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Fibre-reinforced plastic composites — Full-section compressive test for pultruded profiles

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Foreword

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This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Previous attempts to determine compressive properties of pultruded FRP have been hampered by experimental difficulty of clamping and different boundary conditions between test specimen and actual specimen.

The procedure presented in this document uses the full-section compressive test to determine the compressive properties of pultruded FRP. This test is convenient and able to evaluate the mechanical properties of the full-section. The result of this test, despite being lower than that of the coupon test, can better represent the properties across the full-section and thus, is recommended to be used in the strength design of pultruded FRP compressive members.

Fibre-reinforced plastic composites — Full-section compressive test for pultruded profiles

1 Scope

This document specifies a method for determining the compressive properties in the pultruded fibre reinforced plastic (FRP) using full-section compressive tests.

It is applicable to pultruded FRP profiles. The scope is not limited to types of fibres and resins.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometer systems used in uniaxial testing*

ISO 16012, *Plastics — Determination of linear dimensions of test specimens*

ISO 21920-2, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 2 Terms, definitions and surface texture parameters*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
full-section compressive stress
compressive stress
σ
compressive force divided by initial cross-sectional area perpendicular to the loading direction

Note 1 to entry: Full-section compressive stress is expressed in megapascals (MPa).

3.2
full-section compressive strength
compressive strength
σ_c
maximum compressive force divided by initial cross-sectional area perpendicular to the loading direction

Note 1 to entry: Full-section compressive strength is expressed in megapascals (MPa).

3.3
compressive strength at x% compressive strain
σ_x
stress at which the strain, ε, reaches the specified value x% expressed as a percentage

Note 1 to entry: Full-section compressive strength at x% compressive strain is expressed in megapascals (MPa).

3.4
compressive strain
ε
deformation divided by the initial length parallel to the loading direction, in most cases measured by strain indicator

Note 1 to entry: Compressive strain is expressed as a percentage.

3.5
full-section compressive modulus
compressive modulus
E_c
full-section compressive stress divided by compressive strain

Note 1 to entry: Full-section compressive modulus is expressed in megapascals (MPa).

3.6
radius of gyration
r
square root of second moment of area divided by total cross-sectional area

Note 1 to entry: Radius of gyration is expressed in millimetre (mm).

3.7
length
h
length of specimen

Note 1 to entry: Length is expressed in millimetre (mm).

3.8
gauge length
h_0
gauge length of specimen

Note 1 to entry: Gauge length is expressed in millimetre (mm).

3.9
slenderness ratio
λ
length divided by radius of gyration

3.10
width-thickness ratio
β
plate width divided by thickness, while plate width is the larger measurement of plate in longitudinal and transverse orientation

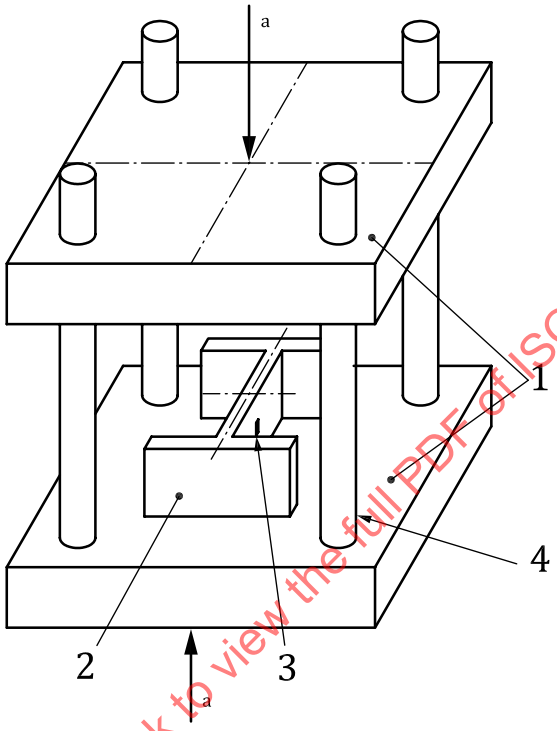
4 Principle

The test is a method for evaluating full-section compressive properties of pultruded FRP. The compressive test is carried out using a universal test machine. Compressive stress is measured from applied force. Compressive strain is measured directly on the specimen via gauges or extensometers.

