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English Version

# Impact attenuating playground surfacing - Methods of test for determination of impact attenuation

Sols d'aires de jeux absorbant l'impact - Méthodes d'essai pour la détermination de l'atténuation de l'impact

Stoßdämpfende Spielplatzböden - Prüfverfahren zur Bestimmung der Stoßdämpfung

This European Standard was approved by CEN on 29 October 2017.

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# Contents

Page

## European foreword

This document (EN 1177:2018) has been prepared by Technical Committee CEN/TC 136 “Sports, playground and other recreational facilities and equipment”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2018, and conflicting national standards shall be withdrawn at the latest by July 2018.

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

This document supersedes EN 1177:2008.

European standards for playground equipment and surfacing comprise this European Standard and the EN 1176 series, which consists of a number of parts as follows:

— *Part 1: General safety requirements and test methods*

— *Part 2: Additional specific safety requirements and test methods for swings*

— *Part 3: Additional specific safety requirements and test methods for slides*

— *Part 4: Additional specific safety requirements and test methods for cableways*

— *Part 5: Additional specific safety requirements and test methods for carousels*

— *Part 6: Additional specific safety requirements and test methods for rocking equipment*

— *Part 7: Guidance on installation, inspection, maintenance and operation*

— *Part 10: Additional specific safety requirements and test methods for fully enclosed play equipment*

— *Part 11: Additional specific safety requirements and test methods for spatial network*

This standard should also be read in conjunction with:

— EN 1176:2017 series

— CEN/TR 16467:2013, *Playground equipment accessible for all children*

— CEN/TR 16598:2014, *Collection of rationales for EN 1176 - Requirements*

— CEN/TR 16396:2012, *Playground equipment for children, replies to requests for interpretation of EN 1176:2008 and its parts*

For inflatable play equipment, see EN 14960, *Inflatable play equipment — Safety requirements and test methods*.

The principal changes from the previous edition of this European Standard are as follows:

a) European foreword: References to CEN/TRs added.

b) Introduction: Rationale for retaining HIC 1 000 and introducing $g_{\text{max}}$ 200 as upper limits for surfacing when assessed in accordance with this standard has been added.

c) Scope: Two methods of impact testing are now provided. Method 1 (as in the previous edition) – Test for determination of Critical Fall Height AND new Method 2 – Test for measurement of impact attenuation on site to enable, upon installation or at periods later in its life, confirmation as required of suitability of the product for that specific site location at the time of the test.

d) Body of standard:

   1) change of the order and adding new clauses by implementation of Method 2;

   2) adaption of recent technology for requirements on test apparatus and measurements in order to improve accuracy of results (including checks by operators);

   3) adapting Annex B and adding new Annexes C, D, E and F.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

# Introduction

This European Standard is based on the safety principles given in EN 1176-1 for playground equipment and provides a method for the assessment of impact attenuation of surfaces intended for use in the impact area as defined in EN 1176-1. This standard (EN 1177) aims to reduce consequences of experiencing risks that are desirable for child development according to the principles set in EN 1176-1.

Injuries arise during the use of playground equipment for a variety of reasons and the great majority are minor. Even the presence of protection features like impact attenuating surfacing is known to affect the behaviour of children, as well as carers and play providers, which in turn can affect the risk. The majority of more serious injuries are attributable to falls and there are many factors that influence injury mechanisms during a fall that are independent of the surfacing, e.g. body orientation, awkwardness of fall, bone density, etc.

The most severe injuries are likely to be injuries to the head. Recent research has indicated that arm and leg injuries are more frequent and could be influenced by the duration of the acceleration pulse. The committee responsible for this European Standard maintains a constant review of research in this area for possible use in a future revision of this standard. The committee recognizes that there is a relationship between the risk of arm and leg injuries and surface type but takes the view that such injuries are not usually in the most severe category. At present the available injury data can be taken into account by limitation of the maximum (peak) acceleration.

Consequently, the committee has chosen to make its priority the reduction of the likelihood of serious head injuries caused by a fall from playground equipment, because even though such injuries are relatively uncommon, they can have the most severe consequences. The severity of injury resulting from an impact to the head can be quantified in terms of Head Injury Criterion (HIC) and the level of HIC = 1 000 together with the upper limit of the peak acceleration of $g_{\text{max}} = 200g$ ( $g$ for gravity) have been chosen as the upper limits for surfacing when assessed in accordance with this standard.

