Confining effects of circular concrete tests reinforced PET fiber

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ABSTRACT

The aims of this study are, first, to determine the confining effect of concrete specimens reinforced with carbon fiber (CF) or glass fiber (GF), and second, to compare the confining effect of PET fiber-reinforced concrete specimens with the above, CF- or GF-reinforced specimens so as to ultimately determine whether PET fiber can play a role as a reinforcement. Toward this end, the study produced circular specimens of 100 mm in diameter and 300 mm in height and conducted a test after reinforcing these specimens with CF, GF, or PET fiber, for which the types of the reinforcement, the number of reinforcement layers, and concrete strength were the key parameters. The test results showed there was little improvement of strength with the specimens reinforced with PET sheets when compared to those with CF or GF; however, the ductility had greatly improved while maintaining the strength so that the test completed as the PET fiber-reinforced specimens did not reach compressive fracture and PET fiber consistently supported lateral confinement. As a result, it showed that reinforcement with PET fiber would prevent the worst case of structures collapsing complete; therefore, that PET fiber would be used in construction projects.

1. Introduction

In steel reinforced concrete structures, concrete endures compressive force in the compressive region while rebar endures tensile force. Being a brittle material, concrete must be used together with ductile materials like rebar in areas under tensile or shearing force. In columns mainly under compressive force, the material properties of concrete greatly affect the column members. As shown in the stress-strain rate curve of concrete, the material properties of concrete shows brittle behavior, and reinforcement of concrete can prevent brittle fracture behavior. For columns, which mainly take most of the compressive force and take relatively less flexural and shearing force, reinforced sheets are generally used to prevent brittle behavior. Sheet reinforcement improves both strength and ductility at the same time by covering or wrapping the exterior of the columns with carbon fiber (CF) sheets, glass fiber (GF) sheets, or aramid fiber sheets using adhesives so that these sheets prevent the columns from expanding laterally by compressive load. Not only offering superior reinforcing effect and constructability, sheet reinforcement allows for a shorter construction duration so that there have been many domestic and overseas case studies and projects that use the method. The increase of strength and ductility by sheet reinforcement is effective in columns with small lateral displacement, but for columns that require large displacement due to big earthquakes, it cannot be expected that sheet reinforcement would offer sufficient ductility. For reinforcing materials like CF, GF, or aramid fiber do not have sufficient material properties to resist large displacement (Donguk et al. 2015; Mander, Priestley, Park 1988; Moon Kwan 2006). Therefore, this study aimed to identify the strength and ductility improvement by polyethylene terephthalate (PET), and to examine the characteristics of PET fiber compared to the existing reinforcing materials like CF sheets or GF sheets so as to determine whether PET fiber can be used for construction projects as a reinforcing material.

2. Methodology

To determine the reinforcing performance and constructability of PET sheets, the study produced circular specimens of 100 mm in diameter and 300 mm in height and conducted a test after reinforcing these specimens with PET fiber. The test parameters considered were the types of reinforcement, the number of reinforcing layers, and concrete strength. Three types of reinforcement, CF sheets, GF sheets, and PET, were used, and one or two layers of CF or GF sheets, and 5, 7, 10, 20, and 30 layers of PET were used. The larger number of layers of reinforcement with PET was used as it was determined that compared to that of CF or GF, the tensile strength of PET is considerably low so that one or two layers of PET would not offer much strength improvement. The study also examined any difference in reinforce effect on the nominal compressive strength of concrete between the generic strength at 28 MPa and the high strength at 48 MPa. There were a total of 36 specimens (18 types), 2
specimens per parameter. The reinforcing sheet is attached with the reinforcing sheet at intervals of 10 mm above and below the specimen. As mentioned above, reinforced with GF and PET, in order to prevent adhesion damage, 1.5 times of circumference was overlapped. The test was conducted using a 1000 kN universal testing machine as shown in Figure 1. In order to measure the horizontal and vertical displacement according to the load, the concrete gauge was attached vertically to the center of the circular specimen and the gauge was attached horizontally to the left. Table 1 are the material properties used for the specimens.

