



**International  
Standard**

**ISO 19350**

**Recycled carbon fibre —  
Determination of tensile strength  
distribution and interfacial  
shear strength of single filament  
embedded in matrix polymer**

*Fibre de carbone recyclée — Détermination de la distribution  
de la résistance à la traction et de la résistance au cisaillement  
interfacial d'un filament unique noyé dans une matrice polymère*

**First edition  
2025-01**

STANDARDSISO.COM : Click to view the full PDF of ISO 19350:2025



**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2025

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

|   | Page      |
|---|-----------|
| <b>Foreword</b> .....                                 | <b>iv</b> |
| <b>Introduction</b> .....                             | <b>v</b>  |
| <b>1 Scope</b> .....                                  | <b>1</b>  |
| <b>2 Normative references</b> .....                   | <b>1</b>  |
| <b>3 Terms, definitions and symbols</b> .....         | <b>1</b>  |
| 3.1 Terms and definitions .....                       | 1         |
| 3.2 Symbols.....                                      | 1         |
| <b>4 Principle</b> .....                              | <b>2</b>  |
| <b>5 Tensile test machine and specimen</b> .....      | <b>2</b>  |
| 5.1 Tensile test machine .....                        | 2         |
| 5.2 Grip.....   | 2         |
| 5.3 Microscope.....                                   | 2         |
| 5.4 Test specimens.....                               | 2         |
| 5.5 Number of tests.....                              | 4         |
| <b>6 Testing technique</b> .....                      | <b>4</b>  |
| 6.1 Test procedure.....                               | 4         |
| 6.2 Validity of the test.....                         | 6         |
| <b>7 Calculation of results</b> .....                 | <b>6</b>  |
| 7.1 Summary of measurement data.....                  | 6         |
| 7.2 Calculation of tensile strength distribution..... | 7         |
| 7.3 Calculation of interfacial shear strength.....    | 8         |
| 7.4 Validity of the test result.....                  | 8         |
| <b>8 Reporting of test results</b> .....              | <b>9</b>  |
| <b>Bibliography</b> .....                             | <b>10</b> |

STANDARDSISO.COM : Click to view the full PDF of ISO 19350:2025

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 61, *Plastic*, Subcommittee SC 13, *Composite and reinforced fibre*.

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](http://www.iso.org/members.html).

## Introduction

The properties of recycled carbon fibres are potentially different from those of the original virgin carbon fibres. Therefore, it is very important to evaluate the properties of recycled carbon fibres in order to reuse them as reinforcing fibres. The tensile strength distribution and interfacial shear strength of recycled carbon fibres are essential for the production of composite materials using recycled carbon fibres. This document describes how to measure the tensile strength distribution and interfacial shear strength of recycled carbon fibres.

STANDARDSISO.COM : Click to view the full PDF of ISO 19350:2025

[STANDARDSISO.COM](https://standardsiso.com) : Click to view the full PDF of ISO 19350:2025

# Recycled carbon fibre — Determination of tensile strength distribution and interfacial shear strength of single filament embedded in matrix polymer

## 1 Scope

This document specifies methods for the simultaneous measurement of the fibre tensile strength distribution, and the fibre resin interfacial shear strength of recycled carbon fibres using the modified fragmentation test<sup>[1]</sup>.

## 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 10618, *Carbon fibre — Determination of tensile properties of resin-impregnated yarn*

ISO 11566, *Carbon fibre — Determination of the tensile properties of single-filament specimens*

ISO 11567, *Carbon fibre — Determination of filament diameter and cross-sectional area*

## 3 Terms, definitions and symbols

### 3.1 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology 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/>

