Annex A (normative)
Determination of cross-sectional area of FRP reinforcement

Note: *This Annex is a mandatory part of this Standard.*

A.1 Scope
This Annex specifies a method for determining the cross-sectional area of FRP reinforcements of all shapes and sizes by the water-displacement method.

A.2 Symbols
The following symbols are used in this Annex:

A = cross-sectional area
d = nominal diameter of the specimen (for bars of a noncircular section, it is the diameter of a circular section having the same cross-sectional area)
L = combined total length of the specimens
V_o = volume of the specimen container, mL
V_1 = volume of water added to fill the specimen container with specimen in it, mL

A.3 Apparatus

A.3.1 Specimen container
A glass or plastic cylinder of about 40 mm internal diameter and 300 mm height shall be used to contain the specimens in water. The container shall have a rigid cap with a 5 mm diameter hole that fits without any slack and does not allow water to leak from the cylinder brim (see Figure A.1).
Note: *The container may be made from either a glass or a clear and rigid plastic tube by sealing one end with a flat plastic disk glued to the squarely cut tube end.*

A.3.2 Weighing scale
A scale of 2 to 5 kg capacity, capable of measuring weight with a resolution of 1 g, shall be used.

A.4 Specimens

A.4.1 Cutting specimens
All specimens shall be cut squarely and cleanly.

A.4.2 Specimen length
The length of specimens shall be 290 mm for bars that are of uniform cross-section along the length. For FRP grids, the longest possible specimens shall be cut from the parts between the grid joints.

A.4.3 Number of specimens
The number of specimens for bars that are of uniform cross-section along the length and the combined length of specimen for grids shall be as specified in Table A.1.

A.5 Test environment

The temperature of the laboratory shall be maintained at 23 ± 3°C and the relative humidity at 50 ± 10%.

A.6 Procedures

A.6.1 Conditioning

The specimens shall be kept in the test environment for at least 24 h prior to testing.

A.6.2 Measuring specimen length

The lengths of all conditioned specimens shall be measured with a ± 0.5% accuracy and shall be added in order to obtain the combined length of specimen.

A.6.3 Measuring container volume

The container and cap shall be dried and weighed. The container shall be filled with water to the top of the hole in the cap, taking care not to trap any air bubbles, and weighed again. The difference between the two weights in grams shall be taken as the volume of the container, V_o, in mL.

A.6.4 Placing specimens in the container

The container shall be dried and all the specimens placed in it so that no part protrudes above the brim (thereby preventing the cap from fitting onto the cylinder). Special care shall be taken in this regard for short specimens from grids. The container shall then be weighed together with its cap.

A.6.5 Adding water

Water shall be added to fill the container up to 10 mm below the brim without the cap in place. The container shall be gently shaken and/or the specimens shall be moved and turned, to drive out any air bubbles that have formed. The remaining part shall be filled, with the cap on, until water appears at the top of the hole; there shall be no bubbles trapped inside.

A.6.6 Measuring volume of added water

The container with water and specimen shall be weighed once again. The volume of water added, V_1, shall be obtained by subtracting the weight of the container and specimens measured in Clause A.6.4 from this new weight.

A.7 Calculations

A.7.1 Cross-sectional area

The average cross-sectional area, A, of the specimens shall be calculated as follows:

$$A = \frac{V_0 - V_1}{L} \times 1000 \qquad \textbf{(A7-1)}$$

A.7.2 Rounding

The combined total length shall be rounded to the nearest 1 mm and the cross-sectional area to the nearest 1 mm^2.

A.8 Report

A.8.1
The trade name, date of manufacture, nominal size, and a brief description of the shape and texture of each type of specimen tested shall be reported.

A.8.2
The temperature and relative humidity at the beginning of the test shall be reported.

A.8.3
The average cross-sectional area determined shall be reported.

