# A Study on the Attachment Effect of CFRP Plates to Internal Reinforcements of Curtain Wall Frames Using GFRP

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**Abstracts:** This study is for the development of internal reinforcing materials using fiber-reinforced plastics that can be used for curtain wall frames. The main material of the reinforcement is light and inexpensive GFRP. However, GFRP has characteristics of low elastic modulus and brittle fracture. Therefore, CFRP is attached to supplement the disadvantages. In this study, a flexural experiment was performed to confirm the performance improvement effect of GFRP reinforced with CFRP. The results of the flexural experiment showed that the total flexural stiffness increased by about two times when the carbon fiber reinforced plastic plate was attached compared to the specimen made of a single material of glass fiber reinforced plastic. Also, the pattern of the load-displacement graph was found to reflect the characteristics of the ductile material. However, it was observed that adhesion failure first occurred on the attachment surface before the member yielded. Therefore, it was determined that it was necessary to increase the adhesive strength or set the minimum length in order to prevent poor adhesion when manufacturing actual stiffeners. Therefore, in this study, additional specimens were prepared using the specimen length, adhesive strength, and adhesive rate as variables, and then the experiment was conducted. As a result of the experiment, the maximum load decreased in the long specimen, but the overall stiffness was similar, and adhesive failure did not appear conspicuously before the member was destroyed. In the case of adhesive strength, the case using epoxy was more stable than the specimen using resin, and the maximum load and stiffness were slightly higher when the adhesive width of carbon fiber reinforced plastic was the whole.

**Keywords:** Carbon Fiber Reinforced Plastic, Glass Fiber Reinforced Plastic, Construction material, Metal reinforcement, Curtain Wall Frame.

## 1. INTRODUCTION

As the number of large-scale construction projects increases in recent years, concrete and steel, which are mainly used as structural materials in the existing construction field, are exposed to problems such as excessive weight and corrosion. Accordingly, in the field of construction materials and new materials, efforts to find alternative materials that can be used in construction work are being actively pursued. As one of the alternative materials, Fiber-reinforced plastic (FRP material) has an advantage in increasing the span or floor height compared to existing structures as its material weight is about 1/4 of that of steel. Accordingly, various related studies are being conducted.

In this study, it is intended to develop an internal reinforcing material for curtain wall frames using fiber-reinforced plastics. The main material of the reinforcing material to be developed is light and relatively inexpensive glass fiber reinforced plastic (GFRP). However, unlike steel, which is a ductile material, it is less stable to replace steel as a single material because of its brittle fracture characteristics and low elastic modulus, which is about 1/4 of that of steel. Therefore, it was determined that it is necessary to improve the disadvantages of glass fiber reinforced plastics by mixing or attaching carbon fiber reinforced plastics (CFRP) with good tensile performance. In addition, the effect of improving the stiffness and strength of the GFRP member according to the attachment of the CFRP material is investigated through an attachment experiment and finite element analysis.

## 2. Experiments

### 2.1 Flexural experiment

In this study, a flexural experiment was conducted to investigate the performance improvement effect of glass fiber reinforced plastic when carbon fiber reinforced plastic was attached to glass fiber reinforced plastic. The size of the initial specimen was set appropriately for the basic flexural experiment standard with 4-point loading. In addition, three specimens made of a single material of glass fiber reinforced plastic and three specimens of glass fiber reinforced plastic with carbon fiber reinforced plastic plates attached to the top and bottom were fabricated and experimented.

