|     | 1%              | 1.5%             | 2321.4             |
| C.P.4|     | 1.5%            | 1.5%             | 2316.5             |
| C.0.5|     | 0%              | 3%               | 2337.2             |
| C.P.3|     | 0.5%            | 3%               | 2327.6             |
| C.P.4|     | 1%              | 3%               | 2322.5             |
| C.p.5|     | 1.5%            | 3%               | 2317.2             |
Ultra-High Performance Fibers reinforced Concrete (UHPFRC) is a relatively new form of concrete that can be used for general applications and especially for rehabilitation works. The main advantages that UHPFRC have over standard concrete are its high compressive strength, relatively high tensile and flexural strength, low porosity, high durability. The objective of this research is to study the effects of adding chemical additives to the concrete mixes and designing these mixes with the optimum amount of polypropylene fibers on-resistance of Ultra-High-Performance Concrete (UHPC).

1. Experimental results show the significant improvement of the residual mechanical properties of UHPFRC containing the polypropylene fibers compared to UHPC without fibers. For polypropylene fibers, 1% by the total weight of cement produced very high compressive strength concrete with 148.13 MPa.

2. The larger the polypropylene fibers content, the larger the splitting tensile strength and Flexural strength of concrete when used polypropylene fibers 1.5% by the total weight of cement. The flexural strength and the tensile strength are increased significantly from 14.1 to 18.3 MPa, and from 14.28 to 20.85 MPa, respectively. because it is working as reinforcement sustaining some of the developed tensile stresses.

3. The non-fiber specimens ended with sudden brittle failure, while the specimens made of UHPFRC containing fibers show ductile behaviour, because the added fibers, works as a reinforcement sustaining some of the developed tensile stresses. This indicates that the fibers at the microscopic level, it has been able to achieve acceptable adhesion and increase the tensile strength.

4. When added the optimum percentage Superplasticizer to the concrete blend, it improves the properties of fresh and hardened concrete, and this plasticizing impact can be used to increase the workability of fresh concrete, making it extremely powerful; and the water reduces to a great degree, resulting in high density, and high strength to the UHPFRC.

5. The improvements in flexural, tensile, and compressive concrete strengths were more pronounced and significant when the concrete mix including a combination of both superplasticizers and polypropylene fibers. In comparison with the reference concrete mix.

6. Fibers in concrete specimens act as a series of tensile clamps, and as the age of the concrete increases, they improve their position in the concrete. But it should be noted that amount of fibers should not exceed a certain amount because, the probability of accumulation increases, and the act of accumulation is caused by weak bonding, so it will be necessary to determine the optimal amount of polypropylene fibers.

Figure 5. Unit weights for samples
7. It is inferred too that fiber concrete can be used in concrete works to increase ductility and safety due it indicates an increase in the adhesion strength of fiber concrete, and from the other side, it helps prevent components from falling out after failure. And it is one of the most effective and economical ways of growing surface erosion resistance and controlling surface cracks.

8. The results show that the density of concrete decreases when increasing the polypropylene fiber percentage in the mix, it is due to the increase in porosity in the sample.

**NOTATION:**
- \( PP.F \) is the Polypropylene fibers
- \( NSC \) is the Normal Strength Concrete
- \( HSC \) is the High Strength Concrete
- \( UHPC \) is the Ultra-High Performance Concrete
- \( UHPFRC \) is the Ultra-High Performance Fiber Reinforced Concrete
- \( C.0.1 \) is the Mixing number one without Polypropylene fiber 0% and 1.5% superplasticizers.
- \( C.P.2 \) is the Mixing number two with Polypropylene fiber 0.5% and 1.5% superplasticizers.
- \( C.P.3 \) is the Mixing number three with Polypropylene fiber 1% and 1.5% superplasticizers.
- \( C.P.4 \) is the Mixing number four with Polypropylene fiber 1.5% and 1.5% superplasticizers.
- \( C.0.5 \) is the Mixing number five with Polypropylene fiber 0% and 3% superplasticizers.
- \( C.P.6 \) is the Mixing number six with Polypropylene fiber 0.5% and 3% superplasticizers.
- \( C.P.7 \) is the Mixing number seven with Polypropylene fiber 1% and 3% superplasticizers.
- \( C.P.8 \) is the Mixing number eight with Polypropylene fiber 1.5% and 3% superplasticizers.

