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Behaviour of different types of fibre reinforced concrete without admixture

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ABSTRACT

In this paper the behaviour of the normal concrete and concrete with different types of fibre (steel, macro-polypropylene and micro-polypropylene fibres) have been studied; in terms of the compressive strength, split tensile strength, density, and the workability for concrete grade 30 without admixture. Varied fibre content to determine the optimum strength with 1%, 2%, and 4% by the volume of cement, cubes specimens of size 100 mm × 100 mm × 100 mm to test the compressive strength were cured for the period of 7, 14 and 28 days before crushing, and cylinder specimens with 100 mm diameter and 200 mm length were cured for 28 days before breaking. The results show that there are some limitations of adding fibres to the mix; however the use of fibres has shown a significant change on the behaviour of the concrete without admixture. In total, 66 specimens including the normal concrete were cast and tested in comparison. The test also results show that the use of steel, macro-fibre, and micro-polypropylene change the failure types to ductile failures, thus overcoming the brittleness problem of the concrete, and improves the split tensile strength.

1. Introduction

Portland cement is commonly utilized in the construction sector, the concrete that is manufactured from this cement has some features. It is strong in compression; however, it is brittle in tension [1]. Generally, it was found that the addition of fibres to the concrete mixtures made significant changes to the brittle tension reaction of the concrete. The efficiency of the fibre depends on factors such as the volume content, the length of the fibre, the aspect ratio, and the tensile strength of the fibre [2].

Moreover, even the addition of small quantities of fibre produces a substantial increase in the strength of the concrete once cracked in the development stage [3]. In addition, substantial achievements have been made towards crack control, with a reduction in the cracks' width and spacing. The reduction in crack width and the increased resistance to corrosion developed the long-term serviceability of fibre concrete by stopping the penetration of chemicals and water, which may have adverse effects [4]. Previous research has investigated the effect on the properties of concrete with the addition of polypropylene and steel fibres which have widely different elastic moduli [5]. The strength properties of hybrid nylon-steel and polypropylene-steel fibre-reinforced high strength concrete were also investigated and compared. The experimental results show that the compressive strength and splitting tensile strengths and modulus of rupture (MOR) properties of the nylon-steel fibre concrete improved by 3.2%, 8.3% and 10.2%, respectively, over those of the polypropylene-steel fibre concrete [6].

The strength and fire resistance properties of glass fibre concrete were also investigated. It was found that reinforcing with glass fibre contributes immensely to enhancing the compressive strength of concrete with an increase equal to 1.78 times that of normal concrete [7]. The durability of fibre reinforced concrete of marine structures was investigated. Polypropylene triangular fibres were used for the reinforcement. It was found that this improved the durability of the concrete as well as the compressive strength to a dosage up to 0.3%, but then started decreasing [8]. Fibre-reinforced concrete in precast applications and the role of fibres in improving mechanical properties and durability were reviewed [9].

An experimental investigation was carried out on steel fibre reinforced concrete beams strengthened with fibre reinforced polymer laminates. The resulting beams were found to have higher load carrying capacity with a 48% increase in the ultimate load and a 63% decrease in deflection at ultimate stage [10]. Concrete reinforced with 0.1 vol% of different synthetic fibres of steel, polypropylene, glass, and carbon were investigated. It was observed that the type of fibre used had a huge impact on the workability of the concrete. Only the steel fibres were found to enhance the density of concrete. It was also found that the given fibre dosage enhances the early

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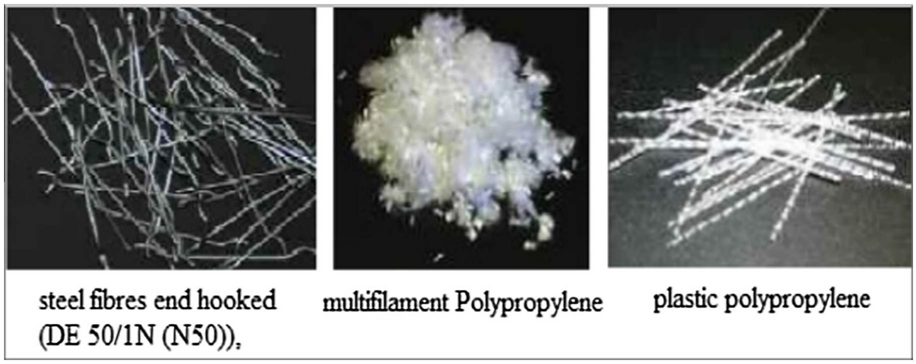

Fig. 1. The different types of fibre that used in this investigation.

compressive strength of concrete but reduces the 28 days compressive strength. Steel fibres increase the tensile strength more than any other fibre used during the investigation. It was noticed that addition of fibres in concrete largely improves the failure pattern of the concrete subjected to compressive loads [11].

