

Effect of Hybrid Fiber Reinforcement on Early-Age Compressive Strength of High-Performance Concrete

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Abstract: This study investigates the effect of hybrid fiber reinforcement on the compressive strength of high-performance concrete at an early age (7 days). Two mixes were prepared: a reference mix and a modified mix containing steel and polypropylene fibers. The results showed that the compressive strength increased from 26 MPa to 45 MPa, representing an improvement of approximately 77%. The findings indicate that hybrid fibers significantly enhance the early-age mechanical performance of concrete.

Keywords: Compressive strength, Concrete, Fibers, Mechanical properties

1. Introduction

Concrete is commonly used in construction owing to its good compressive strength and low production cost but it is, nevertheless, brittle and susceptible to crack initiation and propagation, especially at early ages. For this purpose, studies involving fibers have been carried out to maximize the mechanical performance of concrete. It has been proved that fiber reinforcement increases crack control and ductility, as well as improving compressive strength (though to a certain extent, the effect depends on fiber type, dosage, and mix design).

Tawfik et al. investigated hybrid steel–polypropylene fiber high-strength concrete and obtained significantly better compressive and tensile properties when hybrid fibers were employed than for plain mixes and some single-fiber mixes. They found out that the good compressive strength results had been obtained when steel and polypropylene fibers were mixed in combination and they noted that this was due to the combined crack-bridging effect of steel fibers and microcrack control effect of polypropylene fibers[1].

Karimipour et al. assessed the high-strength concrete composed of steel fibers and polypropylene fibers in specific mixtures, along with nano-silica and silica fume. They reported that fiber addition contributed to improved compressive strength and other hardened properties, but workability was usually decreased with increase in fiber content. Importance: This study confirms that fiber reinforcement can improve compressive performance; however, mix composition strongly affects the final product[2].

Han et al. performed an exploration of hybrid fiber-reinforced concrete for protective structural applications that found that hybrid fibers provided better mechanical properties than single-fiber mixtures produced. In their study, the improvement in compressive strength at early age was present but is small, so hybrid fibers may contribute to a moderate compromise between the compressive strengths enhancement and the crack resistance and toughness improvements[3].

Elsherbiny et al. explored and evaluated the effect of steel fibers and polypropylene fibers on lightweight concrete, and observed the mechanical characteristics improved significantly. The results showed that the deformation capacity was improved by polypropylene fibers, whereas after curing, the compressive strength of steel fibers was increased. Such conclusions also bolster the conclusion that, with the proper mix of fiber types, composite concrete performance can also be greatly improved — on micro-crack & macro-crack level[4].

Mydin et al. studied using polypropylene twisted bundle fiber reinforced lightweight foamed concrete and suggested increased compressive flexural and splitting tensile strengths. They even detected reduction in porosity and water absorption. Their concrete type was not that of this study, but its results support the idea for an enhancement of the internal structure in cement-based materials and improved mechanical properties due to these polypropylene fibers[5].

Although some research studies have focused on the impact of fiber reinforcement on the mechanical characteristics of concrete, most of those studies were on long-term performance (i.e. 28 days) or single types of fibers. Limited attention has been given to the early-age (7 days) compressive strength of high-performance concrete incorporating hybrid fibers. Furthermore, studies in the past generally suggested moderate enhancements in compressive strength, while the impact of hybrid fibers with adjusted mix proportions at early age is still not well understood. The goal of this study is to investigate the effects of hybrid fiber reinforcement and optimized mix proportions on early-age high-performance concrete to measure the level of improvement over conventional concrete.

