A FUTURE GENERATION CARBON FIBER REINFORCED PLASTICS FOR CONCRETE STRUCTURES

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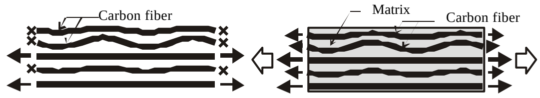
1. INTRODUCTION

Use of continuous carbon fibers in fiber reinforced plastics (FRP) reinforcement for concrete structures introduces a promising solution for deterioration of concrete structures due to corrosion of steel reinforcements. Unfortunately, due to the low elastic modulus of CFRP as well as high cost material caused the limitedness of using of CFRP reinforcement on concrete structures. As an effort to increase the performance of a CFRP as well as to introduce a cheap high performance CFRP, a new concept in manufacturing of a CFRP reinforcing materials is proposed. This system is called UCAS (Unidirectional Carbon-fiber Assembly System). The CFRP produced by this system consists of two main parts that are a rod and the U-end anchors on both end of the rod. The CFRP manufactured by this system is named “Super CFRP”.

2. BASIC CONSIDERATION

The traditional motivation for using FRP composite materials has been to efficiently utilize the extraordinary strength and stiffness properties of small diameter fibers by embedding the fibers in a relatively ductile polymeric binder, or matrix. However, the properties of the un-straight fibers could not be utilizes as effective as the straight fibers due to the relatively low Young’s modulus of resin matrix . This condition is illustrated in Figure 1. The existing of un-straight (slack) fibers cause the crack easy to propagate (Figure 2).

Based on the phenomenons mentioned above, then, it could be considered that the performance of the CFRP could be improved by reduce the un-straight fibers. In the case of CFRP, the higher tensile performance reinforcing material could be expected (Figure 3).



(a) Without resin matrix (b) With resin matrix
Figure 1 Conventional System

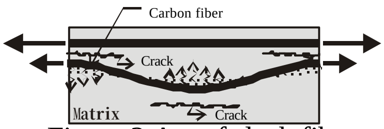
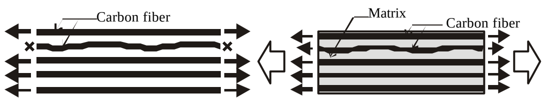


Figure 2 Act of slack fiber



(a) Without resin matrix (b) With resin matrix
Figure 3 UCAS Method

3. MANUFACTURING PROCESS

Manufacturing process of super-CFRP schematically shown in Figure 4 is divided into four steps which are turning of longitudinal carbon fiber strand, wrapping of carbon fiber, curing of matrix and finally, releasing of pre-tensile forces. To achieve the considerations mentioned in the previous section, an assembler robot has been developed at kyushu university to do all steps in manufacturing the super-CFRP.

First step is the turning of longitudinal carbon fiber strand between two end-anchors. During this process, the constant tensile forces in turning process is maintained and controlled with an apparatus attached on robot. The second step is the wrapping of longitudinal fibers with carbon fiber which is done soon after turning of longitudinal fibers. The wrapping is aimed to reduce the matrix content, push-out the trapped air and to increase the bond capacity of the rod. The third step is the electrically curing of matrix under 70^{o}C for about 2 hours.

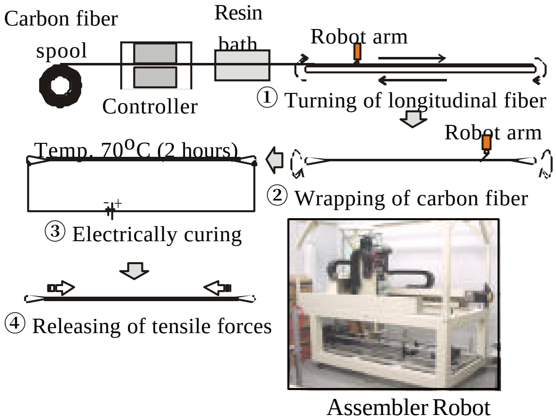


Figure 4 Manufacturing Processes

Keywords: Carbon fibers, CFRP, Tensile Strength, Young’s Modulus
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The last step is the releasing of initial tensile forces (prestress). This process is done when the matrix has completely hardened. This is an important key of this product in which the releasing of initial tensile stress will produce a compressive stress on rod. The lateral deformation of the section area due to the compressive stress will be restrained by the wrapped carbon fibers.

