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A comparative study on mechanical properties of surface modified polypropylene (PP) fabric reinforced concrete composites

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HIGHLIGHTS

- Graft of AA and GO improves surface hydrophilicity and roughness of PP fabric, thereby improves interfacial properties between PP fabric and concrete.
- Graft of AA and Go improved flexural modulus and strength of PP fabric reinforced concrete.
- Modified PP fabric reinforced concretes show a more ductile mode of failure.
- Graft of AA and GO significantly improved the freeze-thaw resistance.

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ABSTRACT

In this study, acrylic acid (AA) and grapheme oxide (GO) were grafted onto the surface of PP fabric in order to improve mechanical property and freeze-thaw durability of PP fabric reinforced concrete composites. Results showed that the successful graft of AA and GO increased the surface roughness of PP fabric as well as improved the hydrophilicity of PP fabric. Compressive property of modified PP fabric reinforced concrete composites showed slight increase. Flexural strength of PP-g-AA-GO fabric reinforced concrete composites increased by 25.6% compared with that of pristine PP fabric reinforced concrete composites. The addition of various PP fabrics in concrete significantly improved its freeze-thaw durability. PP-g-AA-GO fabric reinforced concrete composites achieved the highest relative dynamic modulus of elastic and residual flexural strength, as well as mass remaining percentage.

1. Introduction

Cement based composite is one of the most widely used man-made composite materials in many fields, such as building, roadway, bridge and so on, due to its ultrahigh hardness and outstanding pressure resistance after setting [1]. Concrete, as typical cement based composite, is composed of cement as binder, coarse aggregate as framework, fine aggregate and fly ash as filler, as well as water and other agents. However, cracks and fissures usually appear on the surface of concrete when it is subjected to tensile or flexural loading due to its poor toughness, thereby resulting in the failure of concrete [2].

In order to remedy these defects in utility of applications, various reinforcements have been added into concrete. The development of steel reinforced concrete partly improved the situation. However, steel is vulnerable to corrosion which may result in structural damage of the concrete. Moreover, the steel industry often consumes a lot of energy and produces large amounts of greenhouse gases which may cause environmental damage [3]. Therefore, in recent years, chopped syntheticfibers, such as polyethylene (PE) [4], polyvinyl alcohol (PVA) [5], polyethylene terephthalate (PET) [6] and polypropylene (PP) have been added to concrete as reinforcement to enhance the mechanical and engineering properties of concrete. However, it is inevitable that short fibers randomly dispersed in the concrete when used to reinforce concrete. In this case there is a limitation in controlling the exact location of fibers inside the concrete. Finally, inevitable local aggregation and partially unoriented distribution of chopped syntheticfibers will cause the reduction of concrete effectiveness [7]. With the development of weaving technology, fiber-reinforced concrete has gradually been replaced by fabric-reinforced concrete. Fabric-reinforced concrete composites make up for deficiencies of both steel-reinforced concrete and fiber-reinforced concrete. On the one hand, fabric-reinforced concrete is corrosion resistant

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compared with steel-reinforced concrete, thus prolonging the service life and reducing the maintenance cost of the concrete composite [7]. On the other hand, fabrics have inimitable advantages and properties when used to reinforce concrete when compared with fibers. They can be placed in particular positions and directions subjected to tensile or flexural loadings [7], which allows for designing for specific characteristics as required by loading direction and magnitude, thereby promoting utilization efficiency of reinforcement and more favorable for improving mechanical and engineering property of fabric reinforced concrete composites. Therefore, fabric-reinforced concrete composites have widely potential application prospects in low-rise building, low-volume traffic roads and so on.

Nowadays, PP fabric is one of the most widely used reinforcements in concrete due to light weight, high strength and modulus, excellent abrasion resistance and corrosion resistance, as well as low cost [8]. Many scholars and researchers concentrate on PP fabric-reinforced concrete composites. Peled et al. [9] studied tensile properties of sandwich cement-based composites that combined different layers of single fabric types including PE, PP, AR glass and aramid.

The key factor for outstanding mechanical properties of fabric-reinforced concrete is the interfacial adhesion between fabric and concrete matrix [10]. However, the hydrophobic and smooth surfaces of PP fabric resulted in poor binding forces on fabric/concrete interface, which finally affected the concrete performance [11,12]. It is well known that the fabric/concrete interface can be effectively improved by means of surface treatment [13]. The modification on surface chemistry and morphology of fabrics can effectively increase the interfacial strength of fabric-reinforced concrete composites [14,15]. Many articles have been reported on kinds of surface treatment of PP fiber [16–18], however, there are few related to surface treatment of PP fabric. Acrylic acid (AA) is a surface-active-agent commonly used for improving surface activity of materials. Graphene oxide (GO) has large specific surface area on which exists a large amount of reactive hydrophilic groups, which is favorable for improving interfacial properties between fabric and concrete. Grafting AA and GO onto the surface of PP fiber has been reported by Wang et al. [19] and Li et al. [20]. However, there has no article reported on grafting AA and GO onto the surface of PP fabric before.

