A Comparative Study on Mechanical Properties of Surface Modified Polypropylene (PP) Fabric Reinforced Concrete Composites

Guyu Feng1,2, Diantang Zhang1,2, Xinyue Wang1,2, Haijian Cao1,2, Kun Qian1,2*, Xuéliang Xiao1,2

1Key Laboratory of Science and Technology of Eco-Textiles, Ministry of Education, Jiangnan University, Wuxi 214122, China
2College of Textile & Clothing, Jiangnan University, Wuxi 214122, China

ABSTRACT

There is an intimate connection between mechanical properties and interfacial properties of PP fabric reinforced concrete composites. However, development of PP fabric reinforced concrete composites has been confined due to the hydrophobic and smooth surfaces of PP fabric. In this study, acrylic acid (AA) and grapheme oxide (GO) were grafted onto the surface of PP fabric in order to improve surface hydrophilicity of PP fabric, which indirectly improve interfacial properties between PP fabric and concrete, thus leading to enhancement in mechanical properties of PP fabric reinforced concrete composites. Structures and properties of pristine PP, modified PP-g-AA and PP-g-AA-GO fabrics were investigated by FT-IR, XPS, SEM, AFM and water contact angle measurements. Mechanical properties of three PP fabric reinforced concrete composites were investigated by universal material testing machine. Results showed that AA and GO were successfully grafted onto the surface of PP fabric. The surface roughness of PP fabric increased and the hydrophilicity of PP fabric improved after surface modification. Compressive strength and modulus of PP fabric reinforced concrete composites slightly increased with the improvement in surface hydrophilicity of PP fabric. Flexural strength of PP-g-AA and PP-g-AA-GO fabrics reinforced concrete composites increased by 3.3% and 25.6% respectively, compared to pristine PP fabric reinforced concrete. Flexural elastic modulus basically remained unchanged. In addition, toughness of various PP fabrics reinforced concrete also increased with the improvement in hydrophilicity of PP fabric.

Keywords: PP fabric; concrete; grafting modification; mechanical property; acrylic acid; grapheme oxide

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 a classic 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 may appear on the surface of concrete when it is subjected to tensile or flexural loading due to its poor toughness, thereby resulting in failure [2].

In order to solve these defects in utility of applications, various reinforcements have been added into concrete. The invention of steel reinforced concrete has improved this situation to a certain extent. However, steel is vulnerable to corrosion which will result in damage of the reinforced concrete structure. Moreover, the steel industry often consumes a lot of energy and produces large amounts of greenhouse gases which may cause destruction of ecological
environment [3]. Therefore, in recent years, chopped synthetic fibers, such as polyethylene (PE) [4], polyvinyl alcohol (PVA) [5], polyethylene terephthalate (PET) [6] and polypropylene (PP) have been attempted to use as reinforcement to enhance the mechanical properties of concrete. However, the disadvantages of fiber reinforced concrete are local agglomerate and partially unoriented distribution of fibers over the total cross-section, thus reducing the 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 steel-reinforced concrete and fiber-reinforced concrete. On the one hand, fabric-reinforced concrete is corrosion resistant compared with steel-reinforced concrete, thus prolonging the service life and reducing the maintenance cost of the concrete composite [7]. On the other hand, fabric could be placed in the position where necessary in the direction subjected to tensile or flexural forces [7], thus enhancing utilization efficiency of reinforcement and improving mechanical property as well as bearing capacity of the concrete composite. Therefore, fabric-reinforced concrete composites have wide application prospects in low-rise building, low-volume traffic roads, or namental architectures and so on.

Nowadays, PP fabric is one of the most widely reinforcements used 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 result in poor binding forces on fabric/concrete interface, thus limiting the improvement of concrete performance such as flexural strength and toughness [11, 12]. It is well known that the fabric/concrete interface can be modified by fabric surface treatments such as roughening the fabric surface and altering surface polarity [13]. The modification on surface chemistry and morphology of fabrics can effectively increase the interfacial strength of fabric-reinforced concrete composite [14, 15]. Many articles have been reported about modification on the surface hydrophilicity of PP fibers to improve interfacial properties of fiber-reinforced concrete for better applications [16]. Angel et al. [17] modified the surface of PP fiber by introducing sodium moieties and created additional fiber surface roughness, and studied the influence of modification on adhesion properties between the treated fibres and concrete, as well as mechanical properties of fiber-reinforced concrete. Burak et al. [16] investigated the flexural performance of concrete reinforced by PP fibers, that surface were treated employing low frequency cold plasma treatment technology. Niu et al.[18] presented a biomimetic surface modification based on the mussel-inspired versatile adhesion technology and thiol chemistry to increase the hydrophilicity of PP fibers. Although many articles studied on modification of PP fibers used in concrete, there are few on PP fabrics.