5 Apparatus

5.1 Test machine

The test machine shall be in accordance with ISO 7500-1 and ISO 9513. The force measurement system shall comply with Class 1 as defined in ISO 7500-1. The test machine shall have a measuring system of crosshead displacement. See Figure 1.



Key

1	parallel platens	4	guide rails
2	test specimen	a	Applied force, F_c.
3	strain gauges		

Figure 1 — Schematic illustration of test

5.2 Compression platens

Two parallel platens, well guided to avoid lateral movements and of 5 mm larger size more than the specimen to be tested, shall be used. One compression platen shall be rigidly mounted, while the other platen shall remain parallel during the test. The minimum hardness of the compression platens shall be 700 HV 0,2. The maximum surface roughness of the compression platens shall be 6,3 µm, measured in accordance with ISO 21920-2.

5.3 Strain indicator

If compressive modulus is required, strain gauges shall be used. The grid length of strain gauges shall be longer than 3 mm and adapted to the size of the fibre structure of the material being tested. Strain gauges shall have appropriate electrical resistance. The accuracy of k-factor shall be 1 % of the relevant value or better. According to the cross section of tested specimen, strain gauges shall be attached in different locations, see Figure 2.

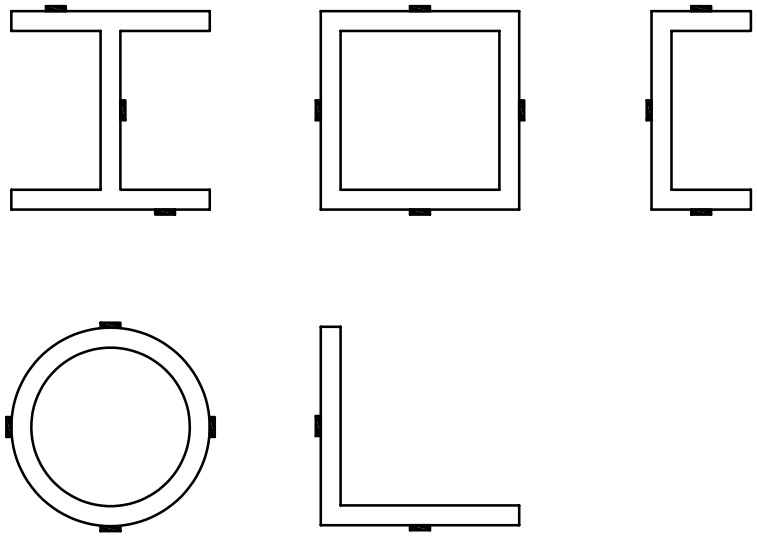


Figure 2 — Strain gauge locations of different sections

6 Specimens

6.1 Geometry

Cross-section shape includes, but is not limited to, I-section, L-section, C-section, rectangular section and circular section. The cross-section shape and geometry shall be recorded in the test report.

The slenderness ratio shall be less than 3. The width-thickness ratio of the free side plate shall be less than 5, and the width-thickness ratio of the plates without free edges shall be less than 8. The width-thickness ratio of the non-double symmetrical section shall be less than 5. The length of the test specimen is the minimum length controlled by the mentioned slenderness ratio.

The length of the test specimen is irrelevant to the width-thickness ratio.

The areas in contact with the platens shall be parallel, and perpendicular to the load direction. The errors of parallelism shall be less than 0,5 mm. Cut surfaces shall have any burrs removed.

6.2 Preparation of specimens

Specimens can be reinforced in ends by steel plates or aluminium plates to prevent local damage. The plates shall be bonded to specimens using a suitable adhesive. The reinforcing length shall less than 1/3 of specimen length.

6.3 Number of test specimens

The number of test specimens shall be no less than three, and a minimum of five is recommended.

