9. TEST METHOD FOR WATER, ACID AND ALKALI RESISTANCE OF CONTINUOUS FIBER SHEETS (JSCE-E 549-2000)

1. Scope

This specification describes the method used to test the water, acid and alkali resistance 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
JSCE-E 543 Test method for bond properties of continuous fiber sheets to concrete
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, JSCE-E 542 and JSCE-E 543.

a) Strength retention

The ratio of the strength (tensile strength, overlap splice strength and bond strength) after immersion divided by the strength before immersion, expressed as a percentage of one hundred (%)

b) Change in mass

The difference of mass before and after immersion, expressed as a percentage of one hundred (%)

4. Test specimens

4.1 Types and dimensions

The test specimens to match the test objectives shall be chosen among the following three types.

a) Type A or Type B test specimen established in JSCE-E 541
b) Type A or Type B test specimen established in JSCE-E 542
c) Test specimen established in JSCE-E 543

The test specimens for both the tensile strength test and the overlap splice strength test may be immersed in plate form. After immersion, the test specimens shall be cut from the plate and provided for each of the tests.

4.2 Preparation

The preparation of test specimens shall comply with the methods of preparation in each of the test methods. The edges of each of the test specimens shall be protected, and appropriate protection work shall be performed for the concrete block test specimen established in JSCE-E 543 to prevent the concrete components from being washed away in the immersion fluid.

4.3 Number of test specimens

A number of test specimens suitable for the test objective shall be determined. However, in each of the tests, there shall be no fewer than five test specimens for before and after immersion.

5. Testing Machine and Measuring Devices

5.1 Immersion container

The immersion container shall be a glass tank or other suitable container of a sufficient size to contain immersion fluid and to accommodate the test plates for immersion. The immersion container shall have a cover which is not impaired by the immersion fluid.

5.2 Constant-temperature unit

The constant-temperature unit shall maintain the prescribed temperature to an accuracy of within ±2°C.

5.3 Tensile strength test and overlap splice strength test

These tests shall comply with JSCE-E 541 and JSCE-E 542.

5.4 Bond strength test

This test shall comply with JSCE-E 543.

6. Test Method

6.1 Types of test fluid

Table 1 shows the standard types of test fluid that shall be used for immersion.

Table 1 Test fluid used for immersion

Test	Type of immersion fluid
Water resistance test	Distilled water
Acid resistance test	10% sulfuric acid solution (pH 1)
Alkali resistance test	10% sodium hydroxide solution (pH 14)

6.2 Immersion temperature

The immersion temperature shall be 20 ±5°C.

6.3 Immersion period

The standard immersion period shall be 60 days.

6.4 Immersion of test specimens

Each of the test specimens shall be immersed completely in the solution or water. Care must be taken to ensure that the water in the solution does not evaporate and that carbon dioxide in the air is not absorbed during immersion.

6.5 Procedure after immersion

After acid or alkali immersion, the test specimens shall be rinsed with water.

6.6 Tensile strength test and overlap splice strength test

These tests shall comply with JSCE-E 541 and JSCE-E 542.

6.7 Bond strength test

This test shall comply with JSCE-E 543.

7. Calculation and Expression of Test Results

7.1 Concentration of acid and alkali solution before and after test

In the acid and alkali resistance tests, the pH level of the acid and alkali solutions shall be measured before the beginning and after the end of immersion and the figures noted in the report.

7.2 Visual inspection

The test specimens shall be visually inspected before and after immersion and compared in terms of color, surface condition and change in shape. If necessary, the test specimen shall be cut and ground and its cross-section observed with a microscope.

7.3 Handling of tensile strength test data

In the tensile strength and overlap splice strength tests, the test data shall be assessed on the basis only of test specimens undergoing failure in the test portion.

7.4 Change in mass

The change in mass α for the tensile strength and overlap splice strength test specimens shall be calculated using Eq. (1) and rounded off to two significant digits in accordance with JIS Z 8401. However, both types of test specimen shall be dried and their mass measured until their weight is constant.

$$\alpha = \frac{w_0 - w_e}{w_0} \times 100 \quad \text{..... (1)}$$

where

α : Change in mass (%)

w_0 : Mass before immersion (g)

w_e : Mass after immersion (g)

7.5 Strength retention

The tensile strength retention, overlap splice strength retention and bond strength retention shall be calculated using Eq. (2), (3) and (4), respectively, and rounded off to two significant digits in accordance with JIS Z 8401.