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, graphene 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 hydrophilicity. 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 resistances of three fabric-reinforced concrete composites and a plain concrete 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 300 tex, 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 use in the experiment was analytical reagents.

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 4h 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 placed into a mould filled with 1.25wt% BPO toluene solution and kept for 0.5h at temperatures ranged from 50‒90°C. The toluene solution was then removed through evaporation for 15min at 95°C. The whole treatment process was carried out with the nitrogen supply.

In Step 2, the PP fabric was soaked into aqueous solution with 20 wt% IPA as solvent, 0.5 wt% BP as initiator and 30 wt% AA. The grafting process was carried out under nitrogen atmosphere at 60 °C for different time ranging from 10 min to 90 min. The wavelength of UV radiation was selected as 312 nm for each sample. 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 achieved. The grafting degree of PP-g-AA fabrics was calculated and investigated to get a better process parameter for the next step.

Step 3 was the process grafting the GO to 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% acetic acid as catalyst and 0.21 wt% thionyl chloride as dispersant. The model 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 the 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 distributions of fine sand, coarse sand and coarse aggregate used for this study are presented in Fig. 2. Concrete was evenly mixed in a standard concrete truck mixer and average slump was 100 mm.

Table 1 Concrete mixture design

<table>
<thead>
<tr>
<th>Material</th>
<th>Content (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.075-0.6 mm Fine sand</td>
<td>750</td>
</tr>
<tr>
<td>0.6-4.75 mm Coarse sand</td>
<td>590</td>
</tr>
<tr>
<td>4.75-9.5 mm Coarse aggregate</td>
<td>680</td>
</tr>
<tr>
<td>Fly ash</td>
<td>134</td>
</tr>
<tr>
<td>Cement</td>
<td>186</td>
</tr>
<tr>
<td>Cellulose</td>
<td>3</td>
</tr>
<tr>
<td>Air entrapment admixture (ml/100kg)</td>
<td>22</td>
</tr>
<tr>
<td>Water (l/m³)</td>
<td>116</td>
</tr>
</tbody>
</table>

Fig. 2. Grain-size distributions of sand and aggregate

2.4 Preparation of PP fabric-reinforced concrete composites

Three PP fabric-reinforced concrete samples and plain concrete samples were casted by
standard rodding compaction method according to the Chinese specification GB/T 50081-2002. Size of compressive sample and flexural sample are shown in Fig. 3(a). Concrete-fabric-concrete sandwich structure was applied to prepare the concrete composites samples. Concrete composites samples were removed from the mould after 24 h at room temperature. After that, all samples were cured in saturated lime water until taken out for tests.

3 Characterizations

3.1 FT-IR analysis

The FT-IR analysis was performed by Nicolet iS 10 FT-IR spectrometer (Thermo Fisher Scientific, USA). The spectra were recorded in the range of 4000 cm\(^{-1}\) - 650 cm\(^{-1}\) at 16 scans per sample.

3.2 X-ray photoelectron spectroscopy (XPS)

XPS spectra were obtained by ESCALAB 250XI X-ray Photoelectron Spectroscopy (Thermo, USA) with Mg K\(\alpha\) X-ray source (200 W, 12 kV, \(\hbar \nu =1486.6\) eV). Survey spectra were recorded with pass energy of 50 eV, whereas selected atomic signals were acquired with 10 eV of pass energy. In the spectra, the position of the C-C/C-H was specified at 284.7 eV, and other peaks of different carbon environments were relative to this peak. The electron take-off angle from coatings was 90° from the surface. The C1s envelope was analyzed and peak-fitting after subtraction of a Shirley background using Gaussian-Lorenzian peak shapes was obtained by XPS peak software.

