Transactions of the Materials Research Society of Japan 25 [2] 593-596 (2000)

Detection and Prevention of Fracture with Carbon Material-Glass Cloth Reinforced Plastics

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Two types of carbon materials (carbon fiber and carbon powder) and glass cloth were used as conductive materials and reinforcing fiber, respectively. The carbon powder was used for fabricating electrically conductive CPGFRP (carbon powder-glass fiber reinforced plastics) rod. The carbon fiber or the CPGFRP rod was stuck on the mortar with epoxy resin and glass cloth. On bending, the electrical resistance of reinforced plastic with the carbon fiber stuck on the mortar increased largely after crack generation, and those with the CPGFRP rod stuck on the mortar increased from the early stage of deflection in the mortar, respectively. The CPGFRP rod is superior to carbon fiber for the detecting ability of fracture. Also, by using the carbon material-glass cloth reinforced plastic, the reinforced mortar has over twice as strength as unreinforcing.

Key words: Carbon Material, Glass Cloth, Electrical Resistance, Detection and Prevention of Fracture

1. INTRODUCTION

Stronger and heavier materials are used in many structures in order to secure damage from fatal fracture. Many industrial waste would be generated in disuse. For preservation of the environment, it is necessary to reduce industrial wastes.

If structure itself possesses a function of predicting fracture, environmental conservation would be feasible through the reduction of fatal accidents and damage by a decrease in sporadic fracture as well as material saving. Therefore, the design of self-detection for concrete structures using CFGFRP (carbon fiber-glass fiber reinforced plastics) composites is researched by author et al.[1)-4)]. However, these were hard to apply in constructed structures. This paper reports results obtained by the investigation of detection and prevention to fracture of mortar reinforced with glass cloth reinforced plastic using carbon materials for electrical conductors.

2. EXPERIMENTAL METHOD

2.1. Raw Materials

Hybrid composites are consisted of electrically conductive materials with a small value of elongation and insulating glass cloth with a large value of elongation. As an electrically conductive material, pitch-typed carbon fiber tows (Mitsubishi Chemical Corporation, Japan: Dialead K-1374U, elongation: 0.57%) and synthetic graphite powders with average particle size of 5 μm (SEC Co., Ltd., Japan: SGP-5) were used, respectively. E-glass cloth (Nippon Sheet Glass Co., Ltd., Japan: 135tex, 19 tows par 25 mm) was used as glass cloth. As the matrix, epoxy resin (Kokusai Chemicals Co., Ltd., Japan: low viscous epoxy resin: Z-1) and denatured polyamideamine curing agent (Kokusai Chemicals Co., Ltd., Japan: hundred minutes type) were used. E-glass roving fiber tows (Asahi Fiber Glass co., Ltd., Japan: ER2220), unsaturated polyester resin (Showa High Polymer Co., Ltd., Japan: Rigolac 158BQT) and styrene (Kanto Chemicals Co., Ltd., Japan) were used for reinforcement fiber, resin and plasticizer of CPGFRP (carbon powder-glass fiber reinforced plastics) rod, respectively.

As cement of mortar specimens, portland cement

(Tokyo Sun Home Co., Ltd., Japan) was used, and which was mixed with sand at necessary volume.

2.2. Fabrication of CPGFRP Rod

To fabricate electrically conductive CPGFRP rod, the slurry containing graphite powder with unsaturated polyester resin were prepared. The slurry was prepared by mixing graphite powders of 10% volume fraction as electrically conductive material, unsaturated polyester resin of 36% volume fraction as matrix and styrene monomer of 54% volume fraction for lowering viscousity of slurry.

Glass fiber tows of 1000 filaments were dipped in the slurry, and impregnated the slurry into glass fiber tows by ultra sonic vibrator. The glass fiber tows were pulled up from slurry, and it was formed with the shape of 0.8 mm in thickness and 2 mm in width. CPGFRP rod was dried for 24 hours at room temperature, and they were cut by 270 mm in length.

2.3. Test Specimens

Mortar test pieces were fabricated from mixture cement containing sand of 81.6% weight fraction and water of 18.4% weight fraction, respectively. The size of the mortar test pieces were 40 mm in thickness, 40 mm in width and 300 mm in length, respectively. They were stuck glass cloth of 40 mm X 300 mm and carbon fiber tows or CPGFRP with epoxy resin on tension side (Fig. 1). Denatured polyamideamine was added for curing agent of epoxy resin. The carbon fiber tows and CPGFRP composites were attached by lead wires with silver adhesive for measuring change in electrical resistance. FRP stuck on mortar was about 1 mm in thickness.

