# INTERNATIONAL STANDARD

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# Carbon-fibre-reinforced plastics — Determination of compression-after-impact properties at a specified impact-energy level

*Plastiques renforcés de fibres de carbone — Détermination des propriétés de compression après impact à un niveau d'énergie spécifié*



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# Contents

Page

## 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18352 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.



# Carbon-fibre-reinforced plastics — Determination of compression-after-impact properties at a specified impact-energy level

## 1 Scope

This International Standard specifies a method for determining the residual compression strength of multidirectional polymer matrix composite laminate plates that have been damaged by impact prior to the application of in-plane compressive loading.

The test method is suitable for continuous-fibre-reinforced polymer matrix composites. Application of the method is limited to fibre-reinforced plastic laminates with multidirectional reinforcements manufactured from unidirectional prepreg tapes/fabrics or woven fabrics.

The test method is referred to as the compression-after-impact (CAI) test when used to determine the residual compression strength of an impacted plate. It can be used to obtain data for material specification, material evaluation, research and development, or construction of a composite database.



## 2 Normative references



The following referenced documents are indispensable for the application 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 1268-4:2005, *Fibre-reinforced plastics — Methods of producing test plates — Part 4: Moulding of prepregs*

ISO 5893, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

ISO 14127, *Carbon-fibre-reinforced composites — Determination of the resin, fibre and void contents*

ISO 80000-1:—[1], *Quantities and units — Part 1: General*

1) To be published. (Revision of ISO 31-0:1992)

## 3 Terms and definitions

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

**3.1**
**compression-after-impact test**
**CAI test**
in-plane compression test undertaken on a composite laminate loaded in the plane of the laminate, after applying an out-of-plane concentrated impact load under defined conditions

**3.2**
**specified impact energy**
potential energy of the drop-weight, specified by the mass and drop height of the indenter, to which composite laminate specimens will be subjected, expressed in joules

**3.3**
**barely visible impact damage**
**BVID**
impact damage corresponding to a dent depth of 0,3 mm

**3.4**
**energy to cause BVID**
$E_{\mathrm{BVID}}$
impact energy required to cause BVID, expressed in joules



**3.5**
**compression-after-impact strength**
$\sigma_{\mathrm{CAI}}$
maximum compressive load sustained by the impacted specimen divided by the initial cross-sectional area of the specimen, expressed in $\mathrm{MN/m^2}$



**3.6**
**compression-after-impact modulus**
$E_{\mathrm{CAI}}$
compression modulus of the specimen calculated between 0,05 % and 0,25 % strain, expressed in $\mathrm{GN/m^2}$

**3.7**
**maximum compressive strain**
$\varepsilon_{\mathrm{cmax}}$
maximum value of the compressive strain sustained by the specimen at the maximum compressive load

**3.8**
**dent depth**
residual depth of the depression formed by the indenter after the impact event, expressed as the maximum distance, in millimetres, in a direction normal to the face of the specimen from the lowest point in the dent to the plane of the undisturbed impact surface

**3.9**
**damage parameters**
quantities used to characterize the extent of impact damage, including the maximum diameter of the delamination and the projected area of the delamination

## 4 Principle

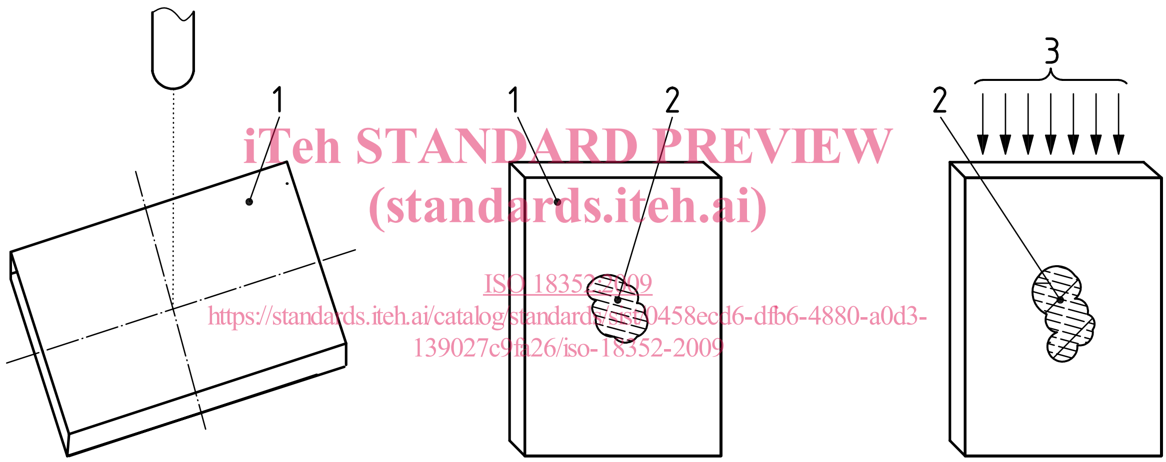
The CAI test detailed in this International Standard consists of three phases as depicted in Figure 1.