Currently, civil engineering installations have structural and durability requirements of their own, each structure has its own intended purpose, and thus to meet this target, the modification in the conventional cement concrete has become necessary. Therefore, this investigation examines the behaviour of various types of fibre and compares it to the normal concrete, and highlights the properties for each type of fibres. In this paper, different sets of concrete specimen were prepared to study the behaviour of steel fibre, micro-synthetic polypropylene fibre, and macro-synthetic polypropylene fibre reinforced concrete in comparison with conventional concrete without admixture (see Fig. 1).

2. Methodology

2.1. Preparation of the samples

The paper focuses on the usage of Steel, Micro-Synthetic Polypropylene, and Macro-Synthetic Polypropylene fibres reinforced concrete. In this investigation the steel fibre is stiff and strong, whilst the polypropylene fibre is more ductile and flexible. Samples have been made to find out the compressive strength, and split tensile strength for each type of fibres. The fibres properties that were used in this experimental investigation are illustrated in Table 1.

Table 1
Properties of the fibres used.

Material	Fibre type	Length (mm)	Diameter	Aspect ratio
Steel fibre	DE 50/1N	50	1 mm	50
Macro-fibre	Plastic polypropylene	50	1 mm	50
Micro-fibre	Multifilament polypropylene	6	18 μm	333.3

In total 66 samples were tested. Table 2 gives the distribution of the tests that were carried out and the number of samples tested for each case.

2.2. Materials and mix proportion

2.2.1. Materials

A. Cement: Ordinary Portland Cement Grade 52.5 was available in this investigation, which has a bulk density of 1200 kg/m^3, and a specific gravity of 3.15. Moreover this cement had a recorded strength of 58.5 MPa after 28 days.
B. Aggregates: The coarse aggregate that have been used were uncrushed gravel, and the maximum size was 10 mm. The river sand was used as fine aggregate with a particles size was less than 3 mm, and the sand specific gravity was 2.6.
C. Water: Tap water has been used to mix the ingredients of concrete.
D. Fibres: All the fibres that were used in this investigation supplied by MAPEI Company [12].
   - Steel fibres: The fibres used were Steel Fibre DE 50/1N. The fibres were supplied by MAPEI by the name DE 50/1N. In the present investigation the fibres have a 50 mm (± 10%) length and 1.0 mm (± 10%) diameter. The steel fibres have a high tensile strength of 1100 MPa (± 15%) and aspect ratio (L/D) of 50.
   - Macro-Polypropylene Fibre: The fibres used were Polypropylene Fibre. The fibres were supplied by MAPEI by the name plastic fibre M50. In the present investigation the fibres have a 50 mm (± 10%) length and (1.28/0.81) mm (± 10%) fibre Width/Thickness. The plastic fibres have a tensile strength of 250 N/mm^2.
   - Micro-Polypropylene Fibre: The fibres used were Polypropylene Fibre. The fibres were supplied by MAPEI by the name PP-fibre M6. In the present investigation the fibres have a 6 ± 1 mm length and 18 ± 3 μm diameter. The plastic fibres have a tensile strength 300 N/mm^2 and 0.91 g/cm^3 density.

Table 2
Distribution of the tests that were carried out and the number of samples tested for each case.

	Normal concrete	Concrete with steel fibres	Concrete with plastic fibres	Concrete with PP fibres
Compressive strength after 7 days	3 Samples	9 Samples, 3 samples for each percentage of fibre content (1%, 2% and 4%)	9 samples, 3 samples for each percentage of fibre content (1%, 2% and 4%)	9 samples, 3 samples for each percentage of fibre content (1%, 2% and 4%)
Compressive strength after 14 days	3 Samples	3 Samples	3 Samples	3 Samples
Compressive strength after 28 days	3 Samples	3 Samples	3 Samples	3 Samples
Tensile strength	3 Samples	3 Samples	3 Samples	3 Samples