**References**

[1] C. M. Tam, V. W. Y. Tam, and K. M. Ng, “Assessing drying shrinkage and water permeability of reactive powder concrete produced in Hong Kong,” *Constr. Build. Mater.*, vol. 26, no. 1, pp. 79–89, 2012, doi: 10.1016/j.conbuildmat.2011.05.006.

[2] S. S. and M. K. M. Arafa, “Mechanical properties of ultra high performance concrete produced in the Gaza Strip.” p. *Asian Journal of Materials Science* 2(1):1-12, 2010.

[3] H. J. Chen, Y. L. Yu, and C. W. Tang, “Mechanical properties of ultra-high performance concrete before and after exposure to high temperatures,” *Materials (Basel)*., vol. 13, no. 3, pp. 1–17, 2020, doi: 10.3390/ma13030770.

[4] M. Zeiml, D. Leithner, R. Lackner, and H. A. Mang, “How do polypropylene fibers improve the spalling behavior of in-situ concrete?,” *Cem. Concr. Res.*, vol. 36, no. 5, pp. 929–942, 2006, doi: 10.1016/j.cemconres.2005.12.018.

[5] F. Pelisser, A. B. D. S. S. Neto, H. L. La Rovere, and R. C. D. A. Pinto, “Effect of the addition of synthetic fibers to concrete thin slabs on plastic shrinkage cracking,” *Constr. Build. Mater.*, vol. 24, no. 11, pp. 2171–2176, 2010, doi: 10.1016/j.conbuildmat.2010.04.041.

[6] S. Ikai, J. R. Reichert, A. V. Rodrigues, and V. A. Zampieri, “Asbestos-free technology with new high toughness polypropylene (PP) fibers in air-cured Hatschek process,” *Constr. Build. Mater.*, vol. 24, no. 2, pp. 171–180, 2010, doi: 10.1016/j.conbuildmat.2009.06.019.

[7] Saman, Khan, R. A. Khan, A. R. Khan, M. Islam, and S. Nayal, “Mechanical properties of Polypropylene Fibre reinforced concrete for M 25 & M 30 mixes : A Comparative study,” *Int. J. Sci. Eng. Appl. Science*, vol. 1, no. 6, pp. 327–340, 2015, [Online]. Available: http://ijseas.com/volume1/v16s6/ijseas20150634.pdf.

[8] B. Łażniewska-Piekarczyk, “The influence of chemical admixtures on cement hydration and mixture properties of very high performance self-compacting concrete,” *Constr. Build. Mater.*, vol. 49, no. January, pp. 643–662, 2013, doi: 10.1016/j.conbuildmat.2013.07.072.
[9] N. Kumar and Sangeeta, “A Review study on use of Steel Fiber as Reinforcement Material with Concrete,” IOSR J. Mech. Civ. Eng. Ver. III, vol. 12, no. 4, pp. 95–98, 2015, doi: 10.9790/1684-12439598.

[10] American Society for Testing and Materials, “ASTM C 150: Standard Specification for Portland Cement,” Annu. B. ASTM Stand., vol. 04.01, no. d, pp. 149–155, 2007.

[11] British S, “Specification for aggregates from natural sources for concrete,” Bs 882/1992, no. 1, 1992, [Online]. Available: http://shop.bsigroup.com/ProductDetail/?pid=000000000030009856.

[12] ASTM C494, “ASTM C494: Standard Specification for Chemical Admixtures for Concrete,” Annu. B. ASTM Stand., p. 10, 2013.

[13] ASTM C-1116-1997, “Standard Specification for Fiber-Reinforced Concrete1 This,” pp. 1–7.

[14] ASTM C496/C496M − 17, “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens ASTM C-496,” ASTM Int., no. March 1996, pp. 1–5, 2011, doi: 10.1111/j.1547-5069.2008.00253.x.

[15] ASTM International (2002), “ASTM Standards C 293-02,” Stand. Test Method Flexural Strength Concr. (Using Simple Beam With Center-Point Loading), pp. 1–3, 2002, doi: 10.1520/D1635.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors)