Japan Concrete Institute Standard

Method of test for load-displacement curve of fiber reinforced concrete by use of notched beam JCI-S-002-2003

1. Scope

This test method covers measurement of the load-displacement curves of fiber reinforced concrete by three-point loading of notched beams[(1)]. Also, tension softening curves can be estimated from the load-displacement curves obtained by this test method by following the procedure specified in the **Appendix (informative)** of **JCI-S-001-2003**.

Note: [(1)] This test method is not applicable to fiber reinforced concrete of the so-called strain-hardening type in which multiple visible cracks occur before reaching the maximum load. Both crack mouth opening displacement (CMOD) and load point displacement (LPD) are specified as the displacement of load-displacement curves, but measurement of both may not be necessary. Either may be selected depending on the purpose of measurement.

2. Normative references

The following normative documents contain provisions which, through reference in this text, constitute a portion of the provisions of JCI-S-002-2003. The latest editions of these citations shall apply.

JCI-SF2: Method of making specimens for strength and toughness tests of fiber reinforced concrete

JCI-SF3: Method of making specimens for strength and toughness tests for fiber reinforced shotcrete

3. Specimens

3.1 Geometry

Specimens shall be beams of rectangular cross section with a notch at the mid-length to a depth of 0.3 times the beam depth as shown in Fig. 1.

a) The depth of the cross section (D) of the specimen shall be not less than 4 times the maximum aggregate size (d_a).
b) The width of the cross section (B) of the specimen shall be not less than 4 times the maximum aggregate size (d_a).
c) When the fiber length exceeds 40mm, the side length of the cross section shall be not less than 150mm. When the fiber length is 40mm or less, the side length of the cross section shall be not less than 100mm.
d) The loading span (S) shall be 3D. The total length of the specimen (L) shall be not less than 3.5D.
e) The notch depth (a_0) and notch width (n_0) shall be 0.3D and not more than 5mm, respectively.

Note: [(2)] The area above the notch subject to rupture is referred to as the ligament. The width and height of the cross section of the ligament are expressed as b and h, respectively.

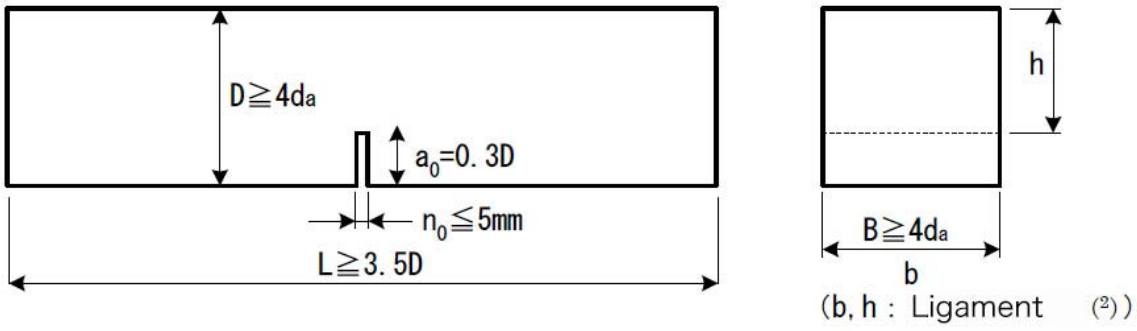

Figure 1 Specimen dimensions

3.2 Fabrication of specimens

a) Specimens shall be fabricated in accordance with **JCI-SF2** (Method of making specimens for strength and toughness tests of fiber reinforced concrete) or **JCI-SF3** (Method of making specimens for strength and toughness tests for fiber reinforced shotcrete).
b) The notch shall be cut using a concrete saw when the concrete has developed sufficient strength[(3)].

