

4. TEST METHOD FOR BOND STRENGTH OF CONTINUOUS FIBER SHEETS TO STEEL PLATE (JSCE-E544-2000)

1. Scope

This specification describes the method used to test the bond properties to steel plate 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
- JSCE-E 542 Test method for overlap splice strength of continuous fiber sheets
- JIS K 7100 Plastics-standard atmospheres for conditioning and testing
- JIS B 7721 Verification of the force measuring system of the tensile testing machine
- 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, JSCE-E 541 and JSCE-E 542.

a) **Bond strength**

The strength calculated by dividing the maximum load at the peeling failure of the continuous fiber sheet by the bonded area of the continuous fiber sheet to the steel plate.

b) Bonded portion

The portion of the test specimen used to test the bond strength of continuous fiber sheets to steel plate.

4. Test Specimens

4.1 Types and dimensions

There may be four types of test specimens: two Type I test specimens (I-A and I-B) and two Type II test specimens (II-A and II-B).

a) Type I test specimen

Type I test specimens are prepared using the methods prescribed in Section 4.2.1 or Section 4.2.2. These test specimens are used when the steel plate is bonded at the same time that the continuous fiber sheets are impregnated. The shape and dimensions of Type I test specimens are shown in Figure 1 and Table 1, respectively.

b) Type II test specimen

Type II test specimens are prepared using the methods prescribed in Section 4.2.3 or Section 4.2.4. These test specimens are used when the steel plate is bonded after the continuous fiber sheets are impregnated and have hardened. The shape and dimensions of Type II test specimens are the same as those for Type I as shown in Figure 1 and Table 1.

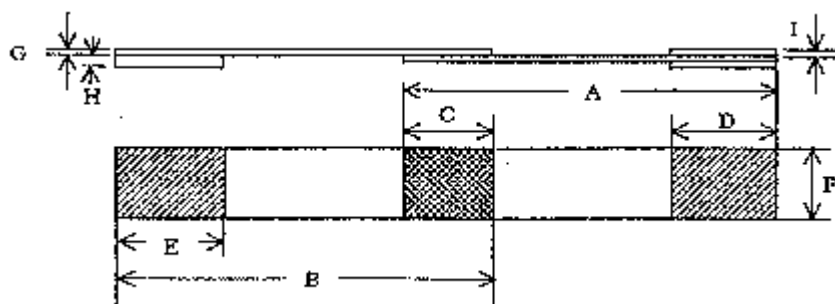


Figure 1 Shape and dimensions of test specimens used to test bond strength of continuous fiber sheets to steel plate

Table 1 Test specimen dimensions (Type I and Type II) (unit: mm)

Type of test specimen	Type A	Type B
A Length of continuous fiber sheets	= 200	
B Length of steel plate	= 200	
C Length of bonded portion	Necessary length	
D Length of anchorage for continuous fiber sheets	= 50	
E Length of steel plate anchorage	= 50	
F Width of test specimen	12.5 ±0.5	10-15
G Thickness of steel plate	Necessary thickness	
H Thickness of steel plate anchorage	= 1 (thickness needed to be parallel with the outer surface of the continuous fiber sheet anchorage)	
I Thickness of continuous fiber sheet anchorage	= 1 (thickness needed to be parallel with the outer surface of the steel plate anchorage)	

4.2 Preparation

4.2.1 Type I-A test specimen

Type I-A test specimens are prepared using the following method.

- a) Line up spacers with the same thickness as the steel plate on the same surface as the steel plate of the prescribed width. Apply separation film to the spacer portion only.
- b) Secure the prescribed anchorage length and then coat the steel plate portion and the spacers, to which separation film has been applied, with impregnation resin for continuous fiber sheets.
- c) Apply the continuous fiber sheet and impregnate.
- d) Apply the top coat of impregnation resin and remove the bubbles.
- e) Cure for the prescribed period of time.
- f) Cut the continuous fiber sheet portion to 12.5 mm.
- g) Attach the anchorages to the steel plate and the continuous fiber sheet anchorage portions.

4.2.2 Type I-B test specimen

Type I-B test specimens are prepared using the following method.

- a) Prepare a continuous fiber sheet cut to a sufficient length for the dimensions of the test specimen. Fasten the sheet so that the fiber axis is in a straight line.
- b) Remove 1-3 fiber bundles from each side of the test specimens having the width of 10-15 mm. When preparing several test specimens from the same continuous fiber sheet, the portions to be used as test specimens should be separated by intervals of at least 50 mm in the direction perpendicular to the fiber axis.
- c) Line up spacers with the same thickness as the steel plate on the same surface as the steel plate of the prescribed width. Apply separation film to the spacer section only.
- d) Secure the prescribed anchorage length and then coat the steel plate section and the spacer, to which separation film has been applied, with impregnation resin for continuous fiber sheets.
- e) Apply the aforementioned continuous fiber sheet, from which the fiber bundles have been removed, and impregnate.
- f) Apply the top coat of impregnation resin and remove the bubbles.
- g) Cure for the prescribed period of time.
- h) Remove the portion of the continuous fiber sheet from which the fiber bundles have been removed and cut to the prescribed width.
- i) Attach the anchorages to the steel plate and the continuous fiber sheet anchorage portions.

