Test Guide
TG-725-31980

Tensile Properties of FRP Composite

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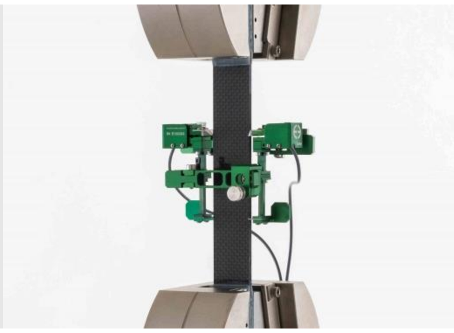

DESCRIPTION

As per Theories, Composite materials are being used from ancient times in direct or indirect ways, either in conventional or non-conventional forms. Research made worldwide has proved that composite materials exhibit extraordinary properties. Hence most of the world is adopting modern composite materials over conventional engineering materials.

Now the question arises: "How come it has been proved that Composites are better than Conventional materials"

Answer: "Testing and analysis of composite materials".

Thorough Testing practices and Standards have helped to evaluate the performance of composite materials. The data derived from composite materials testing and analysis can be used to compare the composite materials against conventional materials.

1. Scope

This guide determines the method of determination of the ultimate tensile strength, tensile modulus and, if required, the Poisson's ratio and strain at failure in tension of polymer matrix composite materials reinforced by high-modulus fibers in the form of unidirectional laminates.

2. Principle

A thin flat strip of composite specimen having a constant rectangular cross section is mounted in the grips of a mechanical testing machine. The specimen is then monotonically loaded in tension while the force is being recorded. The ultimate strength of the material can be determined from the maximum force carried before failure. The ultimate tensile strain, tensile modulus of elasticity, Poisson's ratio, and transition strain can all be obtained from the stress-strain response of the material if the coupon strain is monitored using strain or displacement transducers.

3. Testing Apparatus

3.1 Tensile-testing Machine

3.1.1 Testing Machine Heads: The testing machine shall have both an essentially stationary head and a movable head.

3.1.2 Drive Mechanism

The testing machine drive mechanism shall be capable of imparting to the movable head a controlled velocity with respect to the stationary head.

3.1.3 Force Indicator

The testing machine force-sensing device shall be capable of indicating the total force being carried by the test specimen.

3.1.4 Grips

Each head of the testing machine shall carry one grip for holding the test specimen so that the direction of force applied to the specimen is coincident with the longitudinal axis of the specimen. The grips shall apply sufficient lateral pressure to prevent slippage between the grip face and the coupon.

3.2 Strain-Indicating Device

Force-strain data, if required, shall be determined by means of either a strain transducer or an extensometer. The strain-indicating device's attachment to the coupon shall not cause damage to the specimen surface.

If Poisson's ratio is to be determined, the specimen shall be instrumented to measure strain in both longitudinal and lateral directions. If the modulus of elasticity is to be determined, the longitudinal strain should be simultaneously measured on opposite faces of the specimen to allow for a correction as a result of any bending of the specimen.

4. Test Specimens

4.1 Number of test specimens

Test at least five specimens per test condition. If any of the specimens fails within the grips or at the tabs, or because of damage caused by the extensometer, discard the result and carry out a repeat determination on a fresh test specimen.

4.2 Test Specimen Geometry

The requirements list of specimen shape and dimensions is shown in Table 1.

4.3 Specimen Preparation

4.3.1 Specimen Fabrication

Specimen preparation is extremely important for this specimen. Mold the specimens individually to avoid edge and cutting effects or cut them from plates. Test specimens should be prepared by vacuum process or combining multiple/single layers of fibers with resins and then compressing them under high pressure which produces a uniformly impregnated, smooth specimen. Control of fiber alignment is critical. Improper fiber alignment will reduce the measured properties. This method is only applicable to specimens where the axis is parallel to the direction of the fibres. For each degree of fiber direction deviation, 10-15% should be added to the final results.

4.3.2 Impregnating Resin

The impregnating resin shall be compatible with the yarn and its size. The viscosity of the resin or resin solution shall be such that sufficient resin pick-up is achieved to ensure uniform impregnation.

Since different commercial resins are used in different conditions, the resin used to make the composite specimens should not be of the same commercial resins. The viscosity of the impregnating resin used in preparing the specimen should be in accordance with the proposal of valid codes and standards so that the fiber strength in the composite can be derived according to them.