Table A.1
Number or combined length of specimens
(See Clause A.4.3.)

d, mm	No. of 290 mm specimens for uniform bars	Combined length of specimens for grids, mm
6–10	8	1600–2000
11–14	6	1200–1400
15–18	3	600–800
19 or more	1	250–290

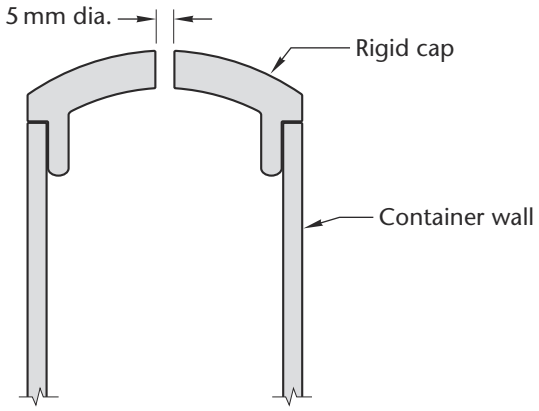

Figure A.1
Specimen container cap
(See Clause A.3.1.)

Annex B (normative)
Anchor for testing FRP specimens under monotonic, sustained, and cyclic tension

Note: *This Annex is a mandatory part of this Standard.*

B.1 Scope
This Annex specifies the requirements for an anchor for FRP reinforcement specimens to facilitate gripping of the specimens for various types of tests carried out under tensile loading. It also specifies the requirements for the preparation of the specimens.

The following tests may be carried out using the anchor:

(a) monotonic tension;
(b) creep;
(c) relaxation; and
(d) pullout bond.

The anchor is not recommended for testing FRP specimens that require more than 300 kN of load in order to fail.

B.2 Symbols
The following symbols are used in this Annex:

A = cross-sectional area of specimen
d = nominal diameter of specimen (for specimens of noncircular section, it is the diameter of a circular section having the same cross-sectional area)
f_u = ultimate tensile strength
L_g = length of grip

B.3 Specification of anchor

B.3.1 Geometry
The geometrical dimensions of the anchor shall be as shown in Figure B.1. The cylinder wall thickness shall be at least 5 mm and its inner diameter 10 to 14 mm greater than d. The length of the cylinder, L_g, shall be at least equal to $f_uA/350$, but not less than 250 mm.

B.3.2 Attachment to testing machine
The anchor shall be adapted to fit into the grips of different types of testing machines or frames, as shown in Figure B.2.

B.3.3 Anchor filler material
The cylinder shall be filled with either pure resin or a 1:1 mixture of resin and clean sand (by weight) or non-shrink cement grout. The filler shall be compatible with the resin of the test specimen.

B.3.4 Specimen preparation

B.3.4.1 Cutting specimens

Specimens of the required length shall be cut from the bars supplied. When obtaining specimens from grids and cages, cutting the cross bars too close to the specimen bar shall be avoided. A 2 mm projection of the cross bars should be left to enhance gripping.

B.3.4.2 Specimen length

The total length of the specimen shall be $40d + 2L_g$ or greater.

B.3.4.3 Surface preparation

Mechanical or chemical surface treatment may be used for promoting adhesion of the specimen with the casting resin, provided that it does not affect the tensile properties of the specimen in the gauge length portion and that failure still takes place outside the anchors.

B.3.5 Anchor casting procedure

B.3.5.1 Casting position

Whenever possible, the anchor shall be cast in a vertical position, as shown in Figure B.1. The FRP bar shall be held axially inside the cylinder before the cylinder is filled with resin or resin/sand mix. If the specimen needs anchors at both ends, at least 12 h shall elapse before the first anchor is flipped in order to cast the other anchor. A suitable jig, as shown in Figure B.3, may be used to keep both cylinders and the specimen axially aligned.

If necessary (e.g., when casting specimens with relatively long FRP bars that are cumbersome to cast vertically), the anchor may be cast in a horizontal position using the filling and bleeding holes shown in Figure B.1. Only pure resin* shall be used in this case. The hole in the rubber cap shall fit tightly around the FRP bar so as to prevent resin from leaking out. Silicone caulking may be used to seal gaps around bars of a noncircular cross-section.

**Sand, if used, settles at the bottom and near the filling end, making an uneven anchor.*

B.3.5.2 Preparation

The inner surface of the hole in the threaded plug shall be lightly oiled by running an oiled wick along the hole in order to prevent bonding of the FRP bar along the plug. Care shall be taken to wipe off any excess oil before inserting the FRP bar. Silicone caulking shall be applied at the bottom of the plug as shown in Figure B.1 to prevent any possible leakage of resin.

