# 5. TEST METHOD FOR DIRECT PULL-OFF STRENGTH OF CONTINUOUS FIBER SHEETS WITH CONCRETE (JSCE-E 545-2000)

## 1. Scope

This specification describes the method used to test the direct pull-off strength of the continuous fiber sheets used for upgrading of concrete members.

## 2. Normative Reference

The following standards, by being referenced herein, form a portion of these specifications. The most recent version of each standard should be used.

| | |
|---|---|
| JSCE-E 541 | Test method for tensile properties of continuous fiber sheets |
| JIS A 5304 | Concrete flags |
| JIS A 6909 | Coating materials for textured finishes of buildings |
| JIS Z 8401 | Guide to the significant digits |

## 3. Definitions

The following are the definitions of the major terms used in this specification in addition to the terms used in the "Recommendations for Upgrading of Concrete Structures with Use of Continuous Fiber Sheets" published by the Japan Society of Civil Engineers and JSCE-E 541.

a) Steel device

Steel device connected to a loading machine to apply tensile force. Adhesive is used to mount the device to the continuous fiber sheet attached to the concrete surface. The shape of the bond surface is either square or circular.

b) Pull-out strength

The strength calculated by dividing the maximum load by the cross-sectional area of the bond surface of the steel device

# 4. Test specimens

## 4.1 Test specimen

The test specimen is a concrete board consisting of a concrete slab measuring at least 6 cm in thickness to which a continuous fiber sheet has been attached using the method described in Section 4.3.

## 4.2 Quality of concrete

The concrete slabs to be used for fabricating test specimens shall be of the same quality and strength as the members to be actually upgraded. If no such members are available, the concrete slabs established in JIS A 5304 shall be used, or concrete with ordinary aggregate having a maximum coarse aggregate diameter of 20 or 25 mm, slump $10 \pm 2$ cm, and compression strength of $30 \pm 3$ N/mm$^2$ for a material age of 28 days shall be used.

## 4.3 Preparation

### 4.3.1 Concrete surface treatment

The surface treatment performed for the concrete test specimens onto which the continuous fiber sheets are attached shall be the same as that used for the members to be actually upgraded. If the method of surface treatment is not otherwise specified, the following procedure shall be used.

a) Scour the surface of the concrete using a disc sander to remove laitance and dirt.
b) Using a rag, wipe away powder and dust from the concrete surface. If there are oils on the surface, wipe them away using acetone.
c) Coat with primer and let it harden to the point where it does not stick to the fingers when touched.
d) Coat with a smoothing agent to even out the unevenness and bubbles on the surface, then wait for it to harden until it does not stick to the fingers when touched. The surface treatment process is now complete.

### 4.3.2 Attaching the continuous fiber sheets

a) Prepare a continuous fiber sheet of a size matching the concrete slab.

b) Apply the bottom coat of impregnation resin and then attach the continuous fiber sheet and remove bubbles.
c) Apply the top coat of impregnation resin and impregnate.
d) Cure for the prescribed period of time to form the test specimen.

### 4.4 Mounting the steel devices and notching

a) As a rule, the steel device[1] shall be the type established in 6.10 "Bond strength test" in JIS A 6909.
b) Figure 1 shows the position at which the steel devices shall be mounted. As the figure shows, the positions are determined through consideration of the distance from the edge of the concrete slab and the distance between devices. Using sandpaper or the like, rough the bond surface of the steel devices and the surface of the test specimen to which the steel device will be bonded. Be careful not to damage the continuous fibers.
c) Coat the bond surface of the steel device with adhesive and attach it carefully to the test specimen. Then attach a suitable weight[2] to the steel device and let it stand.
d) After curing the adhesive, remove the weight and, using a concrete cutter, notch the area around the device.

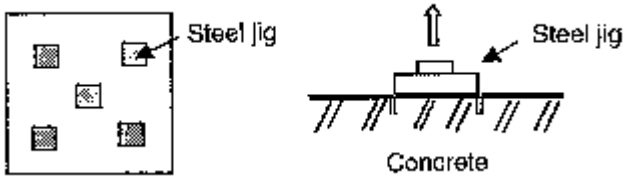


Figure 1 Mounting the steel devices on the test specimen

### 4.5 Number of test specimens

A number of test specimens suitable for the test objective shall be determined. However, there shall be no fewer than three.

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1 Use a steel device whose bonding area measures 40 x 40 mm. A device with a thickness of about 10 mm is generally used.

2 Use a weight of about 1 kg.

## 5. Testing Machine and Measuring Devices

The testing machine used for the direct pull-off strength test shall have the capacity larger than the maximum resistance of test specimens and shall have an indicator that enables the maximum load to be measured.

## 6. Test Method

### 6.1 Setting the testing machine

The steel devices shall be set so that the force is applied normal to the concrete surface.

### 6.2 Loading rate

The standard loading rate shall be a fixed rate equivalent to 5-10 kN per minute.

### 6.3 Test temperature

The test temperature shall be 20 ±5°C. However, if the test specimen is not sensitive to changes in temperature, the test may be conducted at a temperature of 5-35°C. When the specimen is to be used under special work conditions or in special environments, these shall be taken into consideration when determining the test temperature.

### 6.4 Scope of test

The test shall be performed until the steel devices come apart from the concrete slab.