### 3.2 Symbols

| Symbol                         |                                       | Definition   |
|--------------------------------|---------------------------------------|--|
| $E$                            | fibre tensile modulus, GPa            | Tensile modulus of the recycled carbon fibres                                    |
| $D$                            | average fibre diameter, $\mu\text{m}$ | Average fibre diameter of the recycled carbon fibres                             |
| $L$                            | Gauge length, mm                      | Initial distance between grips   |
| $l$                            | Total fibre length, mm                | Total length of a fibre within the observed area of all specimens                |
| $l_i$                          | Fibre length, mm                      | Length of a fibre within the observed area of each specimen $i$                  |
| $m$                            | Weibull shape parameter               | Shape parameter of the 2-parameters' Weibull distribution                        |
| $N(\epsilon_{\text{fibre}})$   | Total number of break points          | Total number of fibre break points in all specimens at $\epsilon_{\text{fibre}}$ |
| $\Delta$                       | Displacement, mm                      | Displacement given between gauges  |
| $\Delta\epsilon_{\text{film}}$ | Incremental film strain               | The magnitude of the strain on the film in each step                             |

| Symbol                                |  | Definition  |
|---------------------------------------|--|---|
| $\Delta n_i (\epsilon_{\text{film}})$ | Incremental number of fibre break points           | Incremental number of fibre break points within each specimen $i$ at $\epsilon_{\text{film}}$ .   |
| $\Delta N (\epsilon_{\text{fibre}})$  | Total incremental number of fibre break points     | Total incremental number of fibre break points within each specimen $i$ at $\epsilon_{\text{fibre}}$  |
| $\epsilon_{\text{film}}$              | Film strain  | Strain applied to the specimen film. Displacement divided by gauge length   |
| $\epsilon_0$                          | Thermal shrinkage                                  | In-plane film shrinkage strain during specimen moulding. In this document, the shrinkage direction is positive direction, and the expansion direction is negative direction |
| $\epsilon_{\text{fibre}}$             | Fibre strain                                       | Film strain minus thermal shrinkage during moulding   |
| $\lambda (\epsilon_{\text{fibre}})$   | Density of break points, $\text{m}^{-1}$           | Total break point number divided by fibre length  |
| $\lambda_{\infty}$                    | Saturated density of break points, $\text{m}^{-1}$ | Break point density at the end of tests   |
| $\tau$                                | Interfacial shear strength, MPa                    | Interfacial shear strength between recycled carbon fibre and matrix polymer   |
| $\sigma_0$                            | Weibull scale parameter, MPa                       | Scale parameter of the 2-parameters Weibull distribution  |

## 4 Principle

The tensile strength distribution (Weibull parameters) and interfacial shear strength of recycled carbon fibres are evaluated using a modified fragmentation test<sup>[1]</sup>. In this test, a single fibre embedded in a polymer film is pulled in steps and the number of fibre breaks at each step is counted. From the double logarithm graph of the fibre break point density and fibre strain, the fibre tensile strength distribution and interfacial shear strength are evaluated simultaneously, assuming that the strength of the recycled carbon fibre follows a two-parameter Weibull distribution.

## 5 Tensile test machine and specimen

### 5.1 Tensile test machine

The tensile test machine shall be able to measure the displacement applied to the specimen. In addition, the displacement of the crosshead of the machine shall be accurate to less than 1  $\mu\text{m}$ . To observe fibre breaks, the specimen should be observed at high magnification observation during the fragmentation test. Therefore, for example, the test machine should be placed under a microscope, or a microscope should be attached to the test machine.

### 5.2 Grip

For accurate measurement of displacement, the grips should be free of slippage. The gripping surfaces should be parallel in order to suppress local deformation of the film.

### 5.3 Microscope

A microscope capable of observing the break points of a single recycled carbon fibre should be used. Video or photographic documentation is preferred.

### 5.4 Test specimens

The specimen is a polymer sheet with a single recycled carbon fibre embedded at the centre.

The Young's modulus and fibre diameter of the fibre to which this document applies shall already be known using ISO 11567, and ISO 10618 or ISO 11566, respectively. The thermal shrinkage of the polymer shall also be known.