Hence, in the first stage of this study, acrylic acid (AA) was grafted onto the surface of PP fabric under UV radiation for different time to find a suitable grafting degree. After that, grapheme oxide (GO) was grafted onto the surface of PP-g-AA fabric by esterification reaction. The effects of AA and GO grafting reaction on the surface hydrophilicity of PP fabrics were investigated in detail by analyzing the changes in chemical component, surface composition, morphology, surface microscopic structure, and surface hydrophilicity of the fabrics. In the second stage, pristine PP fabric, modified PP-g-AA and PP-g-AA-GO fabrics were added into concrete for reinforcement. Mechanical properties and freeze-thaw durability of plain concrete and three types of fabric-reinforced concrete composites were measured and investigated in detail.

2. Experimental

2.1. Materials

PP fabrics were commercially available and purchased from Shandong Xinyu Geotechnical Engineering Materials Co. Ltd. (China) (fiber fineness is 300tex, warp density and weft density are 9/cm). Acrylic acid (AA), benzoyl peroxide(BPO), isopropyl alcohol(IPA), benzophenone (BP), thionyl chloride, acetic acid and acetone were provided by Sino Pharm Chemical Reagent Co. Ltd.(China) and used as received without further purification. The graphene oxide (GO) was purchased from Shanxi Fenghuiyuan Science and Technology Co. Ltd. (China). All chemical reagents used in the experiment were analytical pure grades.

2.2. Preparation of PP-g-AA-GO fabric

The fabrication process of PP-g-AA-GO fabric was shown in Fig. 1. Pristine PP fabric was soaked into acetone with supersonic vibration for 4 h to remove the impurities on fiber surface adequately before use. Step 1 was the process introducing the active sites onto PP backbone through the initiation of BPO [19]. PP fabric was soaked into a mold filled with 1.25 wt% BPO toluene solution for 0.5 h with temperature rising from 50 °C to 90 °C. After that, the toluene solution was removed by evaporation at 95 °C for 15 min. The treatment was carried out under nitrogen atmosphere.

In Step 2, the PP fabric was soaked into aqueous solution contain 20 wt% IPA as solvent, 0.5 wt% BP as initiator and 30 wt% AA. The grafting process was carried out under nitrogen atmosphere with the temperature of 60 °C for different time varied from 10 min to 90 min. The wave length of UV radiation was selected as 312 nm. After grafting process, unreacted monomer and homopolymer were removed from the samples by acetone extraction with supersonic vibration at room temperature for 4 h [20]. The PP-g-AA fabric samples with various grafting time were then obtained. The grafting degree of PP-g-AA fabrics were calculated and investigated to obtain a better process parameter for the next step.

Step 3 was the process grafting GO onto the surface of PP-g-AA fabric by esterification reaction. The PP-g-AA fabric was soaked into aqueous solution with 0.5 wt % GO, 6 wt% acetic acid as catalyst and 0.21 wt% thionyl chloride as dispersing agent. The mold was placed on the constant temperature shaker at 50 °C for 0.5 h, exposed to the air. Unreacted GO was removed from the sample by acetone extraction with supersonic vibration at room temperature for 4 h, and then dried at 60 °C to constant weight.

2.3. Concrete mixture design

Based on previous research and industry practice [3], standard mixture design for 25 MPa concrete used in this study is shown in Table 1. The grain-size distribution of fine sand, coarse sand and coarse aggregate used in this study is presented in Fig. 2. Concrete was homogeneously mixed in a concrete truck-mixer.

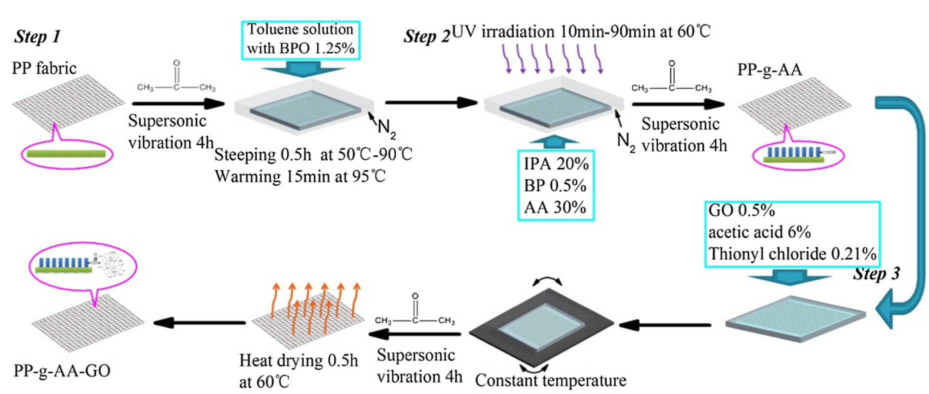

Fig. 1. Schematic illustration of fabrication process of PP-g-AA-GO fabric.