6.4 Sampling of test specimens

The test specimens shall be sampled from pultruded FRP profiles by the suitable machining techniques to minimise damage, for instance using a diamond grit coated blade, water jet, etc. Under no circumstances shall the material properties be affected by the cutting procedure.

6.5 Conditioning atmosphere

The conditioning atmosphere shall be in accordance with ISO 291 Class 2.

7 Test procedure

7.1 Test atmosphere

The test atmosphere shall be in accordance with ISO 291 Class 2, and the temperature and moisture shall be recorded.

The preferred atmosphere is (23 ± 2) °C and (50 ± 10) % RH, except when the properties of material are known to be insensitive to moisture and humidity control is unnecessary.

7.2 Measurement of initial dimensions of test specimen

Dimensions shall be measured in accordance with ISO 16012, accurate to ±0,1 mm for dimensions greater than 10 mm and accurate to 0,01 mm for dimensions less than or equal to 10 mm.

Measurement at a minimum of three measuring points is recommended.

7.3 Test speed

Compress the specimen at a constant speed of the moving compression platen, calculated as Formula (1):

$$v = 0,1h \tag{1}$$

where

v is the test speed in mm/min;

h is the specimen length in mm.

The compression speed shall be recorded in the test report.

8 Calculation and expression results

8.1 General

Typical stress-strain curve is shown in Figure 3.

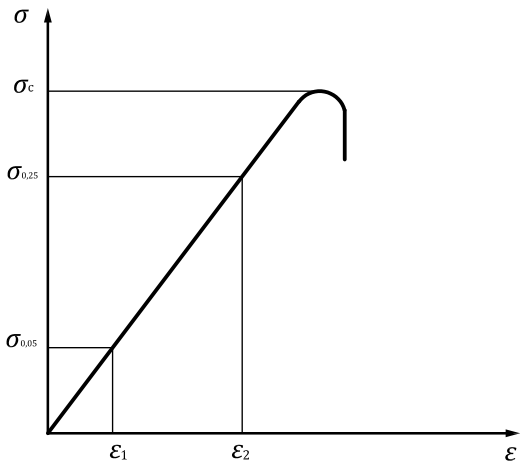


Figure 3 — Stress-strain curve from compression test

8.2 Full-section compressive strength

Calculate the mean maximum compressive force and then calculate the compressive strength from Formula (2):

$$\sigma_c = \frac{F_c}{A} \tag{2}$$

where

σ_c is the full-section compressive strength, in megapascals (MPa);

A is the cross-section area, in square millimetre (mm^2);

F_c is the mean maximum compressive force (N).

8.3 Strain

Compressive strain, defined in 3.3, is equal to the mean value of tested results of strain gauges. Strain gauge results are deemed acceptable when no buckling or local break occurs.

8.4 Full-section compressive modulus

8.4.1 General

Calculate the full-section compressive modulus, defined in 3.5, using one of the following alternatives [see Formulae (3) to (4)].

8.4.2 Chord slope

The full-section compressive modulus can be calculated by chord slope between two stress/strain points.

$$E_c = \frac{\sigma_{0,25} - \sigma_{0,05}}{\varepsilon_2 - \varepsilon_1} \tag{3}$$

where

E_c is the full-section compressive modulus, in megapascals (MPa);

$\sigma_{0,05}$ is the stress, expressed in megapascals (MPa), measured at the strain value ε_1 = 0,000 5 (0,05 %);

$\sigma_{0,25}$ is the stress, expressed in megapascals (MPa), measured at the strain value ε_2 = 0,002 5 (0,25 %).

8.4.3 Regression slope

With computer-aided equipment, the determination of full-section compressive modulus, E_c, using two distinct stress/strain points can be replaced by a linear regression applied on the part of the curve between two points.

$$E_c = \frac{d_\sigma}{d_\varepsilon} \tag{4}$$

where $\frac{d_\sigma}{d_\varepsilon}$ is the slope of a least-square regression line fitted to the stress/strain curve in the stress interval between 25 % to 75 % of maximum compressive stress, expressed in megapascals (MPa).