B.3.5.3 Mixing and handling resin

The resin shall be mixed and handled following the manufacturer's instructions, paying particular attention to safety.

B.3.5.4 Filling resin

For vertical casting, the resin shall be poured directly from a beaker with a narrow spout or with the aid of a funnel with a suitable stem. If the anchor has an internal thread at the filling end, the thread shall be suitably protected so that resin does not contact the thread. The cap shall be placed as soon as resin filling is completed.

For horizontal casting, the resin shall be poured by means of a funnel connected to the hole near the inner end of the specimen. Care shall be taken to avoid leaving any air pocket inside. Towards the end of the filling operation, the resin shall be added very slowly to prevent spillage through the bleed hole, and filling shall be stopped as soon as a resin column forms in the bleed hole. From time to time during the next 3 h, the resin shall be topped up, if necessary, through both holes as the resin shrinks.

B.3.5.5 Curing

At least 48 h shall be allowed before testing for the resin to set inside the cylinder.

B.3.5.6 Handling

The anchored specimen shall be handled by holding both grips to avoid bending or twisting of it.

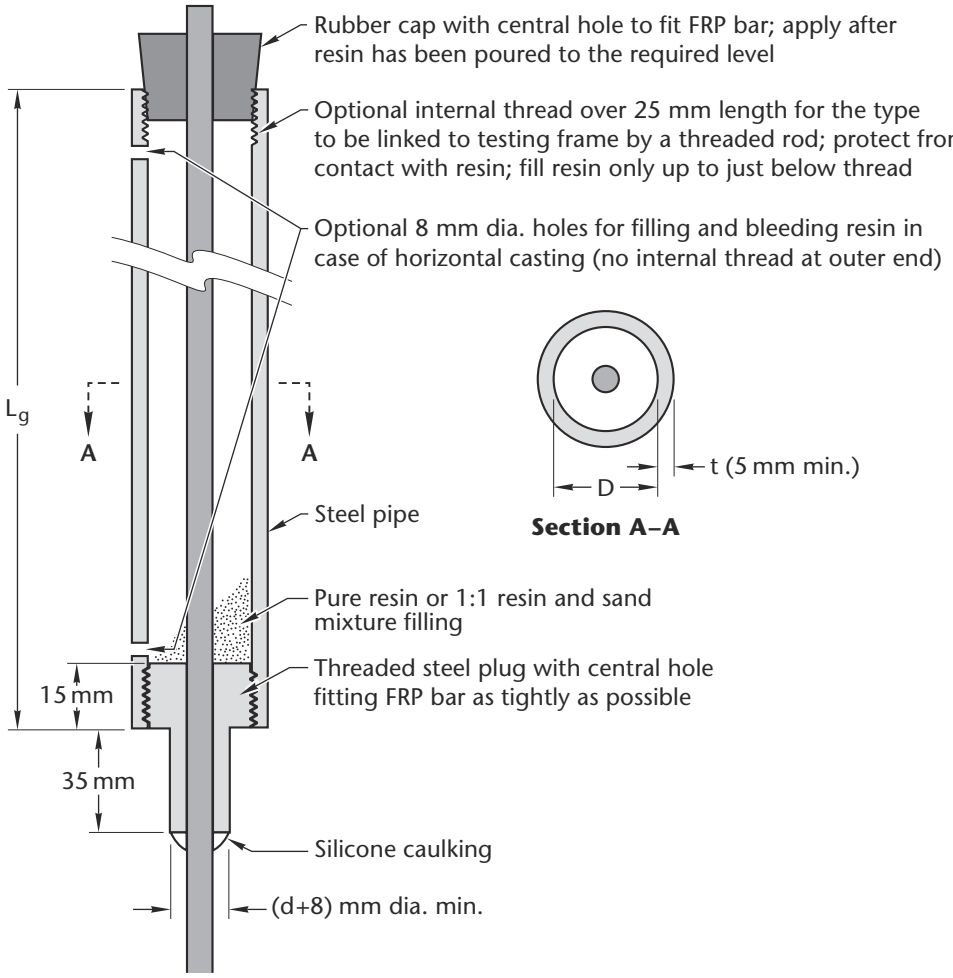

Figure B.1
Anchor details
(See Clauses B.3.1, B.3.5.1, and B.3.5.2.)