Therefore it is recommended the strain at failure of the cured resin shall be at least twice that of the fibre, preferably three times. In this respect, heatcurable epoxy-resin systems with a viscosity during impregnation of preferably less than 1000 mPa.s are suitable. The resin formulation, however, shall be specified in detail.

4.3.3 Reinforcement Content, Volume Percent

Calculate reinforcement content, in volume percent, in accordance with Eq 1.

$$V_r = (M_f / M_i) * 100 (\rho_c/\rho_r) \qquad (1)$$

where:

ρ_r= density of the reinforcement, g/cm^3

ρ_c = density of the specimen, g/cm^3

M_i = initial mass of the specimen, g

M_f = final mass of the specimen after digestion or combustion, g.

The Reinforcement content shall be at least 70 % by volume. If the reinforcement content of the each specimen is outside the acceptable range, the result shall be verified for 70% reinforcement content.

4.3.4 Matrix Content, Volume Percent

Calculate matrix content, in volume percent, in accordance with Eq 2.

$$V_m = (M_i - M_f)/M_i * \rho_c / \rho_m * 100 \qquad (2)$$

where:

ρ_m = density of the matrix, g/cm^3

ρ_c = density of the specimen, g/cm^3

4.3.5 Fiber Effective Cross-sectional Area

Before the tension testing, determine the fiber effective cross-sectional area as $A_{effective}$=(W*h)*V_m , at three places in the gage section, and report the area as the average of these three determinations. Record the average effective area in units of mm^2.

where:

h = specimen thickness, mm

w = specimen width, mm

4.3.5 Labeling

Label the specimens so that they will be distinct from each other and traceable

Table 1 Tensile Specimen Geometry Requirements

Parameter	Requirement
specimen width*	15 mm
specimen overall length	250 mm
Tab Length	56 mm

* Considering the observed changes in the value of tensile strength (by 30-40%) , it is recommended to consider the width of the specimen as 5 mm.

back to the raw material and in a manner that will both be unaffected by the test and not influence the test.

5. Procedure for Tensile Testing

5.1 Specimen Insertion

Place the specimen in the grips of the testing machine, taking care to align the long axis of the gripped specimen with the test direction. Tighten the grips, recording the pressure used on pressure controllable (hydraulic or pneumatic) grips.

5.2 Loading

Apply the force to the specimen at the specified rate until failure, while recording data.

5.2 Speed of Testing

Set the speed of testing to a nearly constant strain rate in the gage section. The strain rate should be selected so as to produce failure within 1 to 10 min. The suggested standard speeds are:

- Strain-Controlled Tests: A standard strain rate of 0.01 min^{-1}.
- Constant Head-Speed Tests: A standard head displacement rate of 2 mm/min

5.3 Data Recording

Record force versus crosshead displacement (and force versus strain, if extensometers are utilized) continuously or at frequent regular intervals. For this test method, a sampling rate of 2 to 3 data recordings per second, and a target minimum of 100 data points per test are recommended.

6. Expression of results

6.1 Tensile Strength/ Tensile Stress

For each test specimen, calculate the ultimate tensile strength using Eq 3 and report the results. If the tensile modulus is to be calculated, determine the tensile stress at each required data point using Eq 4.

$$F^{tu}=P_{max}/A_{effective} \quad (3)$$

$$\sigma_i = P_i/A_{effective} \quad (4)$$

where:

F^{tu} = ultimate tensile strength, MPa

P_{max} = maximum force before failure, N

σ_i = tensile stress at ith data point, MPa

P_i = force at ith data point, N

A = average cross-sectional area, mm^2

$A_{effective}$ = average fiber effective cross-sectional area, mm^2

6.2 Tensile Strain/Ultimate Tensile Strain

If tensile modulus or ultimate tensile strain is to be calculated, and material response is being determined by an extensometer, determine the tensile strain from the indicated displacement at each required data point using Eq 5 and report the results.

$$\varepsilon_i=\delta_i/L_g \quad (5)$$

where:

ε = tensile strain at ith data point, με

δ= extensometer displacement at ith data point, mm;

L_g=extensometer gage length, mm

6.3 Tensile Chord Modulus of Elasticity

Select the appropriate chord modulus strain range from Table 2. Calculate the tensile chord modulus of elasticity from the stress-strain data using Eq 6.

$$E^{chord} = \Delta\sigma/\Delta\varepsilon \quad (6)$$

where:

E^{chord}: tensile chord modulus of elasticity, GPa

Δσ: difference in applied tensile stress between the two strain points of Table 3, MPa

Δε: difference between the two strain points of Table 2 (nominally 0.002)

6.4 Poisson's Ratio

Select the appropriate chord modulus longitudinal strain range from Table 2. Determine (by plotting or otherwise) the transverse strain (measured perpendicular to the applied force), ε_t, at each of the two longitudinal strains (measured parallel to the applied force), ε_l, strain range end points. Calculate Poisson's ratio by Eq 7 and report the results. Also report the strain range used.