The first phase is to generate barely visible impact damage (BVID), avoiding penetration of the test plate. The preferred method of introducing BVID is based on a specified level of impact energy applied to one face of a specimen made of a balanced and symmetrical composite laminate.

NOTE An alternative method allows the operator to vary the level of impact energy in order to determine the energy level required to cause BVID. An additional ISO method will be proposed and drafted to cover this method of setting the impact energy.

The second phase consists of assessing the level of impact damage by non-destructive testing (NDT) [also referred to as non-destructive inspection (NDI)] and by measurement of the dent depth on the impacted face. The area and geometry of the damage created by the impact shall be measured by means of an appropriate non-destructive testing technique, and the dent depth measured by a suitable device.

Measurement of residual in-plane compression properties is undertaken in the third stage. A compressive load is applied to the impacted specimen until failure occurs. The CAI strength, modulus and strain are calculated from the load strain data collected, as detailed in Clause 10.





**a) Impact test configuration** **b) Non-destructive testing and dent depth measurement** **c) Compression test**

**Key**

1 specimen
2 delamination
3 compressive load, $F$

**Figure 1 — Principle of the compression-after-impact test**

A flat, rectangular composite plate is subjected to a transverse, concentrated impact using a drop-weight device with a hemispherical indenter. The energy of the impact, determined by the mass and drop height of the indenter, is specified. Equipment and procedures are prescribed for measurement of the contact force and the indenter velocity during the impact event. Damage resistance is quantified in terms of the extent and type of damage present in the specimen after impact.

After impact, an in-plane compressive load is applied to the specimen until failure, and the compression-after-impact strength, modulus and strain are calculated from the recorded load-strain response.

The properties measured by this test method are highly dependent upon several factors, including specimen geometry, laminate lay-up, indenter geometry, indenter mass, impact energy, impact force, damage size and location and support conditions. Thus, the results are generally not comparable to other CAI test configurations but are particular to the specific combination of geometric and physical test parameters used.

The test does not provide information to satisfy structural-integrity and safety requirements. It is the responsibility of the user to consider and establish appropriate structural-integrity limits and safety factors.

## 5 Conditioning of specimens and test environment

### 5.1 Standard conditioning procedure for specimens

Specimens shall be conditioned at (23 ± 2) °C and (50 ± 10) % RH unless different conditions are agreed upon by the interested parties.

### 5.2 Environmental test chamber for impact and compression tests

An environmental test chamber is required for test environments other than ambient. The chamber shall be capable of maintaining the test specimen at the required temperature and humidity throughout the test. Tests shall be conducted in the same environment as the specimens were conditioned in. When the interested parties agree, it is permitted to undertake impact and compression tests under ambient conditions after hot-wet conditioning procedures.

NOTE The impact and compression properties of fibre-reinforced plastics are affected by moisture absorption.

## 6 Test apparatus

### 6.1 General



The test apparatus consists of an impact facility, a specimen support fixture, suitable non-destructive testing equipment, a compression-testing machine, a compression fixture, tools for measurement of the specimen dimensions and a strain measurement system. Details of each of these items are provided in the following subclauses.

### 6.2 Impact facility

The impact facility shall be fitted with a steel drop-weight indenter with a hemispherical head (16 ± 0,1) mm in diameter. The impact facility shall be mounted on a rigid base and have a suitable guide mechanism for the drop-weight indenter, as shown in Figure 2. The indenter shall impact the centre of the top surface of the specimen by dropping under gravity with minimal friction effects from the guide rails. A second-strike prohibition mechanism shall be employed to ensure that specimens are only impacted once, i.e. to prevent bouncing of the indenter and therefore multiple strikes. The recommended mass of the indenter is 5 kg to 6 kg and the hardness of the indenter tip shall be between 60 HRC and 62 HRC (Rockwell, diamond cone, 150 kg). The minimum drop height is determined by the mass of the indenter, the specimen thickness and the specified impact energy, as given in 8.3.