2. Materials and methods

2.1 Materials

Ordinary Portland Cement (OPC) supplied by Al-Mass Company was used according to Iraqi Specification No. 5/1984. A very fine aggregate (SO_3) from Al-Najaf city was obtained with an amount of sulfate of 0.25% and made Zone 2 as prescribed by Iraqi Specification No. 45/1984. The coarse aggregate consisted of Al-Najaf quarried gravel at a maximum size of 14 mm, and according to Iraqi Specification No. 45/1984 (graded 5 -14 mm), aggregates were fresh and free from impurities and organic material. Hooked steel (13 mm lengths) and polypropylene (Sika) fibers were used in the work. Fibres' properties were obtained from the manufacturer's technical records. A third-generation superplasticiser of BASF Company was used to improve workability and water-cement efficiency. With the superplasticizer, concrete production can be achieved with high-quality concrete with much stronger consistency and less porosity. The properties of the admixture were obtained from the manufacturer's data.

2.2 Mix proportion

Table 1: Mix design in Kg/m³

Materials	Quantity	
	NC	Modified mix
Cement	460	460
Sand	700	680
Gravel	1100	1080
water	129	125
SP	/	8
Steel fiber	/	45
Polypropylene fiber	/	1.5

2.3 Testing procedure

Concrete specimens were prepared and cured under standard conditions, in water tap with $25^{\circ}\text{C}\pm 2$. The compressive strength test was tested at the age of 7 days using a compression testing machine with a capacity of 3000kN. The test was performed on cube specimens with dimensions of 150 mm in accordance with the British Standard (BS EN 12390-3) and Iraqi specifications for compressive strength testing as shown in fig1.



Figure 1: Compressive Strength test.

3. Results and discussions

3.1 Results

The results obtained at 7 days listed in table 2.

Table 2: Results of testing concrete.

Mix type	Compressive strength
Reference mix	26
Modified mix	45

3.2 Discussions

Hybrid fibers significantly enhanced the strength for the compressive properties with the fiber-reinforced combination results and found about 77% increase in compressive strength from the reference mix is attained due to the crack-bridging of steel fibers and micro-crack control provided by polypropylene fibers. These fibers offer additional structure to the inside and delay crack propagation to improve in early stages with the fiber reinforced mix over the reference mix and are good to use in the early.

The increase of the ratio higher in this study in comparison to previous works indicates the significance of hybrid fiber reinforcement treatment with a good optimized mix design. Studies have also suggested fibers contributing to improving the mechanical behaviour of concrete. Zhang et al. showed fiber reinforced concrete with enhanced cracks and stronger internal structure were well suited for this work, while Yoo and Banthia pointed out that fiber addition improves the mechanical behaviour of concrete by controlling crack propagation (strength or toughness) and its long durability. Although the improvement in the compressive strength of the systems is generally lower than that reported so far (77%) the present study shows a significantly higher increase due to hybrid fiber system and optimal mix configuration.

Figure 2 shows a comparison of the percentage change of compressive strength obtained in the present study and those of our open studies. The result here is a significantly greater increase (77%) compared with the more mature and smaller study (which only gave moderate improvements) as a consequence of mixture design, fiber content and superplasticizer.

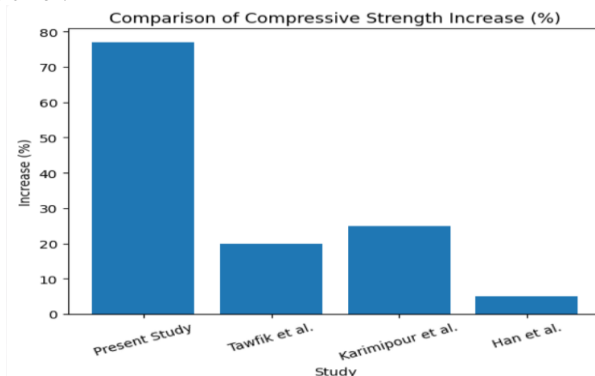


Figure2: Compressive Strength Increase 5 % compared to previous Work.

4. Conclusions

1. Compressive strength increased by about 77% compared to the reference mix.
2. steel fibers improve load-carrying capacity, while polypropylene fibers control micro-cracks.
3. At last, the modified mix be suitable for applications with very high early strength.

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