$\nu = -\Delta\varepsilon_t / -\Delta\varepsilon_l$ (7)

where:

ν = Poisson's ratio

$\Delta\varepsilon_t$=difference in lateral strain between the two longitudinal strain points of Table 2, με;

$\Delta\varepsilon_l$=difference between the two longitudinal strain points of Table 2 (nominally either 0.001, 0.002, or 0.005).

7. Validation

7.1 Values for ultimate properties shall not be calculated for any specimen that breaks at some obvious flaw and retests shall be performed for this type of specimen.

7.2 Reexamine the means of force introduction into the material if a significant fraction of failures in a sample population occur within one specimen width of the tab or grip. Factors considered should include the tab alignment, tab material, tab angle, tab adhesive, grip type, grip pressure, and grip alignment.

8. Test Report

8.1 The test report shall include the following:

8.1.1 A reference to International Standard

8.1.2 Any variations to test method, anomalies noticed during testing, or equipment problems occurring during testing.

8.1.3 Identification of the material tested including: material specification, material type, , filament diameter, tow or yarn filament count and twist, sizing, form or weave, fiber areal weight, matrix type.

8.1.4 Description of the fabrication steps used to prepare the laminate including: fabrication start date, fabrication end date, process specification, cure cycle, consolidation method, and a description of the equipment used.

8.1.5 Ply orientation stacking sequence of the laminate.

8.1.6 Report density, volume percent reinforcement, specimen sampling method and geometries, test parameters, and test results.

8.1.7 Average ply thickness of the material

8.1.8 Results of any nondestructive evaluation tests

8.1.9 Method of preparing the test specimen, including specimen labeling scheme and method, specimen geometry, sampling method, coupon cutting method, identification of tab geometry, tab material, and tab adhesive used.

TABLE 2 Specimen Alignment and Chord Modulus Calculation Strain Ranges

Tensile Chord Modulus Calculation Longitudinal Strain Range	
Start Point μ_ε	End Point μ_ε
1000	3000

8.1.10 Calibration dates and methods for all measurement and test equipment.

8.1.11 Type of test machine, grips, jaws, grip pressure, alignment results, and data acquisition sampling rate and equipment type.

8.1.12 Dimensions of each test specimen.

8.1.13 Temperature and humidity of the testing laboratory.

8.1.14 Number of specimens tested

8.1.15 Speed of testing.

8.1.16 Transducer type and transducer placement on the specimen for each transducer used.

8.1.17 If strain gages were used, the type, resistance, size, gage factor, temperature compensation method, transverse sensitivity, lead-wire resistance, and any correction factors used.

8.1.18 Tabulated data of stress versus strain and Stress-strain curves for each specimen.

8.1.19 Individual strengths and average value

8.1.20 Individual strains at failure and the average value strain range used for chord modulus and Poisson's ratio determination.

8.1.21 Individual values of modulus of elasticity

8.1.22 Failure mode and location of failure for each specimen.

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Tensile Properties of Resin-Impregnated yarn

Building & Transportation | Oil, Gas & Industrial | Offshore & Onshore | Water & Wastewater

DESCRIPTION

Carbon fibre composites are a unique material with exceptional mechanical properties and therefore widely utilized for structural applications in the aerospace, automotive, and wind energy sectors. Carbon fiber is used as a reinforcement material in carbon fiber reinforced plastic (CFRP). In the development of composite materials, understanding the respective mechanical properties of the matrix and the reinforcement material is important.

1. Scope

This guide specifies a method of test for the determination of the tensile strength, tensile modulus of elasticity and strain at maximum load of a resin-impregnated yarn specimen.This guide is applicable to yarns (continuous and staple-fibre yarns) for use as reinforcements in composite materials.

2. Principle

A sample of yarn is uniformly impregnated with resin, and then cured to provide test specimens.The specimen is then mounted in the grips of a mechanical testing machine and monotonically loaded in tension while the force is being recorded.
The tensile strength, the tensile modulus of elasticity and the strain at maximum load are obtained from the stress-strain response of the specimen.