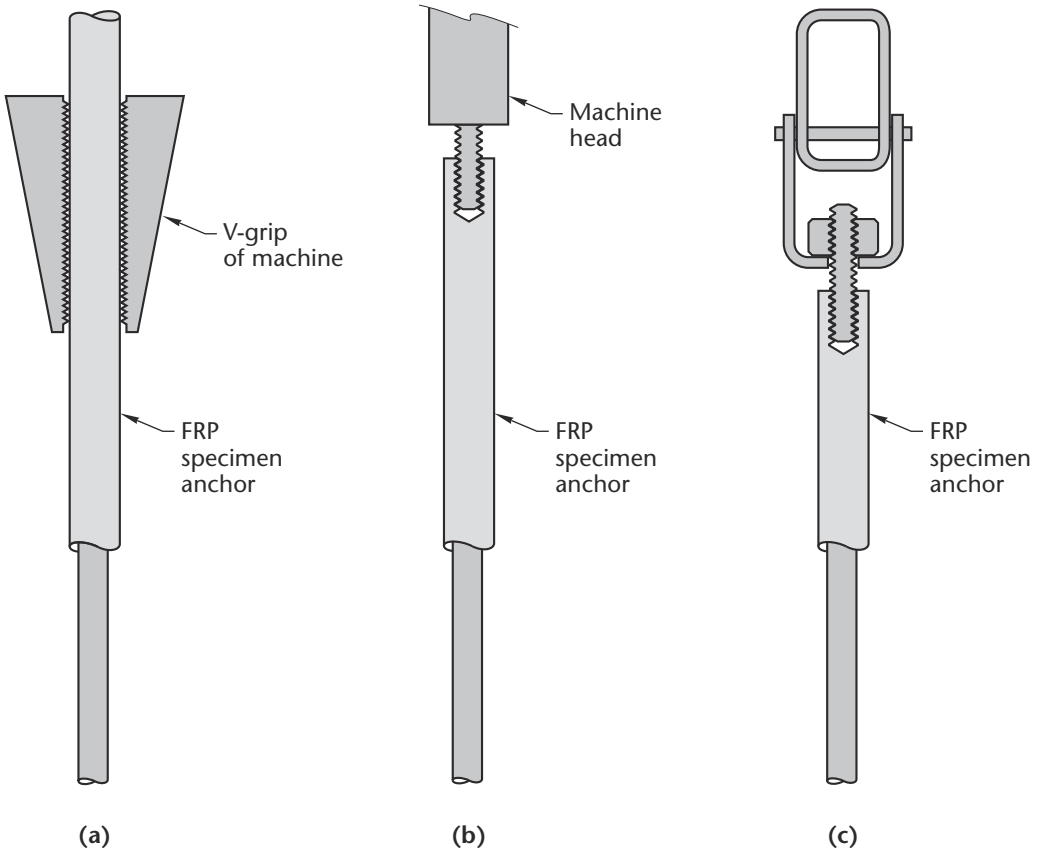

Figure B.2
Attachment of anchor to various testing machines and frames
(See Clause B.3.2.)