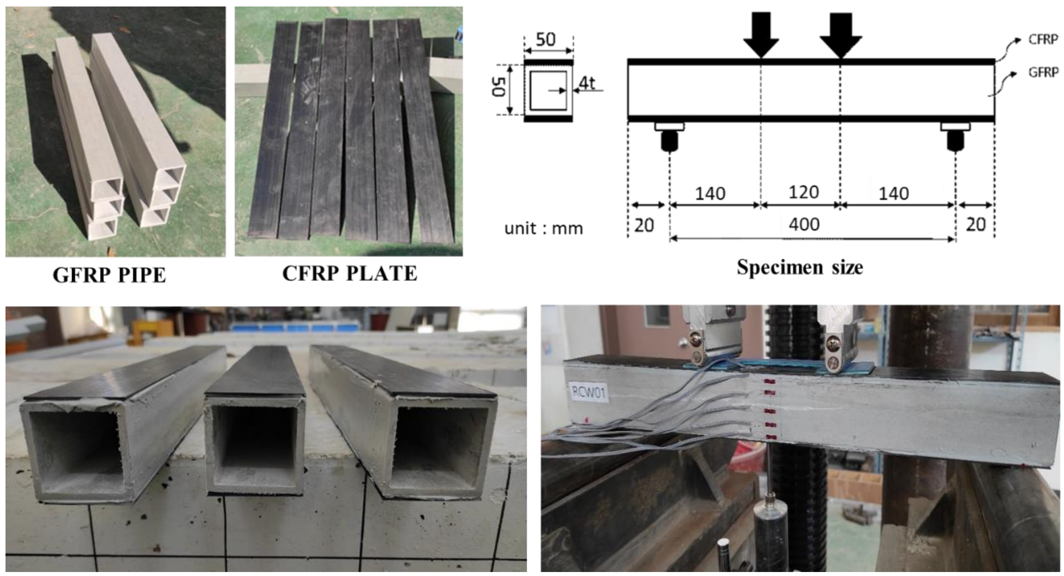


**Fig. 1.** Specimen size and gauge attachment location

The experiment was conducted in the same way as the standard 4-point flexural experiment, and the experiment speed was also applied while maintaining 1 to 500 mm/min according to the standard.

### 2.2 Adhesion destruction experiment

The results of the flexural experiment clearly showed that the stiffness increased, and satisfactory results were obtained. However, it was observed that adhesion failure first occurred on the attachment surface, as shown in Figure 2, before the member yielded. Therefore, it was determined that the adhesive strength should be increased, or the minimum length should be determined to prevent adhesive failure when manufacturing the actual stiffener. Therefore, in this study, additional specimens were fabricated using the length of the specimen, the adhesive strength, and the adhesive ratio as variables, and the experiment was conducted. The span of the additional specimen is 1200mm, which is three times longer than the existing specimen, and two types of adhesive are used for comparison. In addition, in order to compare the effect on the attachment width, the experiment was conducted by preparing specimens in which the CFRP plate had a full width ratio and a 50% ratio.


**Fig. 2.** Destruction of the adhesive part of the specimen

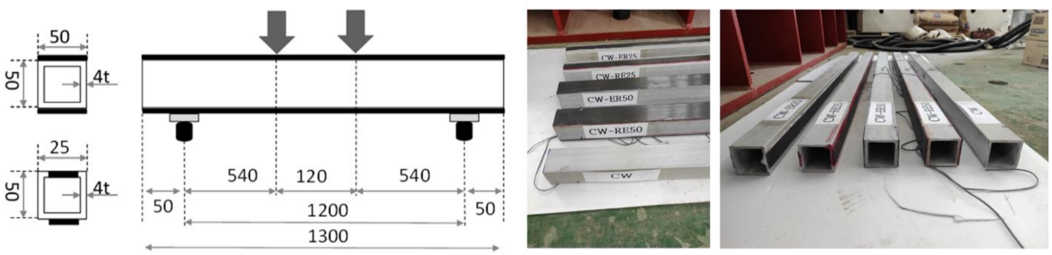


**Fig. 3.** Adhesion destruction experiment specimen

For comparison of the effect according to the difference in adhesive strength, two types of adhesives were used, S&P Resin 220 and HIT-RE 500 V3 epoxy, as shown in Figure 4.


**Fig. 4.** Two types of adhesive.

## 3. Experiment results

### 3.1 Flexural experiment results

The following graph shows the experimental results of each of the GFRP single material experiment specimen and the reinforced specimen attached with the CFRP plate. As shown in the graph, the initial flexural stiffness was found to increase by about two times when reinforced with CFRP compared to single materials. Also, the pattern of the load-displacement graph seems to reflect the characteristics of the ductile material to some extent.

