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Comparative study on the effect of synthetic fiber on the preparation and durability of airport pavement concrete

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HIGHLIGHTS

- Four kinds of synthetic fiber reinforced concrete for airport pavement were researched in this paper.
- The impermeability and the frost resistance of fiber reinforced concrete were investigated.
- Scanning electron microscopy (SEM) was used to analyze the strengthening mechanism of synthetic fibers reinforced concrete.
- The optimum volume of synthetic fiber in airport pavement concrete is obtained.
- The Cost-benefit analysis of the fiber reinforced pavement concrete was put forward.

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ABSTRACT

In order to improve the durability of airport pavement concrete, four kinds of synthetic fiber reinforced concrete were researched in this paper. Modified polyester synthetic fiber concrete (MPFC), Monofilament polypropylene synthetic fiber reinforced concrete (MPSFC), Reticular polypropylene synthetic fiber reinforced concrete (RPFC), and Polyacrylonitrile synthetic fiber reinforced concrete (PSFC) were prepared in this paper. Strength, impermeability and frost resistance of them were investigated. The impermeability test was carried out by hydrostatic pressure and chloride ion penetration method, while the frost resistance test was conducted by quick freezing method. The results show that the synthetic fiber improves concrete flexural strength, but it has little effect on compressive strength. Under the same volume fraction (0.1%), the flexural strength of MPFC and PSFC increased by about 6% compared with that of ordinary concrete (PC), but the flexural strength of PSFC increased slightly, with only 1–2%. Single fiber can improve concrete impermeability and frost resistance. Among them PSFC impermeability is the best, which is 2.4 times of that of PC, up to P24; the frost resistance of MPFC is the best, which is 2 times of that of PC, reaching F350. Polycarboxylic synthetic water-reducer (SDJ) can improve concrete impermeability and frost resistance greatly. It has best impermeability when mixing with polyacrylonitrile fiber, and its frost resistance grades were all up to above F600 when mixing with the four kinds of fibers separately. It is suggested that the optimum volume fraction is 0.10–0.14%, as the fiber content also has certain influence on the performance of the synthetic fiber concrete. At last, the Cost-benefit analysis of the fiber reinforced concrete was put forward, which showed that the application of fiber concrete in the airport pavement engineering has great economic benefits and broad prospects for development.

1. Introduction

Airport Pavement Concrete, as a sheet structure exposed to natural environment, bears the long-term damage from the surrounding and aircraft repeated load, resulting in cracks, voids and other defects. Especially in the harsh natural environment, the airport pavement concrete is very vulnerable to damage, easy to crack, with surface peeling and other durability problems [1–3]. At present, durability failure of the general pavement concrete caused by cracks is the main issue in the current airport engineering [4].

To solve the problem of the increasing load of airplane, the high-strength concrete is used in the airport pavement. However, with the increase of the load level of aircraft and the increase of the daily flow of the airport, the cracking problem of the airport pavement has gradually become the main hidden danger of the normal use of the airport, and has become a hot research direction at home and abroad. For the high-strength concrete, it can improve the carrying capacity of the whole pavement, but it cannot solve

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the outstanding problem of airport pavement crack. Therefore, people began to modify the concrete constantly to improve its comprehensive performance. In the continuous attempt, the researchers have found an economic and effective way of improvement. Through the physical mixing of concrete and various fibers, a new type of building material with excellent comprehensive performance is made, namely fiber reinforced concrete. Currently, the fibers mainly used in concrete are steel fiber, glass fiber, carbon fiber and synthetic fiber, etc. In recent years, synthetic fiber has been more and more popular due to its excellent comprehensive properties. Compared with other fibers, synthetic fiber has been increasingly used in engineering practice, with the characteristics of small density, small filament diameter, suitable price, acid and alkali resistance, easy dispersion and so on. The research and application of synthetic fiber concrete began in the 60 s of last century. In 70 s, it has been developed greatly. In the year of 80 s, it has been widely used in new construction and repair works [5]. In 1963, Romualdi proposed the fiber spacing theory [6–9]. In 1964, Danish Krenchel firstly applied the theory of composite materials to study the mechanism of fiber reinforced inorganic cementitious materials [10]. Shen Rongxi et al studied on the mechanism of low content synthetic fiber in concrete, summarizes the characteristics of synthetic fiber as reinforced concrete, points out that the low content synthetic fiber has the function of crack resistance and toughening in concrete [11]. On the basis of the study of the residual flexural strength of low elastic modulus fiber concrete, Zhao Guofan et al. Put forward the index and method to calculate the flexural capacity of the low elastic modulus fiber reinforced concrete members. [12]. Scholars from all over the country have done some research on the strength of synthetic fiber [13–15], frost resistance [16], durability [17,18], fatigue [19–21] and so on [13–24]. However, these studies are mainly concentrated in the construction and water conservancy projects, with different conclusions. There is no systematic and deep research about the influence of synthetic fiber on airport pavement concrete. In addition, the issues including fiber varieties, best dosage, and construction technology suitable for airport pavement engineering have yet to be resolved. Consequently, it is necessary to investigate the preparation and durability of synthetic fiber concrete pavement.