3.3 Static water contact angle

Sessile drop method was used to measure the contact angle by SL200B static contact angle/interfacial tension meter (Kino Industry Co. Ltd., USA). 5 \(\mu\)L deionized water droplets were gently deposited onto the fabric surface that conditioned to equilibrium moisture content at room temperature. The dropping photos were taken with a high resolution camera after 5 s and water contact angles were measured. The mean and standard deviations were calculated from at least 5 tests for each sample.

3.4 Scanning electron microscope (SEM)

SEM images of various PP fibers extracted from three PP fabrics were obtained using SU1510 scanning electron microscope (Hitachi, Japan).

3.5 Atomic force microscope (AFM)

AFM images were taken using CSPM 4000 atomic force microscope (Benyuan Co. Ltd., China) in a tapping mode over a window of 2 \(\mu\)m \(\times\) 2 \(\mu\)m. Each sample was fixed on a quartz
plate with two pieces of adhesive tape on two ends of the sample. 3.5 Mechanical properties of concrete

3.6 Mechanical property
3.6.1 Compressive properties

Compressive properties of PP fabric-reinforced concrete were measured using universal testing machine with a maximum load capacity of 5000 kN according to GB/T 50081-2002. Compressive strength and modulus were measured respectively on the 7th, 14th, 21st and 28th day, and the mean and standard deviations were calculated at least three times for each concrete sample. The compressive strength of concrete sample was calculated as:

\[ f_{cc} = \frac{F}{A} \]

in which \( f_{cc} \) (MPa) is compressive strength of concrete; \( F \) (N) is fracture load; \( A \) (mm\(^2\)) is area of thrust surface. The modulus was obtained directly from the test machine.

3.6.2 Flexural properties

Flexural properties of concrete samples were measured using universal testing machine under four-point loading. Flexural strength and modulus were measured respectively on the 7th, 14th, 21st and 28th day, and the mean and standard deviations were calculated at least three times for each concrete sample. The schematic diagram of flexural test was shown in Fig. 4. The flexural strength of concrete was calculated as:

\[ f_f = \frac{Fl}{bh^2} \]

in which \( f_f \) (MPa) is flexural strength of concrete; \( F \) (N) is fracture load; \( l \) (mm) is span between two supports; \( h \) and \( b \) are height and width of sample section, respectively. The flexural modulus was obtained directly from test machine. The maximum deflection was measured for analyzing toughness of concrete sample.

Fig. 4. Schematic diagram of flexural test

4 Results and Discussion
4.1 Effect of the grafting time on the grafting degree

It is well known that the grafting time has a major effect on the grafting degree in a grafting reaction. Moreover, in this study, the grafting degree is closely relevant to the weight gain rate of PP fabric. Therefore, in order to investigate the effect of grafting time on AA grafting degree, we calculated the grafting degree under different UV radiation time. A common weighting method was employed to calculate the AA grafting degree onto PP fabric.
The grafting degree (G) was calculated as:

$$G(\%) = \frac{W_1 - W_0}{W_0} \times 100\%$$

in which $W_0$ and $W_1$ are weights of pristine and grafted PP fabrics after extraction, respectively. The AA grafting degree onto PP fabric at different UV radiation time is shown in Fig. 5. It can be observed from Fig. 5 that the grafting degree gradually increases as the radiation time increases. The significant improvement in grafting degree indicated that massive active groups successfully grafted onto the surface of PP fabric. It is well supported by the equal reactivity theory in the radical polymerization [21]. Above a radiation time of 70 min, the grafting degree remained constant around 9.3% and basically remained unchanged even though the radiation time continuously increased. The asymptotic saturation of grafting degree was resulted from the decomposition of BP and self-polymerization of AA [22-24]. Therefore, a radiation time of 70 min was selected as the most suitable grafting time for subsequent experimental procedures.