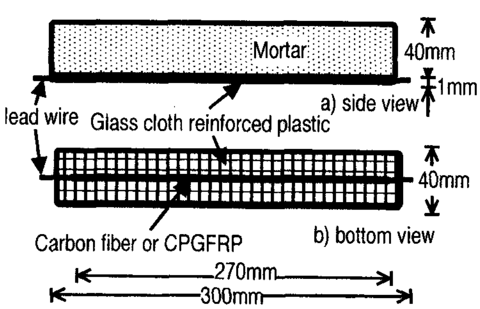

Fig. 1. Schematic drawing of mortar test piece sticking glass cloth reinforced plastic.
a) side view, b) bottom view

2.4. Testing Method

Effect of prevention of test specimen and change in electrical resistance were measured using three point bending test (100 mm in span) with a universal tester (Shimadzu Corporation, Japan: Autograph AGS-10kNH). The crosshead speed at bending test was kept constant at 0.5 mm/min. The electrical resistance was performed by a D.C. two-terminal method. Programmable D.C. / A.C. signal source (HIOKI 7020) as constant current D.C. source, and digital multimeter (ADVANTEST TR6847) as voltage amplifier were used, respectively. Constant Currents of 10 mA and 0.01 mA were currented for carbon fiber and CPGFRP, respectively. A stress of test piece was obtained by calculation from load, and a strain was obtained from deflection of test piece. Furthermore, a strain of largest elongation in test piece was measured by strain gauge (Tokyo Sokki Kenkyujo Co., Ltd., Japan: FLK-6-11). The change of load, displacement of crosshead, electrical resistance and strain measured by gauge were recorded in hybrid recorder (NEC-San-ei RD3218).

3. RESULTS AND DISCUSSION

3.1. Effect of Prevention

Fig. 2 shows stress (σ) and strain measured by strain gauge as a function of strain (ε) calculated from load for mortar test piece unsticking glass cloth reinforced plastic. The mortar test piece is fractured immediately with generation of crack. The strain measured by strain gauge and stress for generation of crack are 0.03% and 6 MPa, respectively.

Fig. 3 shows the result measured for mortar test piece sticking glass cloth reinforced plastic containing carbon fiber in order to detect fracture. The crack of mortar generated at 2% strain corresponding to 0.024% strain of gauge and at 9 MPa in stress, respectively. The mortar test piece didn't fracture with generation of crack, and still withstood till 13 MPa in stress. The mortar structures are able to prevent by glass cloth reinforced plastics after the crack generated.

The result of bending test for mortar test piece sticking reinforced plastic containing graphite powder is shown

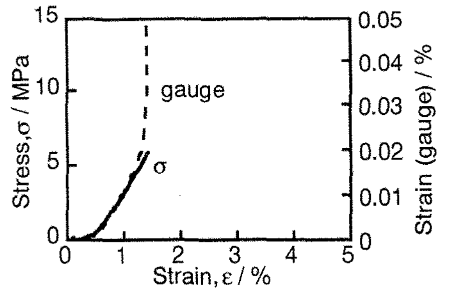

Fig. 2. Stress (σ) and strain gauge measured by strain gauge as function of strain (ε) calculated from load for mortar test piece unsticking glass cloth reinforced plastic.

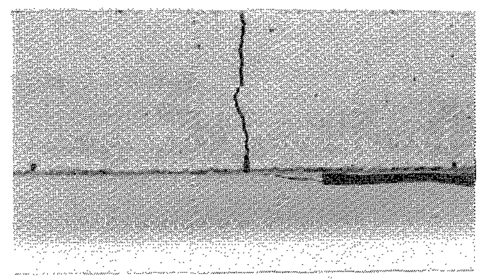

Fig. 5. Photograph of mortar test piece unsticking glass cloth reinforced plastic after bending test.

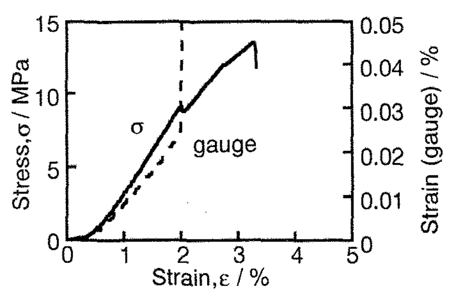

Fig. 3. Stress (σ) and strain gauge measured by strain gauge as function of strain (ε) calculated from load for mortar test piece sticking reinforced plastic containing carbon fiber.

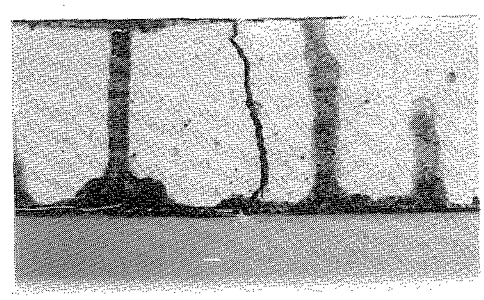

Fig. 6. Photograph of mortar test piece sticking glass cloth reinforced plastic containing carbon fiber after bending test.