NOTE The use of an instrumented impact facility capable of measuring indenter velocity and indentation forces and having a data acquisition system is preferred. ISO 6603-1 and ISO 6603-2 are suggested as references.

### 6.3 Support fixture for specimen during impact test

The specimen support fixture shall hold the specimen flat against the support frame during impact, holding it down with sufficient, but not excessive, force at its four corners using rubber-tipped toggle clamps. The fixture shall consist of a base 18 mm thick made of steel with a surface which is flat to within 0,1 mm in the region of contact with the specimen. The base-plate shall contain a window (125 ± 1) mm in length and (75 ± 1) mm in width. An example of a suitable support is shown in Figure 3.

The support fixture shall be supported rigidly on a solid base such as the impact facility or the room floor.

**Key**

1 indenter
2 crosshead
3 latch mechanism
4 guide rail
5 velocity sensor
6 stop block
7 base-plate

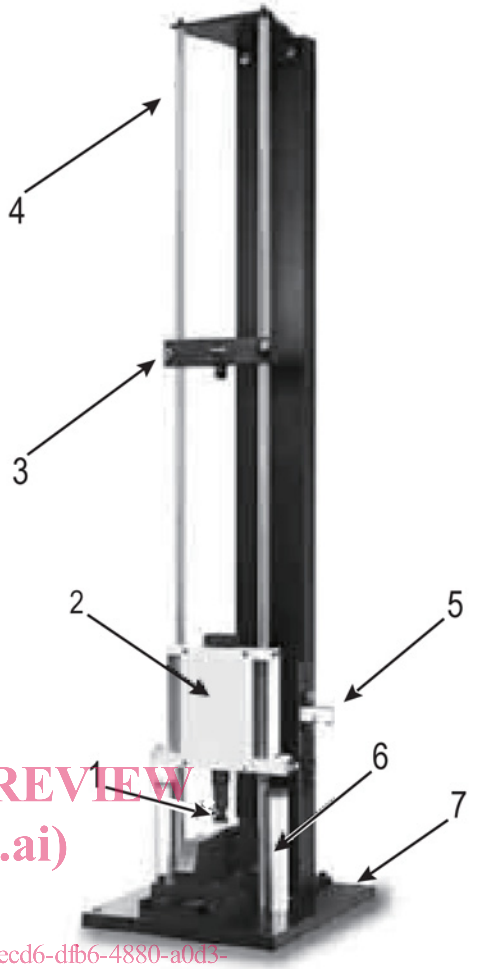





**Figure 2 — Instrumented drop-weight impact device with double guide rails**

Dimensions in millimetres

**Key**

1 specimen
2 guide pin
3 rubber bush
4 (75 ± 1) mm × (125 ± 1) mm window
5 base-plate

a 1 mm × 45° chamfer.