Note: [(3)] The notch should be cut in one side of the specimen with respect to its position as molded so that the specimen would be turned on this side for loading, with the casting surface being vertical. It is not necessary to cut the edges of the notch to specific forms, as the edge shape scarcely affects the test results. When no concrete saw is available, the notch may be formed by embedding a metal or synthetic resin plate of the specified size during placing. In this case, measures should be taken to prevent bonding between the plate and concrete.

c) Specimens shall be subjected to testing in a condition immediately after completion of the specified curing procedure.
d) The number of specimens shall be not less than four.
e) The mass of each specimen shall be measured to the nearest 0.05 kg.

4. Apparatus

4.1 Testing machine

It is desirable to use a testing machine furnished with closed-loop control based on CMOD or LPD. Closed-loop control is desirable but not mandatory if a steady load-displacement relationship can be measured after the peak load without rapid progress of fracture[(4)].

Note: [(4)] Closed-loop control may not be necessary for normal fiber reinforced concrete, as it causes no abrupt drop of post-peak loads. However, rapid propagation of post-peak failure can occur similarly to plain concrete depending on the materials and size of fibers. In such a case, it is desirable to use a testing machine that provides closed-loop control in terms of CMOD or LPD. Nevertheless, it is sufficient if a stable load-displacement relationship can be maintained after the peak load. Tests are therefore also feasible using a testing machine that controls the crosshead displacement or a manually controlled testing machine if unstable failure can be avoided by appropriately repeating loading and unloading after the peak load. In any event, the absence of unstable failure should be confirmed.

4.2 Loading apparatus

In order to eliminate torsional action on the specimen, the loading block and one of the

supports shall be rotatable around their axes in the direction coincidental with the specimen axis. Both supports shall be hinged supports having rollers. The supports shall be horizontally movable to avoid any restraint on the deformation until the specimen completely ruptures[5].

Note: [5] Both supports should be movable, as the horizontal movement of the specimen is restrained at the loading block. Inserting multiple rods under both supports as shown in Fig. 2 is a simple and effective solution for a movable mechanism. In order to ensure the absence of horizontal restraint, it is advisable to press the specimen lightly by hand before applying any load to confirm smooth movement of the specimen in the horizontal direction.

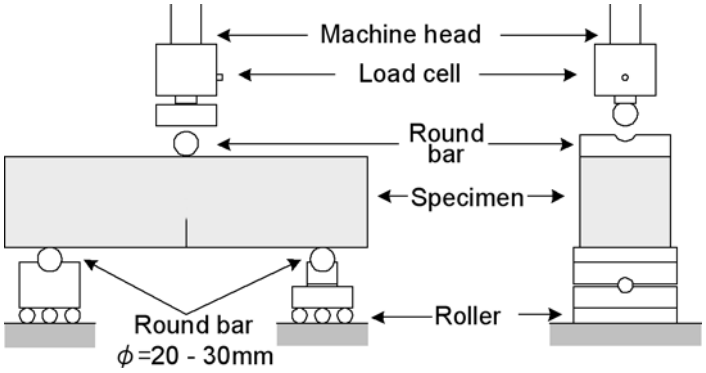

Figure 2 Loading apparatus

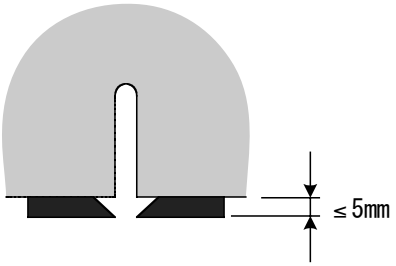

Figure 3 Knife-edges

4.3 Measuring device for loads

The load shall be measured using a load cell with an accuracy of 1% of the estimated peak load or better. The load cell shall be fixed to the testing machine.

4.4 Measuring device for CMOD

The CMOD shall be measured using a clip gauge with an accuracy of 1/500mm or better. The thickness of the knife-edges to which the clip gauge is attached shall be not more than 5mm[6].