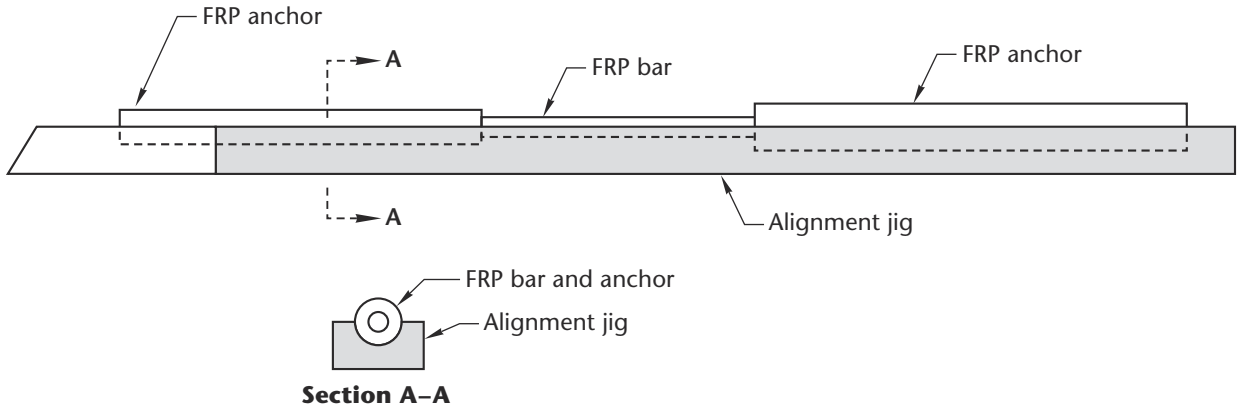

Figure B.3
Jig to align specimen and anchors
(See Clause B.3.5.1.)

Annex C (normative)
Test method for tensile properties of FRP reinforcements

Note: *This Annex is a mandatory part of this Standard.*

C.1 Scope
This Annex specifies a test method for determining the tensile strength, modulus of elasticity, and ultimate elongation of FRP reinforcements.

C.2 Symbols
The following symbols are used in this Annex:

A = cross-sectional area
d = nominal diameter of the specimen, mm (for bars of a noncircular section, it is the diameter of a circular section having the same cross-sectional area)
E = modulus of elasticity
f_u = ultimate tensile strength
L_g = length of grip
P_1 and ε_1 = load and corresponding strain, respectively, at about 50% of the ultimate load
P_2 and ε_2 = load and corresponding strain, respectively, at about 25% of the ultimate load

C.3 Apparatus

C.3.1 Testing machine
The machine shall generally conform to ASTM E4. The machine shall have a loading capacity exceeding the expected strength of the specimen and shall preferably be equipped with strain-rate or load-rate control.

Note: *Universal testing machines might not have enough clearance to accommodate the relatively long anchors required by specimens of high load capacity. Special testing frames might be required in such cases.*

C.3.2 Specimen-anchoring devices
The anchor specified in Annex B may be used. Alternatively, another anchoring device may be used, provided that it satisfies the following conditions:

(a) The load shall be transmitted to the specimen without any eccentricity or torsion.
(b) Failure shall occur in the gauge-length portion of the specimen, not within the grips.
(c) No alteration, chemical or mechanical, shall be made in the gauge-length portion.

Note: *For specimens of high load capacity, such as multiwire tendons of* 300 kN *capacity or greater, special grips are needed and may have to be supplied by the manufacturer.*

C.3.3 Load-measuring device
Either a built-in device in the testing machine or a load cell of adequate capacity shall be used. The device shall be compatible with the data acquisition system.

C.3.4 Strain-measuring devices

Any of the following devices may be used:

(a) a clip-on-type extensometer having a minimum gauge length of $5d$, provided that the surface profile and texture of the specimen allow a secure attachment of the device;
(b) an LVDT of at least 50 mm gauge length mounted on brackets with quick-release features; and
(c) two strain gauges of minimum 12.5 mm gauge length, mounted back-to-back on the specimen, for specimens with a smooth surface of sufficient length to allow mounting the gauges.

C.3.5 Ultimate-elongation-measuring device

An LVDT may be set up to measure the displacement between the machine cross-heads or between the specimen anchors.

C.3.6 Data acquisition system

The system shall be capable of continuously logging load, strain, and displacement at a minimum rate of two readings per second. The minimum resolutions shall be

(a) 100 N for load;
(b) one microstrain for strain; and
(c) 0.01 mm for displacement.

C.4 Specimens

C.4.1 General

Specimens shall be representative of the lot or batch being tested. No chemical or mechanical alteration, such as machining of the specimens, shall be made for the purpose of testing.

C.4.2 Specimen length and cutting specimens

The total length of the specimen shall be $40d + 2L_g$ or greater. To obtain specimens from grids and cages, cutting the cross bars too close to the specimen bar shall be avoided. Leaving a 2 mm projection of the cross bars is good procedure for enhancing gripping.