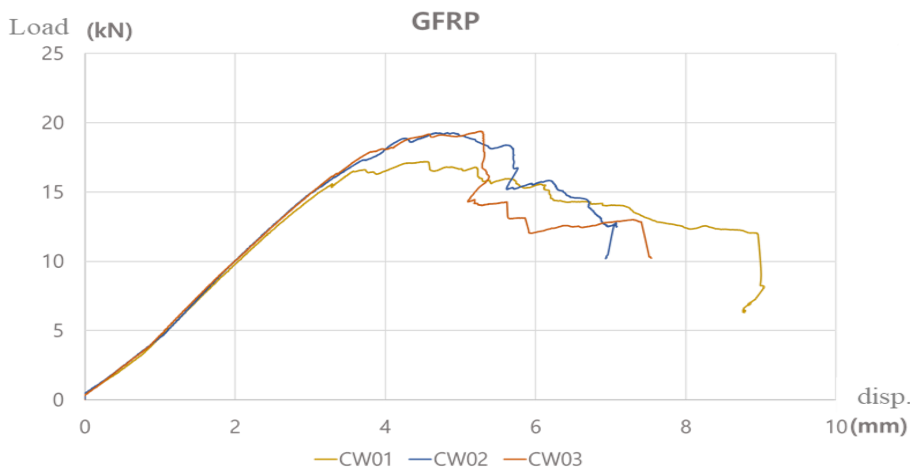


**Fig. 5.** Fexural experiment results of GFRP pipe

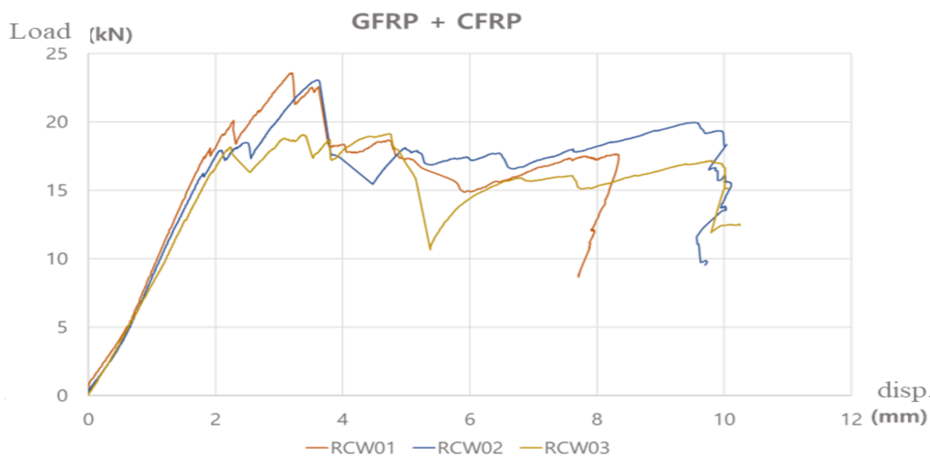


**Fig. 6.** Fexural experiment results of CFRP plate reinforced pipe

### 3.2 Adhesion destruction experiment results

There are a total of 5 specimens, and the specifications for each specimen are shown in Table 1.

**Table 1. Specimen specifications**

| ID | Clear span(mm) | With or without reinforcement | Adhesive |
|---|---|---|---|
| CW-01 | 1,200 | Unreinforced | |
| CW-RE50 | 1,200 | External reinforcement(50mm×1.4t) | HIT-RE 500 V3 |
| CW-RE25 | 1,200 | External reinforcement(25mm×1.4t) | HIT-RE 500 V3 |
| CW-ER50 | 1,200 | External reinforcement(50mm×1.4t) | S&P Resin 220 |
| CW-ER25 | 1,200 | External reinforcement(25mm×1.4t) | S&P Resin 220 |

As can be seen in the graph of Figure 7, when the entire width is reinforced, the stiffness is approximately twice as high as that of the unreinforced specimen. This can be seen as having the same performance improvement effect as the short specimen. One important point here is that adhesive failure did not appear conspicuously before the member was destroyed. This suggests that if the length of the reinforcing member is sufficiently secured, the performance degradation due to adhesive failure can be reduced.

In the case of adhesion strength, specimens using epoxy anchors showed slightly higher strength than specimens using resin. In addition, when the carbon fiber reinforced plastic was attached as a whole, the strength and rigidity were significantly higher than when the attachment width was 50%. When the attachment width is 50%, the strength is somewhat lower than that of the unreinforced specimen, which is considered to be because local failure proceeds quickly due to the concentrated load occurring in the narrow width.

