Construction and Building Materials 165 (2018) 631–638

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effects of high temperatures on mechanical behavior of high strength concrete reinforced with high performance synthetic macro polypropylene (HPP) fibres

Reza Abaeian, Hamid Pesaran Behbahani *, Shahram Jalali Moslem

Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

HIGHLIGHTS

- HPP Fibers did not have significant effect on the compressive strength of concrete.
- Mechanical properties of HSC were enhanced when HPP fibers were added.
- Addition of HPP fibers postponed the spalling of HSC when exposed to high temperatures.
- Discussion about the optimum dosages of HPP fibers was made.

ARTICLE INFO

Article history:
Received 29 September 2017
Received in revised form 8 January 2018
Accepted 9 January 2018

Keywords:
High strength concrete
High performance synthetic macro polypropylene fibres (HPP)
Fibre reinforced concrete
High temperatures

ABSTRACT

Today, the advancement of technology and the achievement of increasing innovations in the field of building materials have increased high-strength concrete (HSC) production. The use of this material has been increased due to economic and technical reasons in the construction of concrete sections. However, the more compressive strength of the concrete is, the more concrete becomes brittle and its tensile strength does not increase with increasing compressive strength. HSC is also more vulnerable to high temperatures due to its high density and low porosity compared to conventional concrete. Researchers have proposed different methods including the use of polypropylene fibres in concrete mix designs in order to overcome these defects of HSC. In this study, a new type of polypropylene fibres, called high performance synthetic macro polypropylene fibres (HPP), have been used in dosages of 1, 2 and 3 kg/m^3. Tests on hardened concrete include compressive strength, tensile strength and flexural strength at temperatures of 25, 100, 200 and 300 °C. By adding 1 kg of fibres to HSC, its compressive strength, tensile strength and flexural strength increased up to 14, 17 and 8.5%, respectively. Furthermore, the greatest improvement in the mechanical properties of concrete exposed to high temperatures was obtained when 1 kg/m^3 of fibres was added to HSC.

1. Introduction

Concrete is one of the most important and most popular building materials, featuring advantages such as plasticity prior to hardening, good compressive strength and the availability of its constituent materials. Due to advances in technology, the use of high-strength concrete (HSC) has been increasing in recent years. In parallel, many studies have been done to improve the weaknesses of this type of concrete, including its low tensile strength and ductility compared to its compressive strength [1,2] and its greater vulnerability at high temperatures among various types of concrete. Studies show low resistance of concrete in high temperatures, so that exposure of concrete to high temperatures leads to cracking and explosive spalling. Accordingly, the strength and modulus of elasticity of HSC drops significantly [3–9].

Concrete may be exposed to high temperatures in cases such as the occurrence of fire in concrete structures, in the explosion of jet engines, in factories in the extraction and melting of metals, in some chemical plants where concrete is close to the furnace, and related-nuclear activities. Adding fibres is the most widely known method to prevent spalling of HSC [10–17]. Among fibres, adding polypropylene (PP) into HSC shows better performance in order to increase

* Corresponding author.
E-mail addresses: hamidbehbahani@gmail.com, hbehbahani@khuisf.ac.ir (H.P. Behbahani).

https://doi.org/10.1016/j.conbuildmat.2018.01.064
0950-0618/

Table 1
Technical specifications of studied HPP fibres compared with a typical PP fibre.

Type of Fibre	Physical Shape	Density (gr/cm^3)	Tensile Strength (MPa)	Modulus of Elasticity (MPa)	Melting Point (°C)	Diameter (mm)	Length (mm)
HPP	Sinusoidal shape	0.9	700	3800	200	0.9	50
Typical PP Fiber	Straight	0.9–0.91	400–500	3500	160–170	–	–