3. Testing Apparatus

3.1 Tensile-testing Machine

3.1.1 Use a tensile-testing machine with a constant crosshead speed, equipped with force- and extension recording devices. The accuracy of the force indication shall be better than 1 % of the recorded value. The specimen-gripping system shall ensure that the test specimen is aligned with the axis of the test machine.

3.1.2 The tensile-testing machine shall include an extensometer linked to a continuous-recording device which automatically records the extension within the gauge length of the extensometer as a function of the force on the test specimen. The extensometer should be sufficiently light to induce only negligible stresses in the test specimen. The gauge length of the extensometer shall be at least 50 mm but preferably 100 mm.

3.2 Impregnation Apparatus

Test specimens can be prepared by single/multiple specimen preparation techniques which produce a uniformly impregnated, smooth specimen. A multiple-specimen impregnation apparatus may consist of:

3.2.1 A holder for the sample yarn bobbin, with yarn-tensioning devices.

3.2.2 An impregnation bath, with temperature-control devices and impregnation rollers or yarn-tensioning bars.

3.2.3 A unit to remove excess resin from the impregnated yarn by passing it over rollers covered with fabric, paper or felt and/or through a die.

3.2.4 A frame to wind up the impregnated yarn, preferably made of wood or metal coated with rubber

3.3 Balance

Use a balance readable to 0,1 g to weigh the test specimens to determine the linear density of the impregnated yarn.

3.4 Ruler

Use a graduated ruler or other measuring device at least 500 mm long and accurate to ± 1 mm.

4. Test Specimens

4.1 Number of test specimens

Test at least four specimens per test condition. If any of the specimens fails within the grips or at the tabs, or because of damage caused by the extensometer, discard the result and carry out a repeat determination on a fresh test specimen.

4.2 Length of Test Specimens

Specimens can be tested with or without tabs. If a test specimen fails within the grips of the tensile-testing machine, the result is not valid. Affixing tabs to the test specimen may help to reduce the frequency of such failures. They may also help to assure correct alignment of the test specimen in the grips. For test specimens with tabs, the length of the test specimen between the tabs shall be either (150 ± 5) mm or (200 ± 5) mm. For test specimens without tabs, the total length of the test specimen shall be (250 ± 5) mm or (300 ± 5) mm (at least the extensometer gauge length plus twice the grip length).

When tab preparation is required, the tab length is depended on tab type and shall be at least 50 mm. Note that, where tabs are used, the gripped length shall be at least 30 mm.

In cases of dispute, for test specimens with tabs, the length between the tabs shall be (150 ± 5) mm; for test specimens without tabs, the length of the test specimen shall be (250 ± 5) mm.

4.3 Impregnating Resin

The impregnating resin shall be compatible with the yarn and its size. The viscosity of the resin or resin solution shall be such that sufficient resin pick-up is achieved to ensure uniform impregnation.

Since different commercial resins are used in different conditions, the resin used to make the specimens should not be of the same commercial resins. The viscosity of the impregnating resin used in preparing the specimen should be in accordance with the proposal of valid codes and standards so that the fiber strength can be derived according to them.

Therefore it is recommended the strain at failure of the cured resin shall be at least twice that of the fibre, preferably three times. In this respect, heatcurable epoxy-resin systems with a viscosity during impregnation of preferably less than 1000 mPa.s are suitable. The resin formulation, however, shall be specified in detail.

4.4 Impregnation of Test Specimens

4.4.1 The procedure for using the impregnation apparatus is as follows:

4.4.2 Place the yarn bobbin on the holder.

4.4.3 Pour the impregnating-resin mixture into the resin bath and adjust the temperature and viscosity to the desired values.

4.4.4 Draw the yarn through the resin bath and through the system designed to remove the excess resin while ensuring adequate resin impregnation.

4.4.5. Adjust the unwinding tension. The unwinding tension used shall be at the discretion of the individual test laboratory.

4.4.6 Wind the impregnated yarn onto the frame.

4.4.7 Place the frame in the oven

4.4.8 Cure the resin in accordance with the resin manufacturer's instructions.

4.4.9 When the resin has been cured, remove the frame from the oven. After removal of the impregnated yarn from the frame, cut off a sufficient number of test specimens.

