

6. TEST METHOD FOR TENSILE FATIGUE STRENGTH OF CONTINUOUS FIBER SHEETS (JSCE-E 546-2000)

1. Scope

This specification describes the method used to test the tensile fatigue 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 K 7083 Testing method for constant-load amplitude tension-tension fatigue of carbon fibre reinforced plastics
- 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) Repeated load
Load that fluctuates periodically within a set load range
- b) Maximum repeated load (P_{\max})
Maximum value for repeated load
- c) Minimum repeated load (P_{\min})
Minimum value for repeated load
- d) Load amplitude (DP)
Difference between the maximum repeated load (P_{\max}) and the minimum repeated load (P_{\min})

e) Average load (P_{mean})

Average of the maximum repeated load (P_{max}) and the minimum repeated load (P_{min})

4. Test specimens

4.1 Test specimens

The test specimens used in this test shall be the Type A and Type B test specimens established in JSCE-E 541.

4.2 Number of test specimens

A number of test specimens suitable for the test objective shall be determined. However, in order to draw the $S-N$ curve, there shall be at least three test specimens for each of the three stress levels.

5. Testing Machine and Measuring Devices

5.1 Testing machine

The testing machine used for tensile fatigue strength tests must be capable of holding the maximum and minimum repeated load and load amplitude at a constant level with the required repetition frequency.

5.2 Strain gauges

The strain gauges shall be capable of recording variations during test with an accuracy of not less than 10×10^{-6} .

6. Test Method

6.1 Dimensions of test specimens

The dimensions shall be those established in JSCE-E 541.

6.2 Setting the strain gauges

The strain gauges shall be mounted as established in JSCE-E 541.

6.3 Mounting the test specimens

The jaw block shall be one that does not break the anchorage of the test specimen during the test, and that can hold the test specimen with a constant clamping pressure, and on which the clamping pressure can be adjusted. When setting the test specimen to the testing machine, make sure that the longer axis of the test specimen coincides with the loading axis.

6.4 Setting the load

Regarding the load amplitude, a suitable value for the minimum repeated load shall be determined that matches the objective of the test. However, when drawing the *S-N* curve, at least three levels shall be set so that the number of repetitions before failure is distributed between 10^3 and 2×10^6 .

6.5 Loading rate

The standard repetition frequency is 2-10 Hz, and the standard waveform is a sine wave.

6.6 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 an actual member to be upgraded is available, the work conditions or use environments for this member may be taken into consideration for determining the test temperature.

6.7 Starting the test

After increasing the load up to the average load statically, load repetition shall be commenced enlarging the load amplitude up to the prescribed load, rapidly but without any shock. The maximum and minimum repeated loads shall remain constant for the duration of the test. Counting of the number of repetitions shall begin from the point at which the load on the test specimen reaches the prescribed load.

6.8 Ending the test

The test shall be continued until failure, and the number of repetitions up to failure shall be recorded. Unless otherwise specified, the test may be ended after the repetitions of 2×10^6 .

6.9 Pausing the test

As a rule, the test should not be paused from the start to the end. If the test must be interrupted due to unavoidable circumstances, the number of repetitions before the pause and the paused period shall be recorded.

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 undergoing failure in the test portion and specimens taking the prescribed number of repetitions. In cases where tensile failure or slippage has clearly taken place at the anchorage portion, the data shall be disregarded and additional specimens shall be tested until the number of test specimens failing in the test portion exceeds the prescribed number.

7.2 *S-N* curve

The *S-N* curve shows the relationship between the maximum repeated stress, the stress range or the stress amplitude and the number of repetitions. When some test results come at the same point in the *S-N* diagram, the number of data shall be noted. Right-facing arrows shall be used to indicate that the test specimen did not fracture at that number of repetitions.

7.3 Fatigue strength after 2 million repetitions

The fatigue strength after 2×10^6 repetitions shall be derived from the *S-N* curve. Fatigue strength values shall be rounded off to three significant digits in accordance with JIS Z 8401.

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) Fabrication date, fabrication method, curing period and conditioning temperature / humidity for test specimens
- e) Test date, test temperature and humidity (from start to end of test)
- f) Shape, dimensions and calculated cross-sectional area for each test specimen
- g) Type of testing and recording machine (notations regarding the method of load [stress] amplitude control, etc.)
- h) Maximum load (stress), minimum load (stress), load (stress) range, number of repetitions until failure, and repetition frequency for each test specimen
- i) Records of observation of the type of failure for each test specimen
- j) *S-N* curve

COMMENTARY ON TEST METHOD FOR TENSILE FATIGUE STRENGTH OF CONTINUOUS FIBER SHEETS

Introduction

This test method may be used when the fatigue strength must be confirmed for the use of continuous fiber sheets in concrete structures subject to repeated loads by running vehicles or high surf. This is prepared by referring to JIS K 7083 "Testing method for constant-load amplitude tension-tension fatigue of carbon fiber reinforced plastics" and JSCE-E 535 "Test method for tensile fatigue strength of continuous fiber reinforcing materials" published by the Japan Society of Civil Engineers.

To confirm the fatigue strength of continuous fiber sheets used to upgrade concrete structures, it would be ideal to perform the test on concrete members to which continuous fiber sheets are attached. However, as concrete members may require a large-scale test, the fatigue strength test on continuous fiber sheet itself is established to make the test comparatively easy to perform.

1. Scope

There are many methods for examining the fatigue strength, including the loading types of tension-tension, tension-compression, and compression-compression. In this specification, a tension-tension fatigue strength test under constant cyclic loading is adopted as the most basic method of evaluating material characteristics.