In order to enlist an anchorage system that will ensure full development of the reinforcement strength particularly for prestressed concrete, the U-anchor is also developed as one of additional merit of Super CFRP. Figure 5 shows the Super-CFRP with U-Anchor. Figure 6 shows the zoomed cross sectional area of the conventional CFRP and Super CFRP. Black pockmarked indicates some pore (defects) on the conventional CFRP. On Super CFRP, as it can be observed, the carbon fiber is uniformly distributed and almost no defects that could be found.

4. TENSILE PROPERTIES

In order to clarify the tensile properties of the Super CFRP, a series of tensile test was done. Table 1 and Table 2 present the mechanical properties of carbon fiber and the list of specimen, respectively. For the gripping purposes, the ends rod were inserted into the steel sleeves and filled with expandable mortar as shown in Figure 7.

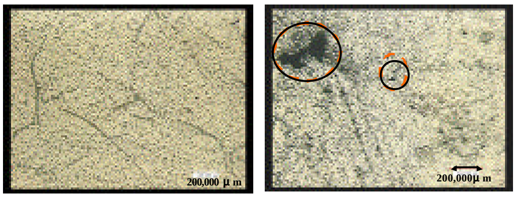
Results indicated that all types had a linear elastic behavior up to failure as presented in Figure 8. The rods reach their ultimate tensile strength without exhibiting any yielding of the material. This is one significant difference between these materials and the steel reinforcement in which the stress-strain relationship does not show any sign of plasticity at high stresses. Table 3 shows the summary of tensile properties of the Super CFRP. The tensile properties reported here are the average value. The maximum tensile stress are obtained by dividing maximum loads by the nominal cross section of the rod.

5. CONCLUSIONS

A new method in manufacturing the fiber reinforced plastic materials was proposed as an attempt to more effectively utilize the extraordinary properties of the high strength fibers. Based on this study, the following conclusion can be made:

1. Microscopic sectional area investigation results indicated that almost no pore or defects that could be found on the super CFRP.
2. The tensile behavior of super CFRP is a linear elastic behavior.
3. High tensile strength and Young's Modulus CFRP could be expected.

Figure 5 Super-CFRP with U-Anchor



(a) Super CFRP (b) Conventional CFRP

Figure 6 Zoomed Cross Section

Table 1 Carbon Fiber's Properties

Carbon Fiber Name	Cross Sectional Area (mm^2)	Tensile Strength (MPa)	Young's Modulus (GPa)
Torayca T700S-12K	0.46	4800	230

Table 2 Specimen List

Type	Number of Turning	Cross Sectional Area (mm^2)
A	20	32.9
B	40	61.5
C	60	88.7

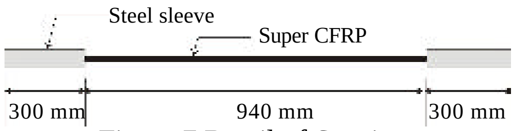


Figure 7 Detail of Specimen

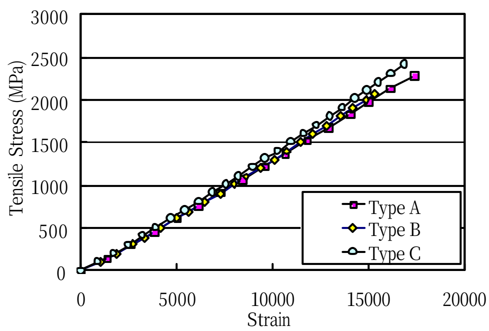


Figure 8 Stees-Strain Relationship

Table 3 Tensile Properties of Super CFRP

Type	Maximum Load (kN)	Maximum Tensile Stress (MPa)	Young's Modulus (GPa)
A	76.5	2320	136
B	144.8	2140	139
C	230.1	2450	144

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