![Fig. 5. Effect of grafting time on the grafting degree](image)

### 4.2 Chemical Structures

Fourier transform infrared (FT-IR) spectroscopy was first carried out to study the changes in chemical structures of PP fabric [25]. Fig. 6 shows the FT-IR spectra of pristine PP fabric, modified PP-g-AA fabric and PP-g-AA-GO fabric. The assignment of various wavelengths is presented in Table 2.
In the spectra of pristine PP fabric, peaks at 2950 and 2870 cm\(^{-1}\) are attributed to -CH\(_3\) stretching vibration. Peaks at 2920 and 2840 cm\(^{-1}\) correspond to -CH\(_2\) stretching vibration. Peaks at 1450 and 1380 cm\(^{-1}\) are related to -CH\(_3\) bending vibration [26]. In the spectra of modified PP-g-AA fabric, newly arisen peaks at 1740 and 1170 cm\(^{-1}\) are related to C=O stretching vibration of carboxyl and -OH stretching vibration of carboxyl, respectively [27], indicating that AA has been successfully grafted onto the surface of PP fabric because the unreacted acrylic acid and its homopolymer have already been removed by supersonic vibration with acetone [28]. As for the spectra of modified PP-g-AA-GO fabric, a evidently arisen peak at 1050 cm\(^{-1}\) is assigned to -O=C-O bending vibration. Similar observations have been reported by Wang [29] et al. The presence of these characteristic peaks indicates that GO has been successfully grafted onto the surface of PP-g-AA fabric. The FT-IR spectra show that AA and GO have been successively grafted onto the surface of PP fabric successfully. Further surface chemical information of pristine PP fabric, modified PP-g-AA fabric and PP-g-AA-GO fabric were obtained by XPS analysis.

### 4.3 Surface Composition

XPS measurement was carried out to further investigate the distribution of different functional groups on the surface of modified PP fabrics. Fig. 7(a) shows the XPS wide-scan spectra of pristine and modified PP fabrics, and the O1s:C1s ratios are shown in the insets. Pristine PP fabric shows almost no oxygen content with the O1s:C1s ratio of around 0. The ratio increased from 0 to 0.36 after grafting AA onto the surface of PP fabric and eventually reached 0.69 after grafting GO onto the surface of PP-g-AA fabric [30]. The increase in
oxygen content on the surface of PP fabric is attributed to the introduction of oxygenous groups. Deconvolution of C1s core level spectra of pristine and modified PP fabrics are shown in Fig. 7(b)-(d). In pristine PP fabric as shown in Fig. 7(b), only one component at 284.8 eV originated from C-C/C-H was identified [18, 31]. After successive grafting AA and GO onto the surface of PP fabric, three newly appeared components at 287.7 eV, 285.9 eV and 288.7 eV were assigned to C-COOH, C-OH, and C-COO, respectively [18]. The atomic percentage of C-COOH on the surface of PP-g-AA was only 3 at.%, but the percentage dramatically increased by grafting GO onto PP-g-AA and eventually reached 27 at.% on PP-g-AA-GO fabric. Meanwhile, the atomic percentage of C-OH eventually reached 10.3 at.% on the surface of PP-g-AA-GO fabric. These changes confirmed the successful grafting of AA and GO, which was consistent with FT-IR results [30], indicating the appearance of a large number of hydrophilic groups. The introduction of numerous hydrophilic groups will certainly improve the hydrophilicity of PP fabric, thus leading to enhancement in mechanical properties. In addition, the surface element compositions obtained from XPS wide-scan and functional group compositions obtained from deconvolution of C1s peaks were shown in Table 3.

Table 3 Surface element and functional group compositions of pristine PP fabric, modified PP-g-AA and PP-g-AA-GO fabrics

<table>
<thead>
<tr>
<th>Samples</th>
<th>Element composition (%)</th>
<th>Functional group composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C1s</td>
<td>O1s</td>
</tr>
<tr>
<td>Original PP</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>PP-g-AA</td>
<td>73.5</td>
<td>26.5</td>
</tr>
<tr>
<td>PP-g-AA-GO</td>
<td>59.2</td>
<td>40.8</td>
</tr>
</tbody>
</table>
4.4 Morphology