4.4.10 Select the test specimens according to the criteria given in 4.5.

4.5 Criteria for Selection of Test Specimens

4.5.1 Each test specimen shall be confirmed as straight when checked using a suitable jig. It shall be uniform in appearance and without any of the following defects:

- broken filaments
- resin droplets
- fibre misalignment

4.5.2 Resin Content

The resin content shall be at least 30% by mass. The resin content of the specimens is calculated from the linear density of the test specimen and the linear density of the yarn from the equation (1):

$$\text{Resin content (\%)} = (T_{ti}-T_{tf})/T_{ti} * 100 \quad (1)$$

Where:

T_{ti} is the linear density of the test specimen, in tex;

T_{tf} is the linear density of the yarn, in tex.

For each preparation batch, a control sample of each yarn type being tested shall be verified for correct resin content. If the resin content of the control sample is outside the acceptable range, each set of specimens from that batch shall be verified for correct resin content.

4.5.3 The yarn shall be uniformly impregnated.

4.6 Determination of Other Fibre Properties

4.6.1 General

In order to make the calculations of tensile strength and tensile modulus, the properties specified in 4.6.2 to 4.6.5 must be determined.

4.6.2 Linear Density of the Yarn

Determine the linear density of the yarn by the method given in ISO 1889.

4.6.3 Size content of the Yarn

Determine the size content of the yarn by the method given in ISO 10548.

4.6.4 Density of the Carbon Fibre

Determine the density of the carbon fibre by one of the methods given in ISO 10119.

4.6.5 Linear Density of Impregnated-Yarn Test

Measure the length of a test specimen, after it has been cut to length and prior to tabbing. Weigh the specimen. Calculate the linear density of the impregnated yarn by dividing the mass of the test specimen by its length, expressing the result in grams per kilometre (tex). Note: It is not necessary to determine the linear density of the impregnated yarn for each specimen.

4.6.6 Cross-sectional Area of Carbon-Fibre Yarn (A_f)

Before the tension testing, determine cross-sectional area of carbon-fibre yarn (A_f) as the linear density of the yarn divided by the density of the carbon fibre (Eq 2). Record the cross-sectional area of carbon-fibre yarn in units of mm^2.

$$A_f = (T_{tf}/\rho_f)*10^{-3} \quad (2)$$

Where:

T_{tf} is the linear density, in tex, of the yarn without size, calculated from the linear density determined in accordance with ISO 1889 and the size content determined in accordance with ISO 10548.

ρ_f is the density of the yarn, in grams per cubic centimetre, determined in accordance with ISO 10119.

4.7 Labeling

Label the specimens so that they will be distinct from each other and traceable back to the raw material and in a manner that will both be unaffected by the test and not influence the test.

5. Procedure for Tensile Testing

5.1 Specimen Insertion:

5.1.1 Place the specimen in the grips of the testing machine, taking care to align the long axis of the gripped specimen with the test direction. Tighten the grips, recording the pressure used on pressure controllable (hydraulic or pneumatic) grips.

5.1.2 For test specimens with tabs, install grips which fit the type of tab used.

5.1.3 For test specimens without tabs, install grips which are equipped with flat faces made of sheet materials of moderate elasticity and high coefficient of friction, such as hard rubber sheet.

5.2 Loading

Apply the force to the specimen at the specified rate until failure, while recording data.

5.3 If the test specimen fails within the grips or the tabs, or because of damage caused by the extensometer, discard the result and carry out a repeat test on a fresh test specimen.

5.4 Speed of Testing

Set the speed of testing to a nearly constant strain rate in the gage section. The maximum recommended speed is 250 mm/min.

5.5 Data Recording

Record force versus crosshead displacement (and force versus strain, if extensometers are utilized) continuously or at frequent regular intervals.

6. Expression of results

6.1 Tensile Strength/Tensile Stress

For each test specimen, calculate the ultimate tensile strength of the yarn using Eq 3. Calculate the arithmetic mean of the individual tensile-strength determinations and report as the result.

$\sigma_f = F_f/A_f$ (3)

where:

σ_f = tensile stress, MPa

F_f = ultimate tensile force, N

A_f = cross-sectional area of the yarn, mm^2

6.2 Tensile Modulus of Elasticity

6.2.1 Method A

The tensile modulus of elasticity as determined by Method A is calculated from the following equation:

$E_f = (\Delta F/A_f)*(L_0/\Delta L)*10^{-3}$ (4)

where:

E_f = the tensile modulus of elasticity, MPa

ΔF = the variation in the force, in newtons, corresponding to the variation in the length, in millimetres, between the strain limits defined in Table 1

A_f = cross-sectional area of the yarn, mm^2

L_0 = the gauge length of the extensometer, mm

ΔL = the variation in the length, in millimetres, corresponding to the variation in the force, resulting from the strain levels to be selected from Table 1.