The sheet embedded recycled carbon fibre is produced by press moulding. Two polymer sheets with a thickness of more than 100 µm are prepared. In the case of thermosets, semi-cured sheets are used. A recycled carbon fibre is sandwiched between two polymer sheets. The sheets are pressed with a spacer more than 200 µm thick to control the thickness of the sandwiched sheet. In the case of a long recycled carbon fibre, the ends of the recycled carbon fibre should be fixed to prevent the fibre from bending during pressing. The pressing temperature is determined by the melting or curing temperature of the polymer used. It is desirable to press under vacuum to remove the air in the sandwich sheet.

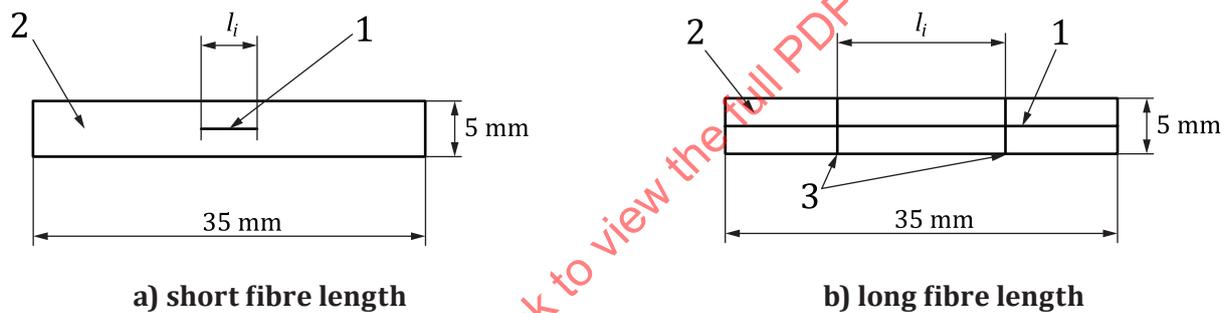
The specimen is prepared by cutting out a 5 mm × 35 mm from the sandwich sheet. The fibre should be at the centre of the film and the fibre axis should be parallel to the long side of the specimen.

Recycled carbon fibre from PAN-based or pitch-based CF can be used. The length of the recycled carbon fibre should be longer than 3 mm. The specimen thickness should be greater than 200 µm. The variation in specimen thickness should be less than 5 % to apply uniform strain.

Although thermosets or thermoplastics can be used as the polymer film material, transparency of the specimen is essential to confirm fibre breaks.

If the fibre length is longer than the observation area or if the strain is calculated from optical observations, draw the marker lines.

NOTE If the test machine is not capable of using standard specimens, the different film size can be used if the film thickness requirement is met.