Changes in chemical structures and surface compositions will certainly influence morphology. Therefore, SEM and AFM measurements were carried out to investigate effects of grafting on morphology of PP fabrics. Fig. 8 shows SEM images of fibers extracted from pristine PP fabric, modified PP-g-AA and PP-g-AA-GO fabrics, respectively. It could be observed from Fig. 8 that the surface of pristine PP fiber was smooth. After modification of AA grafting, thin layer of AA molecule embossment was clearly seen on the surface of PP-g-AA fiber, thus increasing the surface roughness of PP fabric. Increase in surface roughness helped to increase the specific surface area of PP fabric, which would contribute to the subsequent grafting of GO. After GO grafting, it could be seen from Fig. 8(c) that numerous granular GO particles evenly distributed on the surface of PP-g-AA fiber. The successful grafting of GO will help to improve the hydrophilicity of PP fabric thus significantly improving interfacial properties between fabric and concrete and in turn leads to enhancement in mechanical properties of PP fabric-reinforced concrete. SEM images reveal that AA and GO have been successfully grafted onto the surface of PP fabric. In order to obtain more micro-scaled information about effects of grafting on the surface morphology of PP fabrics, AFM height images corresponding to SEM images are shown in Fig. 9. The root-mean-square roughness of pristine PP fiber was $3.71 \pm 0.35$ nm, which gradually increased to $28.72 \pm 5.35$ nm and then $49.79 \pm 7.84$ nm after grafting of AA and GO, respectively, indicating that the surface of PP fabric became rougher after grafting. This was consistent with the observations in SEM images.
4.5 Surface hydrophilicity

Static Water contact angle (SWCA) measurement was carried out to study the effects of grafting on the surface wettability of PP fabric. Fig. 10 showed the static WCA images. The change of WCA could be observed after each step of grafting. The pristine PP fabric was intrinsically hydrophobic with the wetting angle value of around 77° ± 3.7°. After grafted with acrylic acid, static WCA of the resulting PP-g-AA surface showed slight decrease to around 64.1° ± 2.1° due to introduction of relatively hydrophilic carboxyl groups. The improved hydrophilicity of PP-g-AA-GO fabric with a wetting angle of around 29.2° ± 1.3° was eventually achieved by grafting GO which introduced numerous hydrophilic groups including carboxyl groups and hydroxyl groups onto the surface of PP-g-AA fabric through esterification reaction. Static WCA results showed that the grafting significantly improved the hydrophilicity of PP fabric [16], which would help to improve the interfacial properties between PP fabric and concrete, and might in turn led to enhancement in mechanical properties of PP fabric-reinforced concrete.

4.6 Mechanical Properties

4.6.1 Compressive properties

The compressive strength and modulus results of various PP fabrics reinforced concrete
samples and a plain concrete sample were shown in Fig. 11. The relative ratio represents the increase rate for the concrete specimens comparing to the reference specimen (the plain concrete).

![Graph showing compressive properties of various PP fabrics reinforced concrete samples](image)

**Fig. 11. Compressive properties of various PP fabrics reinforced concrete samples**

It shows no obvious effect on compressive strength after addition of pristine PP fabric [32]. Concrete reinforced with pristine PP fabric shows no obvious increase in the value of compressive strength compared to the plain concrete, which has also been confirmed in other research [33]. This is due to poor interfacial properties between pristine PP fabric and concrete. However, modified PP fabrics reinforced concrete samples show larger compressive strength, which is probably due to the enhancement in the interfacial properties. Grafting AA and GO onto the surface of PP fabric significantly improved the hydrophilicity of PP fabric due to the introduction of oxygenous groups leading to enhancement in interfacial properties between fabric and concrete thus eventually resulting in the increase in compressive strength. On the other hand, PP fabric plays the role of redistributing compressive load in the concrete [34]. A closer combination will certainly help to dissipate load more effectively thus increasing the compressive strength of the integral fabric-reinforced concrete. These results well confirmed previous hypothesis that modified PP fabric-reinforced concrete had higher mechanical properties than pristine PP fabric reinforced-concrete.

**4.6.2 Flexural properties**

The variation in flexural strength and modulus of various fabric-reinforced concrete samples are shown in Fig. 12. There is a significant increase in flexural strength of pristine PP
fabric-reinforced concrete sample compared with plain concrete sample, with the value increases by 65.9%. The concrete cracking behavior was delayed by the addition of PP fabric which changed cracking direction and reduced cracking speed. When cracks developed up to the interface between PP fabric and concrete, the development direction of cracks would be changed from vertical direction to horizontal direction along the interface. Moreover, good interfacial properties often lead to excellent mechanical properties in fabric-reinforced concrete. Therefore, it is vital to improve interfacial properties in order to increase flexural strength of fabric-reinforced concrete.