3. Test results

The test results shown in Table 2 and Figure 2 the final specimen failure, the specimens without reinforcement (No. 1 and No. 11) showed a typical compressive failure, whereas the specimens with CF and GF reinforcement showed improved strength and ductility to non-reinforced specimens. However, the specimens with PET reinforcement were shown to have considerable improvement in ductility rather than in strength. Figure 3 shows the stress-strain rate curves by the concrete specimens with normal strength, and Figure 4 are the stress-strain rate curves by the high strength concrete specimens.

4. Conclusions

The study aimed to determine the PET fiber-reinforced specimens’ reinforcement effect and its applicability to construction projects and resulted in the following conclusions.

(1) The CF- and GF-reinforced specimens offered superior reinforcement effect in strength and ductility compared to the specimens without reinforcement.

(2) The CF- and GF-reinforced specimens with two layers of reinforcement showed superior strength to those with one layer of reinforcement, whereas the latter offered better ductility than the former.

(3) Up to 10 layers of PET sheets did not offer much reinforcement effect, and only after 20 or more layers of PET sheets were used for reinforcement could the specimens show strength improvement.

(4) The specimens with 10 or more layers of PET sheets consistently supported load without

| NO. | Specimens | D (mm) | h (mm) | S.M | LS | t_{sp} (mm) | μ_{sp} (%) | f_{sp} (MPa) | f_{e} (MPa) | f_{co} (MPa) | $ε_{co}$ (%) | P_{max} (kN) | S_{f} (kN) | P_{max}/P_{frp} |
|-----|------------|-------|-------|-----|----|-----------|-----------|-------------|-------------|-------------|------------|-------------|----------|----------------|
| 1   | Con-28    | 100   | 300   | -   | -  | -         | -         | -           | -           | -           | -          | -           | -        | -              |
| 2   | CF-28-1   | CF    | 1     | 0.17 | 0.70 | 193.7    | 51.87     | -           | 0.0047      | 916.30      | 407.40     | 44.64       | 309.54   | 1.32           |
| 3   | CF-28-2   | CF    | 2     | 0.35 | 1.39 | 193.7    | 92.87     | -           | 0.0066      | 1286.30     | 729.40     | 125.34      | 390.24   | 1.87           |
| 4   | GF-28-1   | GF    | 1     | 0.34 | 0.48 | 57.1     | 56.84     | -           | 0.0104      | 595.90      | 446.42     | 56.23       | 321.13   | 1.39           |
| 5   | GF-28-2   | GF    | 2     | 0.67 | 0.96 | 57.1     | 95.65     | -           | 0.0130      | 740.30      | 751.20     | 139.71      | 404.61   | 1.86           |
| 6   | PET-28-5  | PET   | 5     | 0.27 | 1.06 | 7.1      | 33.64     | -           | 0.0024      | 16.80       | 264.20     | 1.25        | 266.15   | 0.99           |
| 7   | PET-28-7  | PET   | 7     | 0.37 | 1.48 | 7.1      | 34.66     | -           | 0.0011      | 7.80        | 272.20     | 0.81        | 265.71   | 1.02           |
| 8   | PET-28-10 | PET   | 10    | 0.53 | 2.12 | 7.1      | 35.87     | -           | 0.0028      | 20.10       | 281.70     | 1.03        | 265.71   | 1.02           |
| 9   | PET-28-20 | PET   | 20    | 1.06 | 4.24 | 7.1      | 43.91     | -           | 0.0070      | 50.00       | 344.90     | 14.84       | 279.74   | 1.23           |
| 10  | PET-28-30 | PET   | 30    | 1.59 | 6.36 | 7.1      | 52.04     | -           | 0.0073      | 52.00       | 408.70     | 23.14       | 286.04   | 1.42           |

TS (= Type of the sheet); LS (= Number of lap splice); $t_{sp}$ (= Thickness of sheet); $P_{max}$ (= Maximum load); $S_f$ = f_{sp} × $t_{sp}$ × h (= Strength effect); $f_{sp}$ = $\rho_{cc} × f_{e}$ FRP stress); $P_{frp}$ = $P_{max}$(Standard specimen) + $S_f$.
drastic strength degradation, and until the end of the test, the PET fiber was not ruptured and showed considerably large ductile behavior.

(5) While PET fiber reinforcement showed negligible impact on strength improvement compared to CF or GF, it prevented drastic strength degradation after maximum strength and maintained
ductility, and therefore it could be applied to construction projects.

**Disclosure statement**

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