Durability Evaluation of a Carbon Fiber Reinforced Member

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Summary

Shinkyo, historical wooden bridge, rebuilt in the same form as the present in 1636, repairing work using carbon fiber material was recently conducted. It is required to evaluate the durability of a carbon fiber reinforcement part from a viewpoint of maintenance management. Environmental condition such as temperature and humidity around member of the wooden bridge was measured for four months to grasp conditions of the construction site. These are used as experimental conditions for a carbon reinforced wooden member, and a constant-temperature-bath test and a heat cycle test were carried out. Using these tested members, bending performance and adhesion characteristics were analyzed. Finally, research on evaluation of the repairing method using carbon fiber reinforcement and the method of applying carbon fiber material is described.

Keywords: carbon fiber reinforced plastics, wooden bridge, durability, temperature and humidity, adhesion and bending characteristics

1. Introduction

In this paper, a refurbishment example of a historical wooden bridge using CFRP plates and CFRP sheets is firstly introduced. Then the environmental condition such as temperature and humidity of wooden girder inside of the bridge was investigated at the site. Based on the obtained result, a fundamental experiment was carried out in order to evaluate an influence of temperature and humidity on adhesion and bending characteristics of carbon fiber reinforced member. Finally, the relation between environmental condition and strength property of the wooden member was discussed.

2. Measurement of environmental temperature and humidity

The environmental condition such as temperature and humidity of wooden girder inside of the bridge was investigated at the site. Six small wireless waterproofing temperature-and-relative-humidity data loggers which can collect data on radio were installed in six points in the bridge. Measurement of the temperature and humidity at the site went for four months from June, 2007 to October.

There were few temperature and humidity differences in each measurement part, and it showed that the temperature and humidity inside a girder were being linked with the open air mostly. Thus, it turned out that the installation position of the bridge is an environmental condition very severe about especially humidity. Especially, the humidity of the girder end embedding part, No.5, was 91.1%, and was in the highest state compared with about 85% of other humidity. This measurement result can be used as the basic data of examination of the durability in the case of using reinforcement with carbon fiber outdoors.

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3. Adhesion and bending test for a carbon fiber reinforcing member

The fundamental experiment was conducted for the purpose of grasping the influence the environmental condition of temperature and humidity on the adhesion and bending strength of a carbon fiber reinforcing member. The wood for an experiment used Douglas pine. The object for an adhesion examination set 60mm in width, 60mm in height, 250mm in length, and the object for bending tests to 60mm in width, 30mm in height, and 550mm in length. A carbon fiber laminate material and cloth material were stuck on wood, and the specimen was manufactured. The lamination used board 1.5mm in thickness (Toray TL515: tensile strength 2.4kN/mm^2), and cloth used 0.167mm (Toray UT70-30: tensile strength 3.4kN/ mm^2).

Adhesion characteristics to the wood of the carbon fiber material were evaluated by measuring bond strength. As a result of the adhesion test, all environment test condition was at the same level as the bond strength of the standard condition, except underwater immersion condition. Therefore, an environmental condition wasn't so influential in these cases. Bond strength had fallen in about 1N/mm^2 than the standard case as for the underwater immersion condition of the laminate reinforcement specimen. When strength of adhesive bonding with a cloth is compared with a laminate, the cloth one tended to be slightly strong.

Most was in the state detached from base-wood as the destruction state. Bond strength to wood turned into averagely 2.0-3.0N/ mm^2, and was equivalent as the bond strength to concrete. But the significant difference by the environmental condition couldn't be grasped by this test. It's considered that an evaluation period of an environmental test isn't enough as these reasons.

In order to grasp the rigidity change by reinforcement, the flexural rigidity EI of the beam was calculated and compared using the data of the elastic region of a bending test. The following equation which indicates a relation between deformation and the load of a central point was employed as the way to find the flexural rigidity from an experiment.

As for the average value of flexural rigidity EI_0 of a non-reinforcing member, $1.20 \times 109 N \cdot mm^2$ and flexural rigidity EI_1 of the carbon fiber reinforcing member turned into $2.25 \times 109\ N \cdot mm^2$. From the experiment, it was confirmed that flexural rigidity was improving about 1.9 times by reinforcement. When the elastic modulus of the Douglas pine material used for this experiment was calculated, it was 8,900N/mm^2.

Under seven kinds of environmental states carried out this time, the flexural rigidity of the carbon fiber reinforcing member became an almost comparable value, and the big difference by an environmental condition was not seen. When EI_0 of the standard condition was compared with EI_1 after an environmental test, the rigidity ratio brought an almost equivalent result. It can be judged that there is little influence to which it's given to bending characteristics by this environmental test conditions.

4. Conclusions

In this research, the environmental conditions of outdoor use of carbon fiber reinforcing wood material have been grasped first. It became clear that reinforcing members were severe humidity conditions as a result of survey. Referring these environmental conditions, a fundamental experiment was carried out in order to evaluate an influence of temperature and humidity on the bonded part between wood and CFRP material.

In adhesion tests, bond strength to wood turned into a 2.0-3.0N/ mm^2, and was comparable as the bond strength to concrete. In bending tests, the reinforcement effect of carbon fiber material has been confirmed. However, in the range of this environmental test, the influence which it has on the adhesion and bending characteristic has not been grasped clearly. Therefore, it is required to examine the evaluation period and test method of an environmental test further from now on.

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