4.2.3 Type II-A test specimen

Type II-A test specimens are prepared using the following method.

- a) Prepare a continuous fiber sheet cut to a sufficient length for the dimensions of the test specimen.
- b) Apply the bottom coat of impregnation resin to the separation film and fasten the aforementioned sheet so that the fibers are in a straight line.
- c) Apply the top coat of impregnation resin and remove the bubbles.
- d) After curing the test specimen for the prescribed period of time, cut it to a width of 12.5 mm. The cut length should be at least 200 mm.
- e) Coat the prescribed bond length of the continuous fiber sheet test specimen with adhesive and attach a steel plate with the prescribed dimensions.

- f) After curing the adhesive for the prescribed period of time, attach the anchorages to the steel plate to continuous fiber sheet anchorage portions.

4.2.4 Type II-B test specimen

Type II-B test specimens are prepared using the following method.

- a) Prepare a continuous fiber sheet cut to a sufficient length for the dimensions of the test specimen. Fasten the sheet so that the fiber axis is in a straight line.
- b) Along the fiber axis, remove 1-3 fiber bundles from each side of the test specimens having the width of 10-15 mm. When preparing several test specimens from the same continuous fiber sheet, the portions should be separated by intervals of at least 50 mm in the direction perpendicular to the fiber axis.
- c) Apply the bottom coat of impregnation resin to the separation film and attach the sheet on top.
- d) Apply the top coat of impregnation resin and remove bubbles. Covering with separation film and smoothing would be best to ensure that the thickness of the impregnation resin is even.
- e) After curing the test specimen for the prescribed period of time, cut it to a width of 10-15 mm. The cut length should be at least 200 mm.
- f) Prepare a steel plate of the same width as the cut continuous fiber sheet.
- g) Coat the prescribed bond length of the cut continuous fiber sheet test specimen with adhesive and attach the steel plate.
- h) After curing the adhesive for the prescribed period of time, attach the anchorages to the steel plate to continuous fiber sheet anchorage portions.

4.3 Anchorage portion of test specimen

Anchorage portion of test specimen

The anchorage portion of the test specimen shall not be of a shape that will cause the test specimen to twist or bend. Adhesive shall be used to attach an anchorage made of fiber-reinforced plastic or aluminum to the anchorage portion of the continuous fiber sheet, and to fasten an anchorage of the same type of steel to the steel plate anchorage. A suitable adhesive shall be selected so as to ensure that the adhesive layer will not experience shear fracture before the failure of test specimen.

4.4 Conditioning the test specimen

Test specimens shall be conditioned for at least 48 hours before testing in a Class 2 standard atmosphere (temperature $23 \pm 2^{\circ}\text{C}$ and humidity $50 \pm 10\%$) as described in JIS K 7100.

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 five .

5. Testing Machine and Measuring Devices

The testing machine used for bond properties shall conform to JIS B 7721 and shall be capable of applying the maximum load for the test specimen at the prescribed loading rate.

6. Test Method

6.1 Dimensions of test specimen

The length of the bonded portion of the test specimen shall be measured to an accuracy of 0.1 mm in two locations at each side, and the average of these values shall be the length of the bonded portion. The width shall be measured in three locations (at the end of the continuous fiber sheet in the bonded portion, at the end of the steel plate, and in the center) and the average of these values shall be the width of the bonded portion.

6.2 Mounting the test specimen

The test specimen shall be mounted so that the continuous fiber sheet portion and steel plate portion of the test specimen are parallel to the center line between the two chucks of the testing machine.

6.3 Loading rate

The standard loading rate shall be a fixed strain rate equivalent to 1-10 mm elongation deformation per minute.

6.4 Test temperature

The test temperature shall be $20 \pm 5^\circ\text{C}$. However, if the test specimen is not sensitive to changes in temperature, the test may be conducted at a temperature of $5-35^\circ\text{C}$. 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.

7. Calculation and Expression of Test Results

7.1 Handling of data

The test data shall be assessed on the basis only of test specimens whose failure occurred in the bonded portion and classified as one of the failure categories in Section 7.3. In cases where failure or slippage has clearly taken place at the anchorage portion, the data shall be disregarded and additional tests shall be performed using test specimens from the same lot until the number of test specimens experiencing failure in the test portion is not less than the prescribed number.