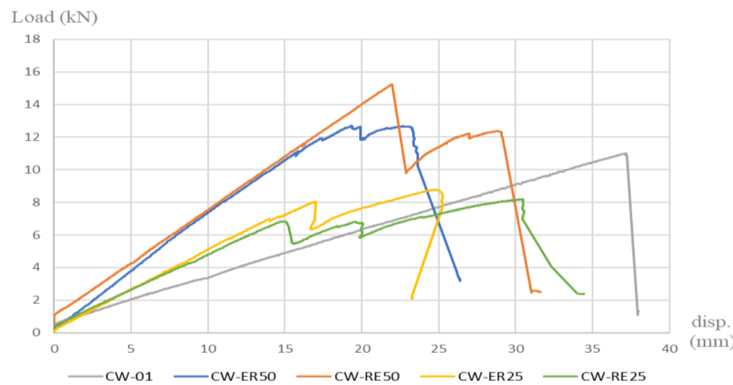


**Fig. 7.** Load-displacement curve for each specimen

## 4. FINITE ELEMENT ANALYSIS

In this study, a finite element analysis model was created and analyzed using Abaqus to predict the results of various variable changes such as length and attachment width. As for the analytical model, 5 models were made up to 3 times the length of the initial specimen fabrication. In addition, the CFRP attachment width was analyzed with full width and 50% width. Table 2 shows the specifications of the analysis models, and Figure 8 shows a graph comparing the analysis results and experimental results of the 400mm span model and a graph comparing the analysis results of each analysis model.

**Table 2. Analysis model**

| ID | Clear span(mm) | Reinforcement |
|---|---|---|
| CW-400 | 400 | External reinforcement(50mm×1.4t) |
| CW-600 | 600 | External reinforcement(50mm×1.4t) |
| CW-800 | 800 | External reinforcement(50mm×1.4t) |
| CW-1000 | 1,000 | External reinforcement(50mm×1.4t) |
| CW-1200 | 1,200 | External reinforcement(50mm×1.4t) |

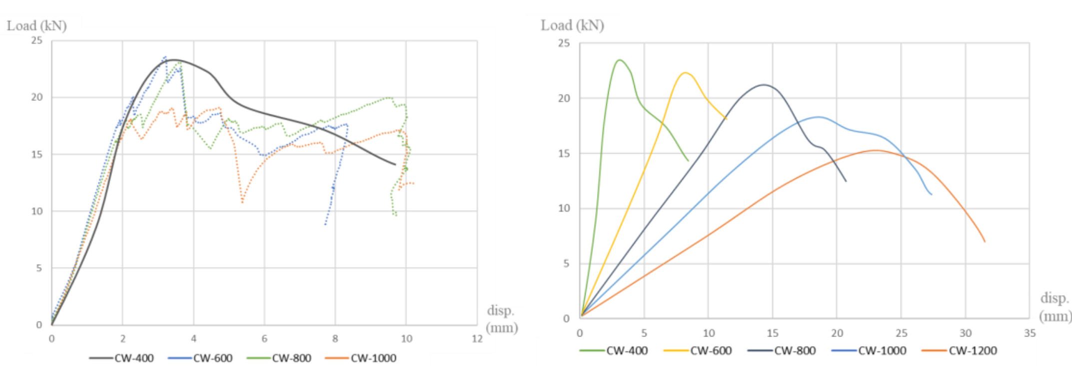


**Fig. 8.** Load-displacement curve for each model

As shown in the 400mm span analysis result in Figure 8, the stiffness and strength of the analysis model appear similar to the experimental results. In addition, the 1200mm span analysis result and the experiment result of the

CW-RE50 specimen are also similar, so the stiffness and strength of the analysis model are judged to be reliable. However, when the analysis is performed with the bonding width of the CFRP plate set to 50%, a concentrated load occurs at the center of the flange as shown in the experiment. As a result, the local destruction proceeded rapidly, and it was not possible to derive results that could compare various analysis models.

## RESULT AND DISCUSSION

The results obtained through experiments and interpretations in this study are as follows.

(1) When the CFRP plate was attached to the GFRP pipe, the stiffness increased significantly regardless of the change in length, and the strength also increased slightly.

(2) If the length is short, adhesive failure may occur more easily on the adhesive surface than member failure. The maximum load decreased as the length of the member increased, but adhesive failure did not appear conspicuously before the member was destroyed.

(3) As for the adhesive, when the epoxy anchor (HIT-RE 500 V3) was used, the adhesive failure was slightly reduced compared to when the resin (S&P Resin 220) was used, resulting in a slight increase in strength.

(4) When the adhesive width was reduced by half, the load was concentrated on the attached part, resulting in localized brittle fracture on the upper and lower surfaces. Accordingly, in the experimental results, it was found to have lower strength than the unreinforced specimen, and the analysis did not yield reliable results either.

Through the above results, it is judged that the performance can be sufficiently improved by mixing or attaching CFRP when manufacturing curtain wall frame reinforcement of GFRP material. In addition, it is judged that sufficient length should be secured when manufacturing the reinforcing material for the curtain wall frame, and it is considered important to manufacture the width of the reinforcing material to fit the entire width of the curtain wall frame.


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