In this paper, four kinds of fibers, Modified polyester synthetic fiber (MP), Monofilament polypropylene synthetic fiber (MPS), Reticular polypropylene synthetic fiber (RP), and Synthesis of polyacrylonitrile fiber reinforced concrete (PS) were selected. And MPFC, MPSFC, RPFC and PSFC were prepared respectively based on ordinary concrete (PC). Moreover, the effect of fiber variety and content on the strength and durability of synthetic fiber concrete pavement was investigated. Meanwhile, the influence of AEWR on its durability was studied, to expand the application of synthetic fiber concrete in airport pavement. In order to better guide the engineering application of synthetic fiber concrete in airport pavement, the optimum content of synthetic fiber concrete was given on the basis of the experimental results. At the end of this paper, the Cost-benefit analysis of the fiber reinforced concrete was put forward, and the comprehensive cost analysis of fiber reinforced concrete in airport pavement is also carried out. The increasing cost of the airport pavement and the change of the durability of concrete were compared and analyzed, and the economy of adding fiber in the airport pavement concrete was discussed.

2. Raw materials and mix design

2.1. Raw material

Cement: 42.5R ordinary Portland cement, with the density of 3.10 g/cm^3 and 80 m screen of 1.6%; the flexural strengths of 3D and 28d are 5.0 MPa and 9.0 MPa; the compressive strengths of 3D and 28d are 28.9 MPa and 52.3 MPa.

Aggregate: Limestone rubble. three graded concrete of 5–10 mm, 10–20 mm, 20–40 mm; Gradation proportion of 10: 30: 60, Density 2.70 g/cm^3, Bulk density 1.69 g/cm^3, Crush index 3.4%; River sand: 2.78 fineness modulus, Density 2.63 g/ cm^3, Level II, Bulk density 1.50 g/ cm^3.

The SDJ water reducer used in this paper is Synthesis of Polycarboxylic water-reducer. It is a kind of polymer surfactant with comb structure composed of macromolecular compounds containing sulfonic acid groups, carboxyl groups, amino groups, and polyoxyethylene side chains. These compounds are synthesized by free-radical copolymerization in aqueous solution. The appearance of SDJ is light gray powdery solid with a density of 500–600 (g/L), a solids content of 98%. In addition, the pH value of 20% SDJ solution at 20 °C is 7, and the chlorine ion content of SDJ is less than 0.01%.

Synthetic fiber: four kinds of fibers (MP, MPS, RP, PS) were selected for the experimental study, of which the specific performance indicators are shown in Table 1, and the appearances are shown in Figs. 1–4.

Experimental water is drinking water.

2.2. Mix design

Fibers are helpful in controlling the post-crack behavior of concrete producing an apparent increase of the cracking strength, although with bigger tensile peak strain, one of which is a representative synthetic fiber with low volume and low elastic

Fig. 1. MP.

Table 1
Technical performance index of synthetic fiber.

Fiber variety	Tensile strength (MPa)	Elasticity modulus (GPa)	Ultimate elongation (%)	Density (g/cm^3)	Length (mm)	Shape	Place of Origin
MP	650–850	10–15	7–12	1.38	19	Bundle filament	Beijing
MPS	400	6–9	15–25	0.91	19	Bundle filament	Ningbo
RP	450–650	8–10	8–10	0.91	19	Reticular	Wuhan
PS	250–440	3–8	12–20	1.18	12	Bundle filament	Shenzhen