C.4.3 Number of specimens

At least five specimens shall be tested, unless otherwise specified in CSA S807.

C.4.4 Cross-sectional area

The cross-sectional area shall be determined in accordance with Annex A.

C.5 Test environment

Tests shall be carried out with the room temperature maintained at 20 ± 10°C and relative humidity at 50 ± 25%.

C.6 Procedure

C.6.1 Handling of specimens

The specimen shall be handled, transported, and mounted on the testing machine carefully, so that no bending or torsion is applied to it.

C.6.2 Mounting of specimens
If the anchor described in Clause B.3 or a similar anchor has been used, the specimen shall be mounted on the testing machine in such a manner that the cylinder ends are flush with the jaws of the machine's wedge grips as shown in Figure C.1. For other anchors, the mounting shall ensure concentric and torsion-free loading.

C.6.3 Attaching measurement devices
The strain-measurement device shall be mounted to measure strain in the middle part of the specimen between the grips. The specimen shall not be damaged in any manner in the process of mounting the strain- and displacement-measurement devices. If an LVDT is used, particular care shall be taken to avoid biting into the bar when clamping the brackets.

C.6.4 Recording
The data acquisition system shall be started 10 s before the commencement of loading.

C.6.5 Rate of loading
The loading shall be applied at a stressing rate of 250 to 500 MPa/min. For machines with displacement control only, the desirable strain rate may be obtained using the extensometer of IVDT data.

C.6.6 Detaching strain-measurement device
When the load reaches about 75% of the estimated ultimate, the extensometer or LVDT shall be detached in order to avoid damage to the instrument.

C.6.7 Safety measure
Because some FRP specimens fail explosively and with the release of a substantial amount of energy, protective eyeglasses shall be worn by all testing personnel.

C.6.8 Rejection
If any test specimen fails partly or fully inside the grip, the test shall be discarded and another sample tested in its place.

C.7 Calculations

C.7.1 Tensile strength
The highest load recorded shall be divided by the cross-sectional area in order to calculate the tensile strength.

C.7.2 Modulus of elasticity
The following equation shall be used to calculate the value of the modulus of elasticity:

$$E = \frac{1000(P_1 - P_2)}{(\varepsilon_1 - \varepsilon_2)A} \qquad \textbf{(C-1)}$$

C.7.3 Ultimate elongation
The value of displacement (mm) corresponding to the highest load recorded shall be divided by the length of the specimen between grips (mm) and multiplied by 100 in order to obtain ultimate elongation as a percentage. The ultimate elongation can be calculated by dividing the ultimate tensile strength by the tensile modulus of elasticity of the tested FRP bar.

C.7.4 Rounding

Tensile strength shall be rounded to the nearest 10 MPa and the modulus of elasticity to the nearest 1000 MPa. Ultimate elongation shall be rounded to the nearest one-tenth of a percentage point.

C.8 Report

C.8.1

The trade name, date of manufacture, nominal size, and a brief description of the shape and surface texture of each type of specimen tested shall be reported.

C.8.2

A brief description of the gripping device used shall be given.

C.8.3

The cross-sectional area of each type and size of specimen shall be reported.

C.8.4

For each specimen, the values of each the following shall be reported:

(a) tensile strength;
(b) modulus of elasticity;
(c) ultimate elongation; and
(d) the average values and standard deviation of the quantities in Items (a) to (c) for the set of specimens tested.

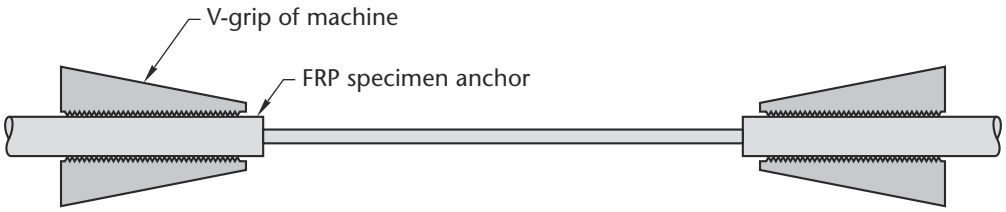

Figure C.1
Mounting specimen in testing machine with V-grips
(See Clause C.6.2.)