## 7. Calculation and Expression of Test Results

### 7.1 Handling of data

When the steel devices have come apart from the continuous fiber sheets in the bonded portion, the data shall be disregarded and additional tests shall be performed, with steel devices mounted in advance in different locations, until the prescribed number of test specimens is obtained.

### 7.2 Bond strength

The bond strength $f_{au}$ shall be calculated using Eq. (1) and rounded off to three significant digits in accordance with JIS Z 8401.

$$f_{au} = \frac{F_{au}}{A_s} \quad \text{.....(1)}$$

where

$f_{au}$ : Bond strength (N/mm$^2$)
$F_{au}$ : Maximum load (N)
$A_s$ : Area of steel device (mm$^2$)

### 7.3 Failure categories

Table 1 shows the categories for the failure of test speciments.

If the failure occurred in the concrete and the steel device came apart having a piece of concrete with it, this indicates a concrete fracture. If the failure occurred in the interface between the concrete surface and the primer, or the primer and the smoothing agent, or the smoothing agent and the continuous fiber sheet, this indicates an interfacial fracture. If the failure occurred within the continuous fiber sheet or between the layers of the continuous fiber sheet, this is categorized as a "fracture between layers of continuous fiber sheet."

Table 1 Categories for the failure of test specimens

| Code | Type of failure |
|---|---|
| MF | Concrete fracture |
| IF | Interfacial fracture |
| SF | Fracture between layers of continuous fiber sheet |

## 8. Report

The report shall include the following items:

a) Name of continuous fiber sheet

b) Type of continuous fiber sheet, primer, smoothing agent and impregnation resin
c) Fiber mass per unit area and density of continuous fiber sheet
d) Number of plies of continuous fiber sheet
e) Concrete mixture, slump and compression strength at testing
f) Fabrication date and fabrication method for test specimens
g) Test date, test temperature and loading rate
h) Shape, dimensions and calculated cross-sectional area of the steel device at each test location
i) Tensile capacity at each test location and average of these values
j) Maximum bond strength at each test location and average of these values
k) Failure type at each test location
l) Other special notations

# COMMENTARY ON TEST METHOD FOR DIRECT PULL-OFF STRENGTH OF CONTINUOUS FIBER SHEETS WITH CONCRETE

## Introduction

This test method specifies the direct pull-off strength of the continuous fiber sheets used to upgrade concrete members. It is mainly done for quality control during construction and primarily by referring to JIS A 6909 "Coating materials for textured finishes of buildings."

## 1. Scope

## 2. Normative Reference

## 3. Definitions

Steel devices are also referred to as bonding terminals or attachments.

## 4. Test specimens

### 4.1

In general, the concrete slabs used in this test method may be concrete slabs for pavement, measuring 30 cm square and a thickness of 6 cm. However, it is also possible to use an actual portion of a concrete member.

### 4.3

There should be one ply of continuous fiber sheet. However, the test may also be conducted with a test specimen having a couple of plies actually used for upgrading. In such cases, it should be noted in the report.

**4.4**

JIS A 6909 "Coating materials for textured finishes of buildings" specifies a steel device with a rectangular cross-section in which each side measures 4 cm. However, one with a circular cross-section may also be used if the cross-sectional area is approximately the same. Test results with a small cross-sectional area of steel devices involve the intensive influences of the notched end, which may reduce the bond strength or change failure mode. Accordingly, as a rule such devices should not be used for the direct pull-off test of continuous fiber sheets with concrete.

The adhesive used to bond the steel device must be one with the prescribed properties; in general, an epoxy resin adhesive should be used. In order to prevent air intrusion between the steel device and the surface of the continuous fiber sheet at attaching the device, coat with adhesive until the adhesive comes out from the end when the steel device is pressed against the surface.

The depth of the notch around the steel device should be about 10 mm from the surface of the concrete slab.

## 5. Testing Machine and Measuring Devices

In general, when this method is used for quality control at the work site, a portable hydraulic jack is used. In such cases, the capacity of the jack should be at least 20% greater than the expected maximum load of test specimens.

## 6. Test Method

**6.1**

If the force is not applied normal to the test specimen due to unevenness in the surface of the concrete slab, the ultimate strength may be reduced. In such cases, it is important to adjust the position of the jack normal to the test specimen by inserting a thin plate between the base of the reaction frame and the concrete slab.

**6.3**

When using this method for quality control during construction, the test may be performed under actual environmental temperature conditions. Particularly when the temperature is low, it takes a long time for the steel devices to become firmly bonded. Therefore, care must be taken with adhesive selection and curing time.

## 7. Calculation and Expression of Test Results

**7.3**

There are three types of interfacial fracture (IF): those occurring in the interface between the concrete and primer, between the primer and smoothing agent, and between the smoothing agent and the continuous fiber sheet. In such cases, observe the fracture surface carefully and distinguish the failure mode by observing the color of the primer, the color of the smoothing agent and the color of the impregnation resin, and note this judgment in the report. If it is impossible to determine the fractured interface, note this in the report.

When a couple of failure mode are observed, report the failure mode which covers the widest area and include a note summarizing the proportional area of each failure mode.

## 8. Report

When the concrete slab established in JIS A 5304 "Concrete flags" is used, this should be noted, and the concrete mixture, slump and compressive strength at testing be omitted.