As for concrete samples reinforced with PP-g-AA fabric and PP-g-AA-GO fabric, flexural strength increased by 3.3% and 25.6%, respectively, compared with pristine PP fabric-reinforced concrete sample. This could be fully attributed to the enhancement in interfacial properties by grafting of AA and GO introducing numerous oxygenous groups which improved the hydrophilicity of PP fabric. The integrity of fabric-reinforced concrete was also improved through a tighter combination due to better interfacial property which retarded development of cracks along horizontal direction.

As shown in Fig. 12, it shows no obvious effect on flexural elastic modulus after adding various PP fabrics into concrete. In other words, the addition of PP fabric did not change the stiffness of the concrete. The determined factors of elastic modulus are bond strengths between atoms, molecules or ions [35]. Elastic deformation behavior of concrete occurs when bond length and angle between atoms, molecules or ions of components in concrete changes [36]. However, the addition of PP fabrics didn't change these factors during elastic deformation. Therefore, flexural strength shows no obvious change among various PP fabrics reinforced concrete samples.
Deflection value at maximum flexural load represents the concrete toughness, and the results are shown in Fig. 13. It is clearly observed that improvement in hydrophilicity of PP fabric significantly increases the toughness of fabric-reinforced concrete samples. In other words, PP-g-AA-GO fabric-reinforced concrete sample is the most ductile and least stiff sample among various fabrics reinforced concrete samples. It should also be noted that during flexural tests, failures of various PP fabrics reinforced concrete were characterized by numerous minor surface cracks, while the plain concrete failed catastrophically with large single cracks [3]. That is to say, fabric-reinforced concrete displays a more ductile mode of failure. In the long run, modified PP fabrics reinforced concrete would undergo higher deformation without collapsing [37] compared with plain concrete. Hence using modified PP fabric reinforced concrete as basic building materials will open up avenues for many applications in the future.
15

Fig. 13. Toughness of various PP fabrics reinforced concrete samples

5 Conclusions

Surface hydrophilic modification of PP fabric was successfully conducted by successively grafting the AA and GO onto the surface of PP fabric under UV radiation. This method introduced active functional groups onto the surface of PP fabric and changed the chemical activity of PP fabric. Moreover, outstanding surface hydrophilicity resulted in excellent interfacial properties between PP fabric and concrete matrix.

Based on the current results, the following conclusions can be acquired:

- The maximum grafting degree of AA was 9.3%, arising at 70 min of grafting time, under 312nm UV radiation at 60 °C.
- The FTIR and XPS results prove that AA and GO have been grafted onto the surface of PP fabric successfully.
- The AA and GO grafting increase the surface roughness of PP fabric.
- The hydrophilicity of PP fabric shows substantial increase, due to introduction of active functional groups from AA and GO.
- As the hydrophilicity of PP fabric increases, compressive strength and modulus of various PP fabrics reinforced concrete basically remain unchanged.
- Compared with pristine PP fabric reinforced concrete, the flexural strength of PP-g-AA and PP-g-AA-GO fabrics reinforced concrete increase by 3.3% and 25.6%, respectively. However, grafting of AA and GO shows no obvious effect on flexural elastic modulus of fabric reinforced concrete.
- The concrete toughness increases with the improvement in hydrophilicity of PP fabric.

Acknowledgements:

This work was supported by the National Key Research and Development Program of China (2016YFC-0304301 & 2016YFB0303200), Cooperative Innovation Fund-Prospective Project of Jiangsu Province (No. BY2015019-33).

References:

reinforced plastic-prestressed self-compacting concrete, Cement Concrete Comp. 49 (2014) 36-42.


[18] Y. Zhao, W. Sun, S. Shi, Y. Gong, Biomimetic surface modification of polypropylene by surface chain transfer reaction based on mussel-inspired adhesion technology and thiol chemistry, APPL. SURF. SCI. (2016)


[20] S. Li, J. Wei, H. Yang, L. Wang, A. Wang, Y. Zhang, Y. Nie, A novel sorbent prepared by


[34] V. Corinaldesi, A. Nardinocchi, Mechanical characterization of Engineered Cement-based Composites prepared with hybrid fibres and expansive agent, Compos. Part B Eng. 98 (2016) 389-396.