- Key**
- 1 carbon fibre
  - 2 polymer film
  - 3 marker line

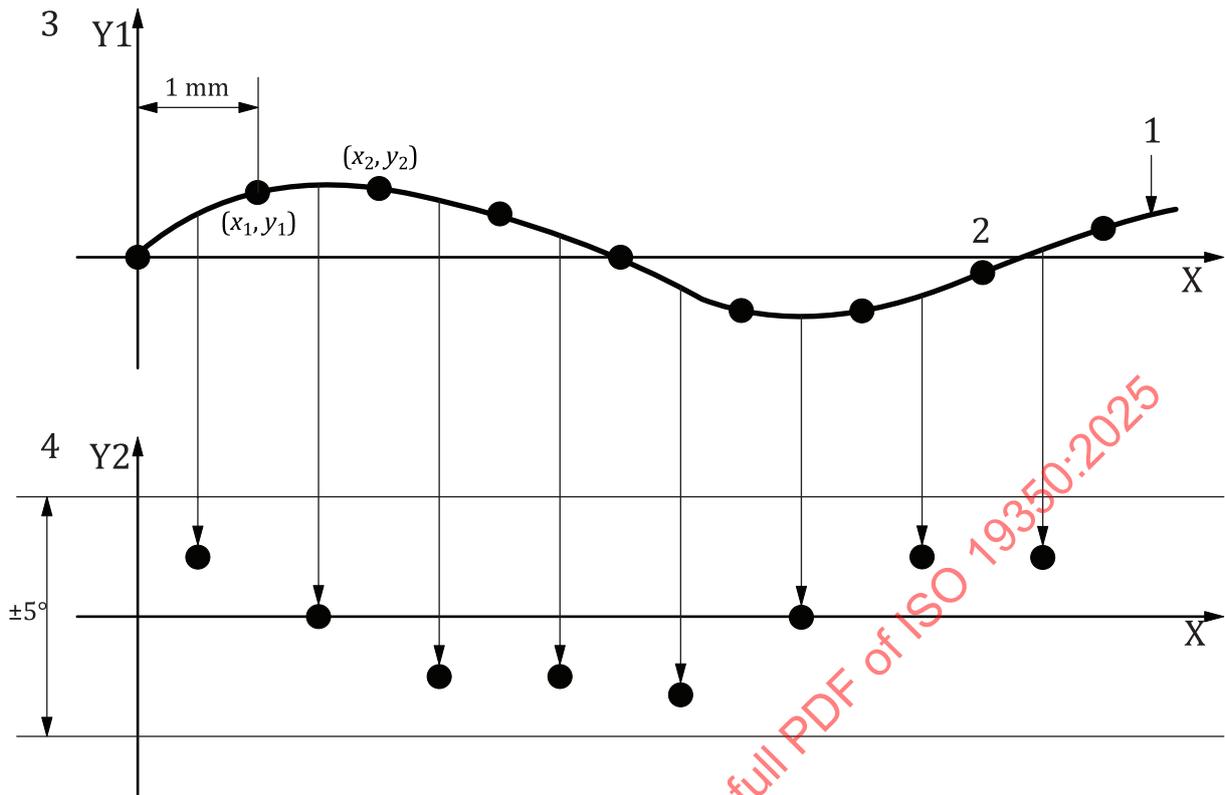
**Figure 1 — Test specimens for short fibre length and long fibre length comparing to observation area**

Check the straightness of the fibre in the specimen. Check the position of the fibre  $(x_i, y_i)$  approximately every 1 mm in the x-axis direction and calculate the straightness of the fibre using [Formula \(1\)](#), where the x-axis is in the tensile direction. If the observed point has a waviness of 5° or more with respect to the tensile direction, it shall not be accepted as a specimen.

$$\theta_i = \text{Arctan} \left( \frac{y_{i+1} - y_i}{x_{i+1} - x_i} \right) \quad (1)$$

where

- $\theta_i$  is the waviness angle.
- $x_i$  is the x coordinate position of i-th point.
- $y_i$  is the y coordinate position of i-th point.
- Arctan(x) is the inverse function of tan(x) .



**Key**

- X position in tensile direction of carbon fibre
- Y1 position in perpendicular to tensile direction of carbon fibre
- Y2 waviness angle of  $\theta$
- 1 carbon fibre
- 2 polymer film

**Figure 2 — Plots of (3) fibre position and (4) fibre waviness angle for checking fibre straightness**

**5.5 Number of tests**

The total fibre length,  $l$ , shall be at least 100 mm and preferably greater than 150 mm.

For example, if the fibre length,  $l_i$ , is 5 mm, at least 20 specimens should be prepared.

**6 Testing technique**

**6.1 Test procedure**

Place the specimen in the tensile test machine so that the gauge length,  $L$ , is 20 mm. When the film is held by the grips, the grips should hold the specimen evenly in the thickness direction.

The specimen should be gripped without wrinkles, because the wrinkles of the specimen lead to the error in the calculation of the strain. In order to attach the specimen without wrinkles, when one side of the film is gripped, the other side of the edge of the film is slightly tensioned and gripped in order to prevent wrinkles. The tension load should be less than 0,5 N.