2. Normative Reference

3. Definitions

In addition to the terms used in the "Recommendations for Upgrading of Concrete Structures with Use of Continuous Fiber Sheets" and JSCE-E 541, JIS K 7083 "Testing method for constant-load amplitude tension-tension fatigue of carbon fibre reinforced plastics" is also used as a reference for the definitions of terms.

a)-e)

These definitions refer to loads but the word "stress" may be used in place of "load."

4. Test specimens

4.1

Except for the repetition of load, the method of load application to test specimens is the same as that of the tensile strength test in JSCE-E 541. Accordingly, the test specimens established in JSCE-E 541 are used.

4.2

In order to draw an *S-N* curve properly as shown in Figure C1, at least three specimens should be tested for at least three stress levels. However, if the *S-N* relationships cannot be clearly plotted due to unsuitable stress level settings, wide variations in data or other reason, additional specimens must be tested as needed. If the static tensile strength is required as the basis for setting the loading levels for the test, the static tensile strength test should be performed using the same lot and same shape of test specimen as the fatigue strength test, in accordance with JSCE-E 541 "Test method for tensile properties of continuous fiber sheets."

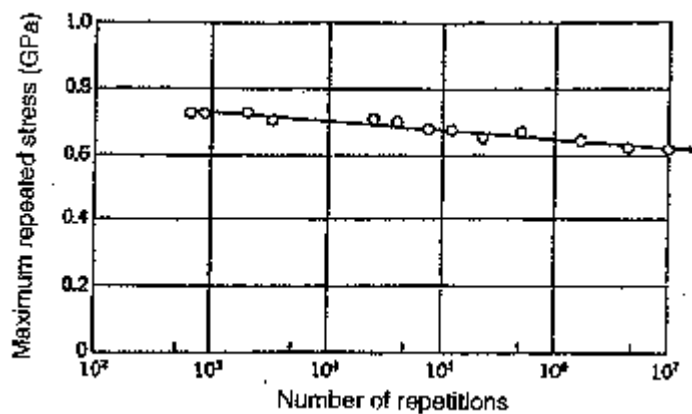


Figure C1 *S-N* curve

5. Testing Machine and Measuring Devices

5.1

The testing machine should be capable of controlling the load to a constant level automatically. If a testing machine with electrohydraulic control is to be used, care must be taken so that minute rotations are not happening in the knobs on the excitation side.

6. Test Method

6.3

If the clamping pressure of the knob is too great or too small, appropriate test results may not be obtained, so care is needed. If any slight horizontal movement or rotation of the knob on the excitation side of the testing machine is noticed, a guide should be fitted before testing to prevent such movement or rotation.

6.4

If the effects of creep on the tensile fatigue strength are known in advance, this should be taken into consideration in the setting of the test load and repetition frequency. In general, the number of repetitions before fatigue fracture occurs is affected not only by the maximum stress ratio but the stress amplitude. Therefore, different results may be obtained when the maximum and minimum stress ratios are different. In actual concrete structures subject to variable loads, the design load should be set as the maximum load.

The static tensile test should be performed in advance for test specimens from the same lot as the fatigue test in accordance with JSCE-E 541. If it is difficult to determine the maximum load for the initial test, use the following procedure.

- a) From stresses equivalent to 5-55% of the static tensile strength, select the appropriate stress level and start the test with this value as the maximum repeated load.
- b) If the test specimen does not fracture after 10^4 repetitions with this maximum repeated load, increase the maximum repeated load by 5% of the static tensile

strength and continue the test using the same test specimen. In such cases, the test should be conducted quickly without interruption, with the maximum repeated load incorporating 5% of the static tensile strength.

- c) If the test specimen does not fracture after another 10^4 repetitions of the test in b) above, use the same procedure to increase the maximum repeated load again by 5% of the static tensile strength.
- d) Repeat the procedure in (c) above until the test specimen fractures.
- e) Set the maximum repeated load for the initial tensile-tensile fatigue test to the level at which the test specimen fractured, minus 5% of the static tensile strength.

6.5

The repetition frequency should be about 2-10 Hz. The upper limit for the repetition frequency should be one at which the test specimen does not get heated excessively.

6.6

The temperature and humidity for the test should conform to JSCE-E 541 and the test should be performed under the same conditions.

6.7

After the test starts, check and adjust the load level as needed to keep it at the prescribed level.

6.8

The number of repetitions should be expressed as a multiple of 10^n , such as 2.34×10^5 , and rounded off to three significant digits.

7. Calculation and Expression of Test Results

7.2

For repeated loading, the stresses corresponding to the maximum load and minimum load represent the maximum repeated stress (S_{max}) and minimum repeated stress (S_{min}), respectively. The terms "load" or "stress" may be chosen depending on the context. In the fatigue test with a constant average load or constant minimum repeated load, the relationship is generally sought between the maximum repeated stress (or stress amplitude) and the number of repetitions until failure ($S-N$ curve). Depending on the test objective, however, a fatigue strength curve for the prescribed number of repetitions may be plotted with the vertical axis showing the stress amplitude and the horizontal axis showing the average stress, or with the vertical axis showing the maximum stress and the horizontal axis showing the minimum stress.

In the test, it is difficult to draw a distinction between tensile fatigue strength and creep failure strength, and this issue awaits further study. In the calculation and expression of test results, therefore, the number of repetitions and the repetition frequency, i.e. the length of time that the repeated load is applied, must be clearly identified. Where the creep failure strength is known, this may be plotted on a fatigue strength diagram.

8. Report

If the test specimen does not fracture or the test is halted after the prescribed number of revolutions, this should be noted in the report. If the failure of test specimen is other than a separation rupture, the condition of the test specimen during the test and the failure mode should be noted.