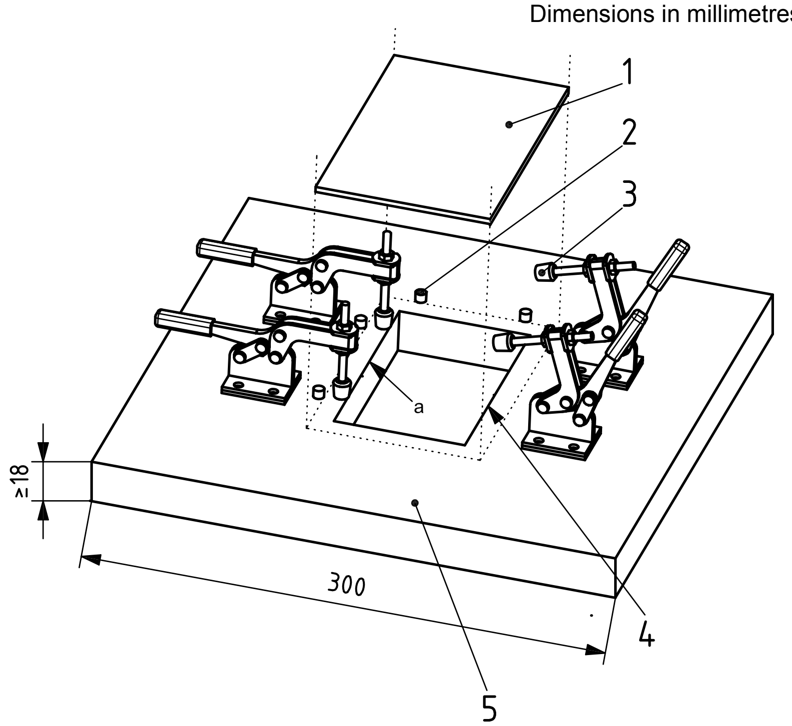



**Figure 3 — Example of a specimen support fixture**

## 6.4 Non-destructive testing instrument

Non-destructive testing shall be undertaken using a technique capable of detecting delamination damage created by impact between laminae in the specimen. Although the recommended technique is ultrasonic C-scan (using traceable procedures as detailed in Reference [1]), other proven techniques including X-ray radiography with penetrant and pulse thermography may be used for determining delamination extent as well, whereas X-ray radiography with penetrant is usually used for detecting fibre breakage and matrix cracks in laminae. From the image, the edge of the delamination can be identified. Commercially available pulse thermography systems can be used for delamination detection with almost the same reliability as ultrasonic C-scan.

## 6.5 Compression-testing machine

### 6.5.1 General

The test machine shall comply with ISO 5893 and meet the specifications given in 6.5.2 and 6.5.3.

### 6.5.2 Test speed and configuration

The test machine shall be capable of maintaining the required test speed (see 8.6.3). A short loading train and flat end-loading platens shall be used. The test machine shall be mounted with well-aligned, fixed (as opposed to spherical-seat) platens. The platen surfaces shall be parallel to within 0,03 mm across the test fixture top-plate length of 100 mm. If the platens are not sufficiently hardened, or simply to protect the platen surfaces, a hardened plate (with parallel surfaces) can be inserted between each end of the fixture and the corresponding platen. The lower platen should preferably be marked to help centre the test fixture between the platens.



### 6.5.3 Indication of load

The error in the indicated load shall not exceed ± 1 %.