7.2 Bond strength

The bond strength \bar{t}_{su} shall be calculated using Eq. (1) and rounded off to three significant digits in accordance with JIS Z 8401.

$$\bar{t}_{su} = \frac{P_u}{l \cdot b} \dots\dots\dots(1)$$

where

- \bar{t}_{su} : Bond strength (N/mm²)
- P_u : Maximum load (N)
- l : Length of bonded portion (mm)
- b : Width of bonded portion (mm)

7.3 Failure categories

Table 2 shows the categories for the failure of test specimens.

The determination of mode of failure is as follows: if there are continuous fibers remaining on the steel plate, it indicates a sheet failure. If the steel plate surface is exposed in its surface-treated condition, it indicates an adhesive failure. If the adhesive layer has fractured, this indicates a cohesive failure.

Table 2 Categories of failure

Code	Type of failure
BF	Adhesive failure
RF	Cohesive failure
SF	Sheet failure

Reference: Steel plates are subjected to rustproofing and other treatment. When this layer fails, it should be categorized as an adhesive failure, but it should be clearly noted that the failure occurred in the rustproofing section.

When more than one mode of failure is applicable, select the mode where the failure occurred over the widest area and include a note summarizing the proportional area applicable to each mode of failure.

8. Report

The report shall include the following items:

- a) Name of continuous fiber sheet
- b) Type of continuous fiber sheet and impregnation resin
- c) Fiber mass per unit area and density of continuous fiber sheet
- d) Type, thickness and surface processing method for bonded materials
- e) Fabrication date, fabrication method and curing period for test specimens
- f) Temperature, humidity and duration of test specimen conditioning
- g) Test date, test temperature and loading rate

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- h) Shape and dimensions of each test specimen and calculated cross-sectional area
- i) Tensile capacity of each test specimen and average and standard deviation of these values
- j) Maximum bond strength of each test specimen and average and standard deviation of these values
- k) Failure type of each test specimen
- l) Other special notations

COMMENTARY ON TEST METHOD FOR BOND STRENGTH OF CONTINUOUS FIBER SHEETS TO STEEL PLATE

Introduction

This test method is used to calculate the bond length between continuous fiber sheets and steel plate in such situations as when the end of a continuous fiber sheet is anchored via a steel plate. In establishing this test method, reference was made to JIS K 6850 "Test method for tensile shearing adhesive strength of adhesives" and JIS K 6848 "Test method for shearing adhesive strength of adhesives."

- 1. Scope**
- 2. Normative Reference**
- 3. Definitions**
- 4. Test specimens**

4.1

The continuous fiber sheets and adhesives should be the same as the actual materials to be used, and the continuous fiber sheet to steel plate should be bonded using the same procedure as the one used under actual work conditions. Use the Type I test specimen when impregnating the continuous fiber sheet with impregnation resin on the steel plate to bond the continuous fiber sheet and steel plate at the site. Use the Type II test specimen when work at the site involves using adhesive to bond the steel plate to the continuous fiber sheet after the impregnation resin has hardened. The specifications for the use of Type A or Type B test specimens should conform to JSCE-E 541 and JSCE-E 542.

4.2

When the test specimen is fabricated by impregnating the continuous fiber sheet with impregnation resin and bonding it to the steel plate, the linearity of the fibers in the continuous fiber sheet must be ensured. Use spacers, etc. to which separation

film has been applied and which has the same thickness as the steel plate and perform the work carefully. If members for which the process will actually be performed are not available, use a steel plate with a thickness appropriate for the strength and estimated bond strength of the continuous fiber sheet.

4.3

Anchorage must be attached to the anchorage portions on both sides of the continuous fiber sheet for protection. To prevent eccentricity from being applied during the tensile strength test, adjust the thicknesses of the anchorages and supports to make sure that the anchorage on one side is flush with the surface of the steel plate and the anchorage on the other side is flush with the support for the steel plate, as shown in Figure C1.

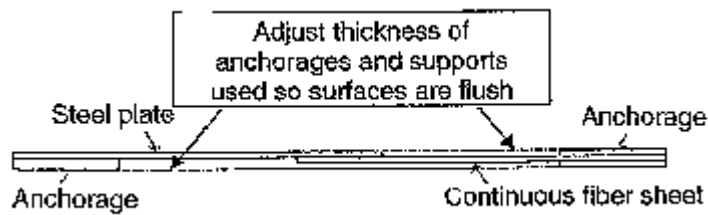


Figure C1 Side view of test specimen

5. Testing Machine and Measuring Devices

6. Test Method

When the test specimen is mounted on the testing machine, it must be parallel to the direction of applied force.

7. Calculation and Expression of Test Results

8. Report