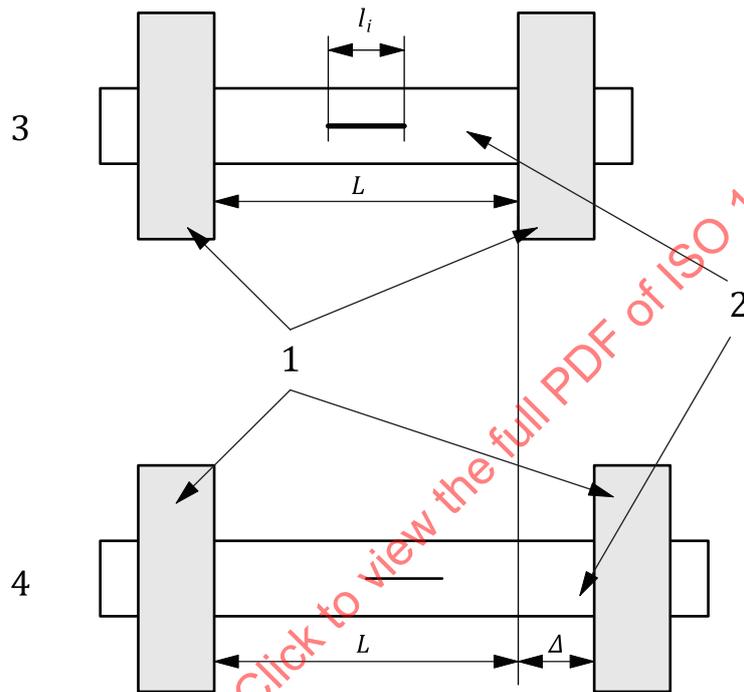
Start by stretching the film so that film strain,  $\epsilon_{\text{film}}$ , is 3,5 %. If many break points appear, change the specimen, and give a film strain smaller than 3,5 %.

Then apply the film strain,  $\epsilon_{\text{film}}$ , in steps and measure the incremental number of fibre break points,  $\Delta n_i(\epsilon_{\text{film}})$ , in the observation area. The incremental film strain,  $\Delta\epsilon_{\text{film}}$ , given in steps, should be less than 0,25 % up to 7,5 % and less than 0,5 % above 7,5 %. The strain rate should be less than 0,05 %/s and the maximum strain should be greater than 10 %.

NOTE 1 If observation records can be kept by videotaping or photography, the number of incremental fracture points can be determined from the records after the experiment.

NOTE 2 The incremental film strain,  $\Delta\epsilon_{\text{film}}$ , can be calculated from the amount of movement of the marker lines.

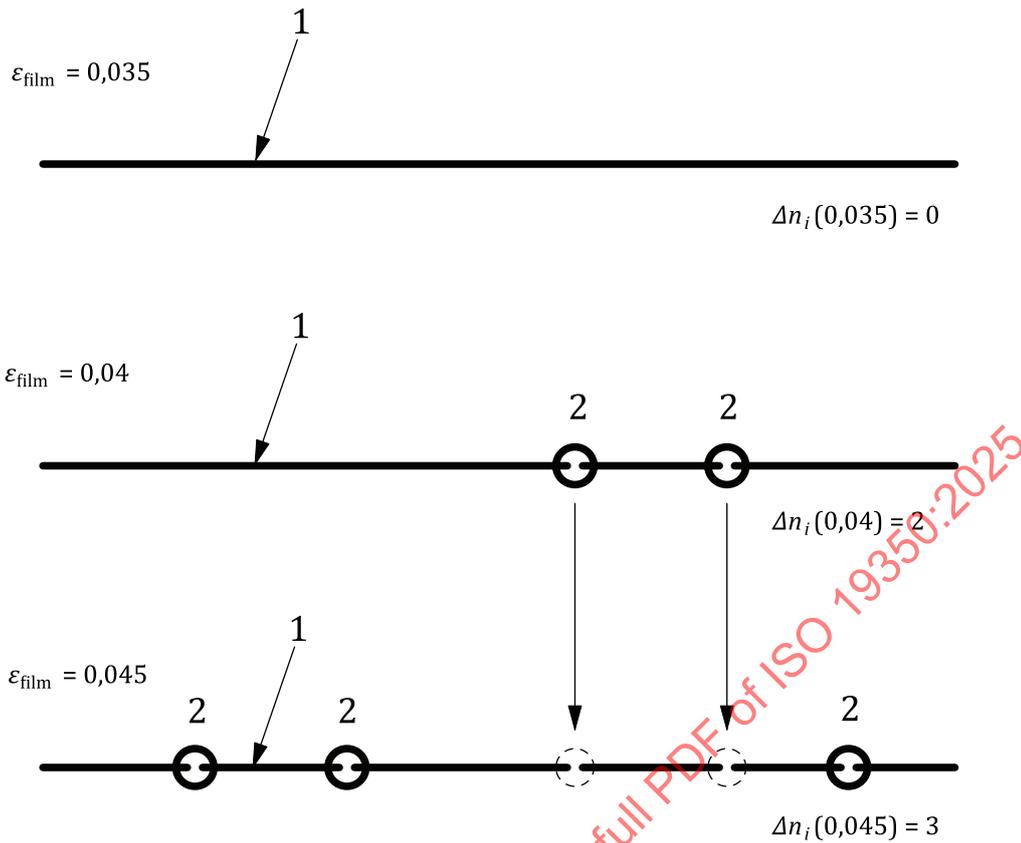
NOTE 3 If the test machine is not capable of using standard specimens, the gauge length can be changed if the strain requirement is met.