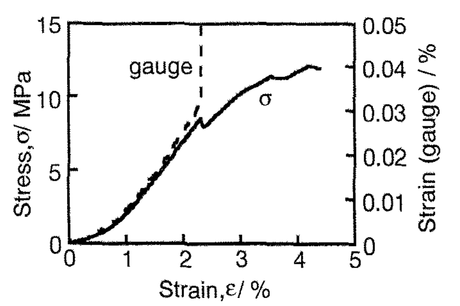

Fig. 4. Stress (σ) and strain gauge measured by strain gauge as function of strain (ε) calculated from load for mortar test piece sticking reinforced plastic containing graphite powder.

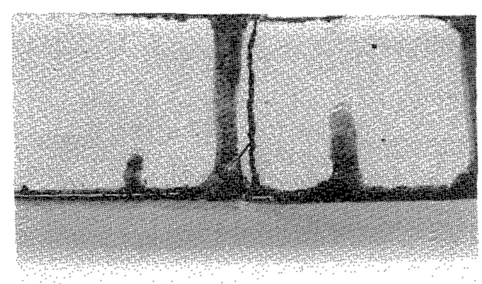

Fig. 7. Photograph of mortar test piece sticking glass cloth reinforced plastic containing graphite powder after bending test.

in Fig. 4. This result is also indicated the capability withstanding till 12 MPa by reinforced plastic.

Photographs of mortar test pieces after bending tests show in Figs. 5, 6 and 7, respectively. Unreinforcing mortar test piece generated only single crack (Fig. 5). This indicates that the mortar test piece was fractured only by growth of generated crack. On the other hand, plural cracks generated in the reinforcing mortar test pieces (Figs. 6 and 7). It is considered that the generated crack didn't grow with sticking reinforced plastic, and other cracks generated. Since the glass cloth reinforced plastic has the effect to inhibit growth of crack in mortar, the mortar test piece is able to withstand after the crack generated.

3.2. Detection of Fracture

Fig. 8 shows the change in electrical resistance (ΔR) and stress as a function of strain for test piece stuck glass cloth reinforced plastic containing carbon fiber (R_0: 8.05 Ω). The crack of mortar test piece generated at

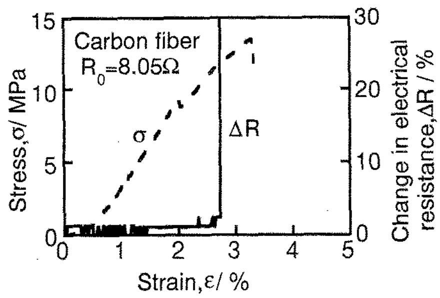

Fig. 8. Stress (σ) and change in electrical resistance (ΔR) as function of strain (ε) for mortar test piece sticking glass cloth reinforced plastic containing carbon fiber, R_0=8.05Ω.

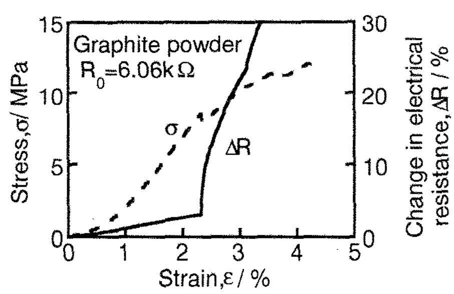

Fig. 9. Stress (σ) and change in electrical resistance (ΔR) as function of strain (ε) for mortar test piece sticking glass cloth reinforced plastic containing graphite powder, R_0=6.06kΩ.

2% in strain, but the resistance of carbon fiber didn't increase with crack generation. The electrical resistance of carbon fiber increased at 2.7% in strain. This phenomenon by the strain of mortar test piece with generated crack very small, and carbon fiber didn't fracture. The strain measured by strain gauge when the crack generated was only 0.024% (Fig. 3). After the crack generated, the electrical resistance increased by carbon fiber fractured with expansion of the crack. The electrical resistance of carbon fiber increased largely with fracture fiber, but was little changes in small strain.

The result of test piece used CPGFRP (R_0: 6.06 kΩ) is shown in Fig. 9. The electrical resistance of CPGFRP increased with the strain of the mortar test piece, and increased largely by generation of crack in the mortar test piece. The change in electrical resistance of the CPGFRP was caused by separating contacts of graphite powders. The CPGFRP contained glass cloth reinforced plastic is better than the carbon fiber contained for detecting fracture in small strain.

4. CONCLUSIONS

The following conclusions were obtained in the investigation on detection and prevention of carbon material-glass cloth reinforced plastics.

1) By using the carbon material-glass cloth reinforced plastic, the reinforced mortar has over twice as strength as unreinforcing.
2) The electrical resistance of reinforced plastic containing carbon fiber increases largely after the crack generated in mortar.
3) The reinforced plastic used CPGFRP is effective to detect fracture as the electrically resistance increases with small strain before generation of cracks.

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(Received December 16, 1999; accepted February 7, 2000)