7.5.1 Tensile strength retention

$$R_{ett} = \frac{\bar{f}_{fue}}{\bar{f}_{fu0}} \times 100 \quad \text{..... (2)}$$

where

R_{ett} : Tensile strength retention (%)

$\bar{f}_{fu0}$: Average value for tensile strength before immersion (N/mm^2)

$\bar{f}_{fue}$: Average value for tensile strength after immersion (N/mm^2)

7.5.2 Overlap splice strength retention

$$R_{ets} = \frac{\bar{f}_{fuse}}{\bar{f}_{fus0}} \times 100 \quad \text{..... (3)}$$

where

R_{ets} : Overlap splice strength retention (%)

$\bar{f}_{fus0}$: Average value for overlap splice strength before immersion (N/mm^2)

$\bar{f}_{fuse}$: Average value for overlap splice strength after immersion (N/mm^2)

7.5.3 Bond strength retention

$$R_{etb} = \frac{\bar{\bar{\tau}}_{ue}}{\bar{\bar{\tau}}_{u0}} \times 100 \quad \text{..... (4)}$$

where

R_{etb} : Bond strength retention (%)

$\bar{\bar{\tau}}_{u0}$: Average value for bond strength before immersion (N/mm^2)

$\bar{\bar{\tau}}_{ue}$: Average value for bond strength after immersion (N/mm^2)

Note: In each case, the width of the continuous fiber sheets is measured before immersion. Also, the same value should be used for effective bond strength before and after immersion.

8. Report

The report shall include the following items:

a) Common items
   (1) Name of continuous fiber sheet
   (2) Type of continuous fiber sheet and impregnation resin
   (3) Fiber mass per unit area and density of continuous fiber sheet
   (4) Identification of test specimen
b) Items relating to immersion in water, acid or alkali solution
   (1) Content, pH level and temperature of acid or alkali solution
   (2) Dates of starting and ending of immersion
   (3) Observation records for visual inspections and change in mass (%)
c) Items relating to tensile strength test
   (1) Fabrication date, fabrication method and curing period for test specimens
   (2) Temperature, humidity and duration of test specimen conditioning
   (3) Test date, test temperature and loading rate
   (4) Shape, dimensions and calculated cross-sectional area for each test specimen (immersed / not immersed)
   (5) Tensile capacity of each test specimen (immersed / not immersed) and average for these values
   (6) Maximum tensile strength of each test specimen (immersed / not immersed) and average for these values

(7) Young's modulus of each test specimen (immersed / not immersed) and average for these values
(8) Ultimate strain of each test specimen and average for these values
(9) Load-strain curve for each test specimen
(10) Tensile strength retention

d) Items relating to overlap splice strength test
(1) Fabrication date, fabrication method and curing period for test specimens
(2) Temperature, humidity and duration of test specimen conditioning
(3) Test date, test temperature and loading rate
(4) Shape, dimensions and calculated cross-sectional area for each test specimen (immersed / not immersed)
(5) Tensile capacity of each test specimen (immersed / not immersed)
(6) Maximum tensile strength of each test specimen (immersed / not immersed) and average for these values
(7) Mode of failure for each test specimen
(8) Overlap splice strength retention

e) Items relating to bond strength test
(1) Fabrication date, fabrication method and curing period for test specimens
(2) Temperature, humidity and duration of test specimen conditioning
(3) Test date, test temperature and loading rate
(4) Dimensions of each test specimen (immersed / not immersed), average values for width and length of continuous fiber sheet before immersion, and number of plies
(5) Concrete mixture, slump and compressive strength testing
(6) Tensile capacity of each test specimen (immersed / not immersed)
(7) Bond strength of each test specimen (immersed / not immersed) and average for these values
(8) Mode of failure for each test specimen
(9) Bond strength retention

COMMENTARY ON TEST METHOD FOR WATER, ACID AND ALKALI RESISTANCE OF CONTINUOUS FIBER SHEETS

Introduction

JSCE-E 538 "Test method for alkali resistance of continuous fiber reinforcing materials" is the only test method shown for the chemical resistance of continuous fiber reinforcing materials. This test method is established because continuous fiber reinforcing materials comprise mainly bars, and in most cases these are embedded in concrete and so alkali resistance is the most important aspect of durability.