**Key**

- 1 grip
- 2 specimen

**Figure 3 — Schematic of the test for (3) initial position and (4) after deformation**



**Key**

- 1 carbon fibre
- 2 break

**Figure 4 — Method of counting incremental number of fibre break points**

**6.2 Validity of the test**

If a specimen is pulled out of the grips, the result shall be excluded.

If the specimen is locally deformed due to necking, etc., during the tensile test, the result shall be excluded.

If the number of break points does not reach saturation, the result shall be discarded.

**7 Calculation of results**

**7.1 Summary of measurement data**

The fibre strain,  $\epsilon_{\text{fibre}}$ , is given by [Formula \(2\)](#):

$$\epsilon_{\text{fibre}} = \epsilon_{\text{film}} - \epsilon_0 \tag{2}$$

where:  $\epsilon_{\text{film}}$  is the film shrinkage;  $\epsilon_0$  is thermal shrinkage.

The total number of break points,  $N(\varepsilon_{\text{fibre}})$ , at each fibre strain,  $\varepsilon_{\text{fibre}}$  is given by [Formula \(3\)](#):

$$N(\varepsilon_{\text{fibre}}) = \sum_{\varepsilon \leq \varepsilon_{\text{fibre}}} \Delta N(\varepsilon) \quad (3)$$

where  $\Delta N(\varepsilon_{\text{fibre}})$  is the total incremental number of break points and given by [Formula \(4\)](#):

$$\Delta N(\varepsilon_{\text{fibre}}) = \Delta N(\varepsilon_{\text{film}} - \varepsilon_0) = \sum_i \Delta n_i(\varepsilon_{\text{film}}) \quad (4)$$

where  $\Delta n_i(\varepsilon_{\text{film}})$  is the incremental number of fibre break points of each specimen.

The density of break points,  $\lambda(\varepsilon_{\text{fibre}})$  is given by [Formula \(5\)](#):

$$\lambda(\varepsilon_{\text{fibre}}) = \frac{N(\varepsilon_{\text{fibre}})}{l} \quad (5)$$

Where  $l$  is the total fibre length and given by [Formula \(6\)](#):

$$l = \sum_i l_i \quad (6)$$

where  $l_i$  is the fibre length of each specimen.

## 7.2 Calculation of tensile strength distribution

Plot a double logarithm graph of both the breakpoint density,  $\lambda(\varepsilon_{\text{fibre}})$ , and the fibre strain,  $\varepsilon_{\text{fibre}}$ .