Note: [6] Knife-edges may not necessarily be used when clip gauges can be directly attached to the notch. Knife-edges, which should be made of metal, should be attached as shown in Fig. 3 using an adhesive to ensure bond with the specimen. When wet testing is to be conducted with knife-edges attached to the specimen with an adhesive, the surfaces receiving the knife-edges have to be temporarily dried at the time of adhering. In this case, it is advisable that the portions other than the surfaces receiving the knife-edges be covered with a wet cloth or immersed in water to avoid drying.

4.5 Measuring device for LPD

The LPD shall be measured using displacement transducers with an accuracy of 1/500mm or better as shown in Fig. 4. Holder frames shall be used to hold the displacement transducers to

eliminate the rigid-body displacement of the specimen and its deformation due to crushing at the loading and support points. The measuring points shall as a rule be on both sides of the specimen directly below the loading point. However, if it is difficult to fix displacement transducers at such points, measurement at the shoulders of the notch near the bottom center is permitted.

5. Test procedure

a) Set the specimen on its side with respect to its position as molded so that the notch would be located on the bottom.
b) Load the specimen continuously and without shock. When closed-loop control is executed in terms of CMOD or LPD, the preliminary load for starting loading shall be not more than 20% of the estimated peak load.
c) The loading rate shall be 0.0005D to 0.004D/min (D = depth of specimen) in terms of the CMOD rate or 0.0004D to 0.003D/min in terms of the LPD rate within the range of achieving stable fracture[(7)].

Note: [(7)] Though it is desirable to keep the loading rate constant from the beginning through the end of testing, it can be increased within the range of not substantially affecting the load-displacement curve, to shorten the testing time, after the post-cracking reductions in the load have settled. The method of such a change in the loading rate shall be reported.

d) Measure the load and CMOD or LPD continuously from the beginning through the end of testing. The intervals between readings by a digital measuring device shall be short enough to permit 20 or more readings before the peak load is reached. Testing shall be continued until the CMOD or LPD reaches at least 0.02D or 0.015D, respectively. It is desirable to continue testing until the CMOD or LPD reaches 0.04D or more or 0.03D or more, respectively, when evaluating the fracture properties up to a large CMOD[(8)].

Note: [(8)] It is often difficult to continue testing of fiber reinforced concrete until the specimen completely ruptures. It is therefore necessary to determine the time to discontinue testing in accordance with the purpose of testing.

e) Tests are regarded as stable when the load and CMOD or LPD change slowly throughout the test without abrupt jumps. Results of tests that involve any unstable phenomenon shall be discarded.
f) When using a manually controlled testing machine with intermittent loading after the peak load to avoid unstable fracture or when relocating the clip gauge or displacement transducers because of their insufficient capacities, adopt the envelope as the load-CMOD curve.
g) Measure the width (b) of the broken ligament to the nearest 0.2mm at two locations and calculate the average to four significant figures.
h) Measure the height (h) of the broken ligament to the nearest 0.2mm at two locations and calculate the average to four significant figures.
i) Express the load-CMOD curve or load-LPD curve as averages of at least four specimens[(9)].

Note: [(9)] To average the load-CMOD curves or load-LPD curves, calculate the averages of the loads on specimens at the same arbitrary displacements. The intervals between displacements for averaging should be similar to the intervals between measurements specified in section d) above.

6. Estimation of tension softening curve

The tension softening curve shall be estimated following the **Appendix (Informative)** of **JCI-S-001-2003**.

7. Report

The test report shall include items from the following list as required:

a) Number of specimens
b) Curing conditions and test age
c) Geometry of specimen
d) Height and width of broken ligament
e) Mass of specimen
f) Type of testing machine
g) Mass of loading jig
h) Loading rate
i) Load-CMOD curve
j) Load-LPD curve
k) Tension softening curve

Report of the technical committee on the test method for fracture property of concrete (JCI-TC992)(2001.5)

Member of technical committee on the test method for fracture property of concrete (JCI-TC992)(1999.4-2001.3)

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