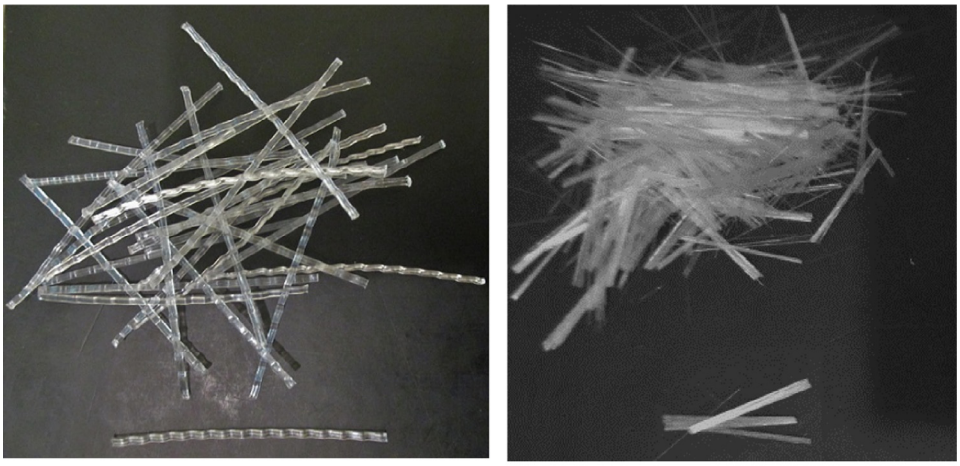

Fig. 1. Physical shape of fibres (a) studied HPP fibres (b) typical type of PP fibres.

Table 2
Concrete mix design of samples.

Type of Concrete Sample	W/C	D_{max} (mm)	Coarse Aggregate (kg/m^3)	Fine Aggregate (kg/m^3)	Cement (kg/m^3)	Fibre Content (kg/m^3)	Super Plasticizers (%)
NC	0.4	19.5	1024	671	462	0	0
HSC	0.35	19.5	898	646	572	0	0.3
HSC.1	0.35	19.5	898	646	572	1	0.3
HSC.2	0.35	19.5	898	646	572	2	0.3
HSC.3	0.35	19.5	898	646	572	3	0.3

resistance of HSC at elevated temperatures [18–20]. In addition, it caused improvement in the mechanical properties of HSC and its shrinkage control [21–27]. Investigating the spalling phenomena for concrete by incorporating polypropylene fibres, Lura and Terrasi [18] found that spalling was substantially decreased by adding to the concrete small quantities (almost 0.1% by volume) of fibres made from a low melting-point polymer. Noumowe [28] and Sahmaran et al. [29] studied the mechanical and microstructure properties of HSC in face of high temperatures. It was found that the pore structure at high temperature may have a considerable influence on the spalling behavior of the high strength polypropylene fibre concrete. Polypropylene fibres are melted when exposed to high temperatures, and creating channels in concrete mass prevents the formation of high vapor pressure in concrete pores, which reduces the spalling of concrete. In addition, the fibrous concrete cool slower than normal concrete, resulting in fewer cracks in cooling phase. Other researches have studied properties of HSC with combination of Polypropylene and other fibres, e.g. steel fibres in order to improve the mechanical properties of HSC [30,31].

This study investigates the effects of adding a new type of polypropylene fibres, called high performance synthetic macro polypropylene fibres (HPP), on the mechanical properties of concrete at elevated temperatures up to 300 °C. These fibres are made of polymer materials that have an especial sine-shape. The physical shape of these fibres makes them superior for concrete mixture when compared with the common type of fibres. In addition, compared to typical fibres, they also have a higher modulus of elasticity and tensile strength [32,33]. Among advantages of this type of fibre are enhancing the concrete resistance to stress, fatigue, heat, and increase tensile, shear and flexural strength in concrete. Table 1 shows the differences between properties of HPP fibers and a common type of polypropylene fibers. Their physical shapes are displayed in Fig. 1. The objectives of this research are (i) to obtain the effect of high temperatures on the mechanical properties of conventional normal concrete (NC) and HSC; (ii) to study the effect of adding polypropylene fibres with different dosages on mechanical properties of HSC; (iii) to examine mechanical behavior of high strength HPP fibre concrete at elevated temperatures up to 300 °C.

2. Test program and procedures

2.1. Concrete mix design and testing

Two different types of concrete including normal concrete and HSC are used in this research with strength of 25 and 69 (MPa).