Find the slope of the graph,  $a$ , and the intercept of the graph,  $b$ , by linearly fitting the linear part of both logarithmic graphs in the low strain region.<sup>[1]</sup> Find the density of saturated break points,  $\lambda_{\infty}$ , from the maximum value of the breakpoint density.

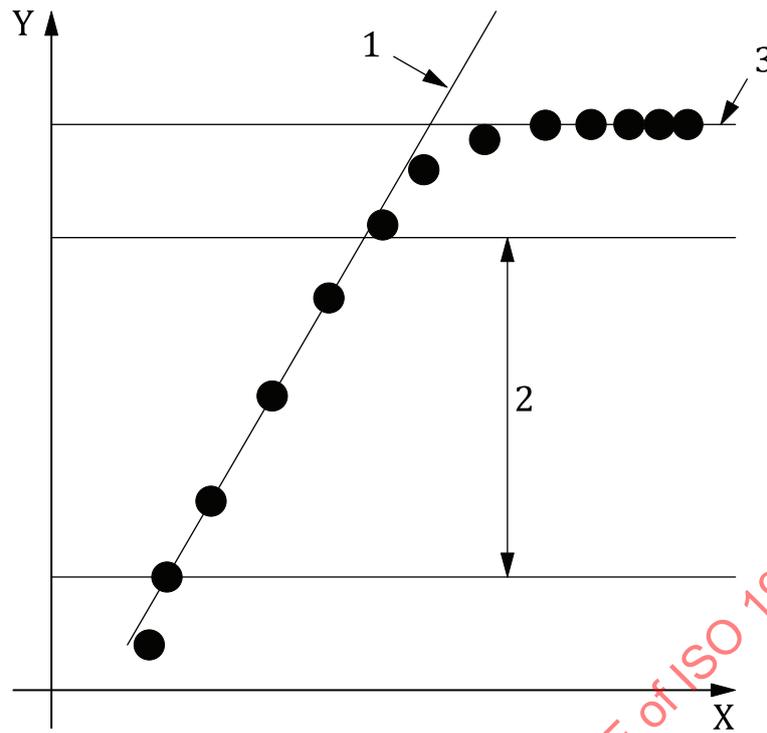
Calculate the Weibull parameter and the interfacial shear strength.

Weibull shape parameter,  $m$ , is given by [Formula \(7\)](#):

$$m = a \quad (7)$$

Weibull scale parameter,  $\sigma_0$ , is given by [Formula \(8\)](#):

$$\sigma_0 = E \exp\left(-\frac{b}{a}\right) \quad (8)$$



**Key**

- X  $\ln(\epsilon - \epsilon_0)$
- Y  $\ln(\lambda)$
- 1 fitting line
- 2 fitting range
- 3  $\ln(\lambda_\infty)$

**Figure 5 — Double logarithm graph of the density of break points and the fibre strain**

**7.3 Calculation of interfacial shear strength**

The interfacial shear strength,  $\tau$ , is given by [Formula \(9\)](#):

$$\tau = \frac{3D\sigma_f}{2l_c} \tag{9}$$

where  $l_c$  is the critical fibre length, and  $\sigma_f$  is the fibre strength.

The critical fibre length,  $l_c$ , and the fibre strength,  $\sigma_f$ , are given by [Formulae \(10\)](#) and [\(11\)](#), respectively:

$$l_c = \frac{4}{3(\lambda_\infty + 1)} \tag{10}$$

$$\sigma_f = \sigma_0 \left( \frac{l_c}{L_0} \right)^{\left( \frac{-1}{m} \right)} \Gamma \left( 1 + \frac{1}{m} \right) = \sigma_0 \left( \frac{4}{3L_0(\lambda_\infty + 1)} \right)^{\left( \frac{-1}{m} \right)} \Gamma \left( 1 + \frac{1}{m} \right) \tag{11}$$

where  $\Gamma(x)$  is the gamma function.

**7.4 Validity of the test result**

The following results are unacceptable.