The continuous fiber sheets dealt with here, on the other hand, are mainly attached to the surface of existing concrete members for upgrading. Therefore, in addition to alkali resistance presumed necessary due to contact with the concrete, it is also necessary to show test methods for water resistance presumed necessary due to leakage of water from cracks in the concrete and acid resistance through consideration of their application in sewer facilities.

Each of these three types of test methods has a different objective. However, the test results are organized together since they are similar in many aspects.

In the preparation of these test methods, reference is made to JIS K 7114 "Testing method for evaluation of the resistance of plastics to chemical substances" and JIS K 7070 "Test method for chemical resistance of fiber reinforced plastic."

1. Scope

2. Normative Reference

3. Definitions

4. Test specimens

4.1

Three types of test specimens are established for use in each of the tests. The tensile strength, overlap splice strength and bond strength test specimens should conform to JSCE-E 541, JSCE-E 542 and JSCE-E 543, respectively.

4.2

In the tensile strength and overlap splice strength test methods, the solution may seep into the test specimen from the edges, reducing the strength of the continuous fiber sheet. Therefore, impregnation resin or the like is used to seal the test specimen completely and prevent the solution from seeping in from the edges. Due to concern that the concrete components of the test specimen for the bond strength test may dissolve into the immersion solution, the entire surface of the concrete is protected in the same manner.

5. Testing Machine and Measuring Devices

5.1

Care must be taken to ensure that the test specimens in the immersion container do not come in contact with one another or with the container. The test specimens must be immersed at all times.

6. Test Method

6.1

The test solutions given as examples in JIS K 7114 should be used. The standard solutions should be distilled water for the water resistance test; a 10% sulfuric acid solution (equivalent to pH 1) for the acid resistance test, and a 10% sodium hydroxide solution (equivalent to pH 14) for the alkali resistance test.

The concentrations for the solutions conform to the sheet lining method, which has the highest concentrations among the quality test methods for anticorrosion covering layers indicated in the quality standard in the Recommendations for Corrosion Protection of Concrete.

When the purpose of use for the continuous fiber sheets differs from that of the test method, test solution types and concentrations other than these test solutions must be determined.

During long-term immersion testing, there is a possibility of water in the solution evaporating or absorbing carbon dioxide from the air, resulting in changes in the composition and pH level of the test solution or in sedimentation. Therefore, the immersion test should be conducted in a container that can be sealed from the outside air.

6.2

When chemical resistance is required, alkali resistance tests of continuous fiber reinforcing materials are often conducted at a temperature of 60°C since these materials are embedded in new concrete. This method, on the other hand, is intended primarily for waterworks and sewer facilities where the environment is thought to be at an almost constant temperature. Accordingly, reference is made to Class 2 standard atmosphere and the test temperature in JIS K 7114, and, as a rule, the immersion temperature is set to 20 ±5°C. However, when the environment is different, a temperature different from the one in this test method must be determined.

6.3

In the same manner, the immersion period conforms to 60 days, which is the maximum period for acid and alkali resistance tests indicated in the anticorrosion covering method noted in the Recommendations for Corrosion Protection of Concrete. However, depending on use conditions, the immersion period may be set anywhere between seven days and approximately one year. For longer immersion periods, sampling tests should be conducted during immersion.

7. Calculation and Expression of Test Results

7.2

Elution of the fiber bond into the acid or alkaline solution may cause changes in the surface condition, color or shape of the continuous fiber sheet. Accordingly, a visual comparison of the continuous fiber sheets before and after immersion is required. If a more detailed inspection is needed, the sides and ground sections of the test specimen should be inspected using an optical or electron microscope, and the test specimen should also be subjected to physical and chemical analysis if necessary.

7.4

The test specimens should be rinsed thoroughly to remove any acid or alkali adhering to the surface after immersion in acid or alkali solution, then dried until their mass is constant. Drying should preferably be carried out in a short time while avoiding thermal degradation of the test specimen by drying in a vacuum at no more than 60°C. After drying, the test specimens should be left in a constant-temperature, constant-humidity environment for 24 hours and then weighed to an accuracy of 0.1 g. Naturally, the mass and length of the test specimens must also be measured prior to immersion using the same procedure.

8. Report

Reference test methods :

The test method depends greatly on the skill of the test personnel. Methods that are almost identical to the methods indicated in other standards are not taken up in the test methods in the codes and specifications of the Japan Society of Civil Engineers. However, the following two test methods are sometimes needed in actual practice, so that they are presented here as reference test methods.