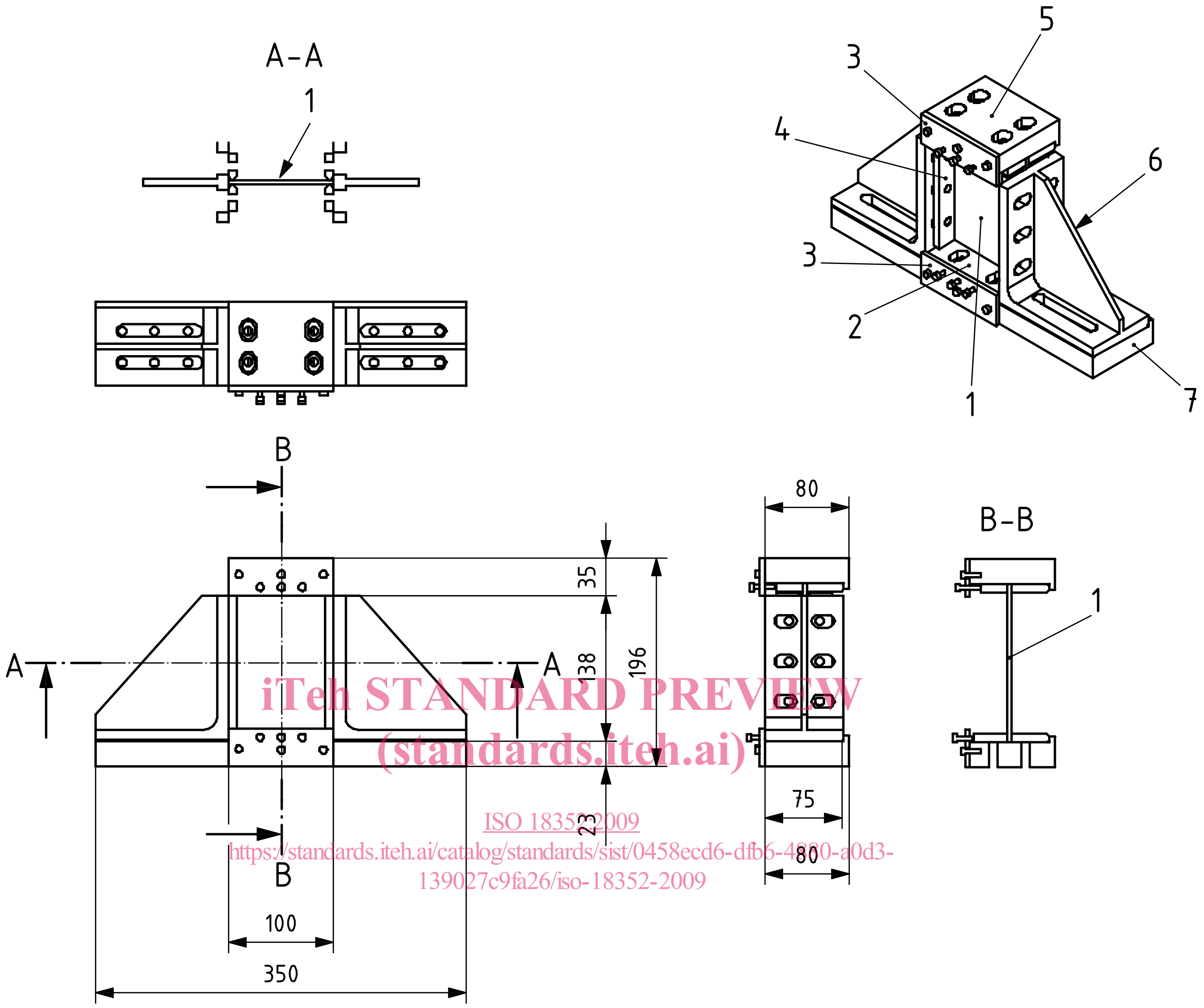
## 6.6 Compression-loading fixture

The compression-loading fixture (see Figure 4) shall be designed to provide support to the specimen and to introduce an in-plane compressive load perpendicularly to its upper and lower edges. The support conditions at the four edges of the specimen shall be as follows: the specimen shall be supported in a way which approximates to simple support using knife edges along the longitudinal sides (translational motion of the specimen in the out-of-plane direction prevented, but rotation allowed) and the upper and lower edges shall be clamped in a way which prevents, as far as possible, both translational motion in the out-of-plane direction and rotational motion of the edges of the specimen. The fixture shall be adjustable to accommodate small variations in specimen length, width and thickness. The sliding edges shall be sufficiently short to ensure that a gap is maintained between each lateral angle bracket and the upper platen during the test. An example of a suitable compression-loading fixture is shown in Figure 4. Detailed drawings of each component, including dimensional tolerances, are provided in Annex A. The test fixture may be made of low-carbon steel for ambient-temperature testing. For non-ambient environmental conditions, the recommended fixture material is non-heat-treated ferritic or precipitation-hardened stainless steel (heat treatment for improved durability is acceptable but not required).

Prior to the test, the fixtures shall be checked for conformity with the dimensions specified in Annex A. The position of the lateral angle brackets shall be adjusted such that 0,8 mm to 1,5 mm clearance will be present between each bracket and the longitudinal edge of the test specimen. The fixture shall be placed between the platens and loaded in compression at each end.

NOTE This test is sensitive to the parallelism of the specimen ends as well as to the precise perpendicularity of the various components of the compression-loading fixture. Experience has shown that fixtures may be damaged in use, thus periodic verification of the fixture dimensions and tolerances is important.

Dimensions in millimetres






**Key**

1 specimen
2 lower clamp plate
3 clamp
4 sliding edge
5 upper platen
6 lateral angle bracket
7 base-plate

**Figure 4 — Example of a compression-loading fixture**

## 6.7 Measuring apparatus

### 6.7.1 Micrometer

A micrometer, or equivalent, capable of reading to 0,01 mm or better, shall be used to determine the thickness and width of the specimen. The micrometer head shall have faces appropriate to the surface being measured (i.e. flat faces for flat, polished surfaces and hemispherical faces for irregular surfaces).

A micrometer with a suitable attachment may also be used for the measurement of the depth of the dent caused by the indenter on impact, as described in 8.5 (see Figure 5). For such measurements, the micrometer head shall be hemispherical with a diameter of 1,5 mm to 5,0 mm. The length of the attachment shall not be less than 40 mm.