6.2.2 Method B

The tensile modulus of elasticity as determined by Method A is calculated from the following equation:

$E_f = (\Delta F/A_f)*(L_0/\Delta L)*10^{-3}$ (5)

where:

E_f = the tensile modulus of elasticity, GPa

ΔF = the variation in the force, in newtons, corresponding to the variation in the length, in millimetres, between 400 mN/tex and 800 mN/tex

A_f = cross-sectional area of the yarn, mm^2

L_0 = the gauge length of the extensometer, mm

ΔL = the variation in the length, in millimetres, corresponding to the variation in the force, between 400 mN/tex and 800 mN/tex

6.3 Strain at Maximum Load (Percent Elongation at Failure)

The strain at maximum load can be determined by extensometry or by calculation from the tensile strength and tensile modulus. It is a dimensionless quantity, expressed as a percentage. Calculate the arithmetic mean of the individual strain determinations and report as the result.

6.3.1 The strain at maximum load ε_E as determined by extensometry is calculated from the following equation:

$\varepsilon_E = (L_u - L_0)/L_0*100$ (6)

where:

L_u= the gauge length of the extensometer at maximum load, mm

L_0= is the gauge length of the extensometer at zero load, mm

6.3.2 The strain at maximum load ε_C as determined by calculation from the tensile strength and tensile modulus is calculated from the following equation:

$\varepsilon_C = (\sigma_f)/E_f*0.1$ (7)

where:

σ_f = tensile stress, MPa

E_f= tensile modulus of elasticity, MPa

7. Validation

7.1 Values for ultimate properties shall not be calculated for any specimen that breaks at some obvious flaw and retests shall be performed for this type of specimen

7.2 Reexamine the means of force introduction into the material if a significant fraction of failures in a sample population occur within one specimen width of the tab or grip.

Factors considered should include the tab alignment, tab material, tab angle, tab adhesive, grip type, grip pressure, and grip alignment.

8. Test Report

8.1 The test report shall include the following:

8.1.1 A reference to International Standard

8.1.2 Any variations to test method, anomalies noticed during testing, or equipment problems occurring during testing.

8.1.3 Identification of the material tested including: material specification, material type, , filament diameter, tow or yarn filament count and twist, sizing, form or weave, fiber areal weight, resin type.

8.1.4 Description of the fabrication steps used to prepare the specimen including: fabrication start date, fabrication end date, process specification, cure cycle, and a description of the equipment used.

8.1.5 Report density, volume percent reinforcement, specimen sampling method and geometries, test parameters, and test results.

8.1.6 Average ply thickness of the material

8.1.7 Results of any nondestructive evaluation tests

8.1.8 Method of preparing the test specimen, including specimen labeling scheme and method, specimen geometry, sampling method, identification of tab geometry, tab material, and tab adhesive used.

8.1.9 Calibration dates and methods for all measurement and test equipment.

8.1.10 Type of test machine, grips, jaws, grip pressure, alignment results, and data acquisition sampling rate and equipment type.

8.1.11 Dimensions of each test specimen.

8.1.12 Temperature and humidity of the testing laboratory.

8.1.13 Number of specimens tested

8.1.14 Speed of testing.

8.1.15 Transducer type and transducer placement on the specimen for each transducer used.

TABLE 1 Relationship Between Fibre Type and Strain Limits

Strain at break ε typical of fibre type	Strain limits
ε ≥ 1.2 %	0.1 % to 0.6 %
0.6 % ≤ ε < 1.2 %	0.1 % to 0.3 %
0.3 % ≤ ε < 0.6 %	0.05 % to 0.15 %

NOTE The typical value of the strain at break (percent elongation at maximum load) may be determined by extensometry or calculated from typical strength and tensile-modulus values for the type of carbon fibre under test.

8.1.16 If strain gages were used, the type, resistance, size, gage factor, temperature compensation method, transverse sensitivity, lead-wire resistance, and any correction factors used.

8.1.17 Tabulated data of stress versus strain and Stress-strain curves for each specimen.

8.1.18 Individual strengths and average value

8.1.19 Individual strains at failure and the average value.

8.1.20 Individual values of modulus of elasticity