Limiting the HIC value at a maximum of 1 000 is equivalent to a 3 % chance of a critical head injury (MAIS[1] 5), an 18 % probability of a severe (MAIS 4) head injury, a 55 % probability of a serious (MAIS 3) head injury, a 89 % probability of a moderate head injury (MAIS 2), and a 99,5 % chance of a minor head injury (MAIS 1), to an average male adult.

Limiting $g_{\text{max}}$ to a maximum of $200g$ as well as limiting HIC to a maximum of 1 000 takes account of impacts of very short duration and follows the current research on arm injuries as a means of improvement to the Standard.

Two methods of impact tests are provided. The first method is for determination of the Critical Fall Height to enable full and detailed confirmation of a product's range of suitability. The second method describes an on-site drop test, without determination of critical fall height to enable, upon installation or at periods later in its life, confirmation as required of the performance of the surfacing in that specific site location at the time of the test.

The EN committee is aware of discussions within ASTM International since 2014 about a reduction in the HIC threshold to 700 in its corresponding standard. The current limiting value of HIC ≤ 1 000 has been used in Europe since 1998 and the EN committee considers that at present, there is insufficient evidence of net overall value to playground users to support a change. It has therefore chosen to retain the value HIC ≤ 1 000 and to provide a second threshold of $200g$ as the criteria of acceptability in this standard, whilst continuing to monitor research publications on this subject. The same has been decided by ASTM for the time being.

[1] Maximum Abbreviated Injury Scale, first developed by the Association for the Advancement of Automotive Medicine and used extensively in the automotive industry as an indicator of the severity of head-related injuries.

A variety of materials, both natural and synthetic, may be used as impact attenuating surfacing with different attributes and performance. These include grass growing in soil, sand, wood chips, bark, gravel, and various rubber-based products which may be in the form of tiles or continuous coatings or combinations of these materials. Whilst the methods described in this Standard can be used to assess the impact attenuation performance of any of these surfaces, attention of users is drawn that the behaviour of some materials can be highly variable and dependent on prevailing test conditions and that test results will likely vary over time or with climatic conditions.

# 1 Scope

This European Standard specifies the test apparatus and the impact test methods for determining the impact attenuation of surfacing by measuring the acceleration experienced during impact. Test apparatus in compliance with this standard are applicable to tests carried out in a laboratory or on site by either methods described.

NOTE The test methods described in this standard are also applicable for impact areas required in other standards than for playground equipment, e.g. for outdoor fitness equipment and parkour equipment.

# 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 933-1, *Tests for geometrical properties of aggregates — Part 1: Determination of particle size distribution — Sieving method*

EN 1176-1:2017, *Playground equipment and surfacing — Part 1: General safety requirements and test methods*

EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025)*

# 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1176-1 and the following apply.

**3.1**
**impact attenuation**
property of a surface, which dissipates the kinetic energy of an impact by localized deformation or displacement in such a way that the acceleration experienced by the impacting object is reduced

**3.2**
**impact attenuating surfacing**
IAS
surfacing intended to reduce the risk of injury when falling onto it

Note 1 to entry: product or material having the inherent ability to attenuate the impact of a user falling onto it

**3.3**
**critical fall height**
CFH
maximum Free Height of Fall (FHF), for which a surface will provide an adequate level of impact attenuation, determined by test Method 1 as described in Clause 6 of this standard

**3.4**
**head injury criterion**
HIC
measure of the severity of a head injury likely to arise from an impact, determined as described in Clause 5 of this standard

**3.5**
**peak acceleration**
$g_{max}$
maximum acceleration $a$ experienced by the headform during an impact, expressed in units of $g$ (gravity)

**3.6**
**impact measurement**
HIC value and $g_{max}$ calculated from the recorded acceleration $a$ (in $g$) of the headform falling from one drop height onto one test position of the surface (see 5.1)

**3.7**
**test position**
position on the surface to be tested, located vertically below the centre of the headform

**3.8**
**drop height**
Free Height of Fall, measured between the test position on the surface and the lowest point of the free falling headform prior to release; or, in the case of a guided headform, calculated from measurement of headform velocity immediately prior to impact

**3.9**
**drop test**
procedure for conducting impact measurements on one test position of the impact area

Note 1 to entry: The number of drops and the drop heights of drop tests are specified separately in Method 1 for specific types of products (see 6.2.4) and in Method 2 for all types of surfacing material (see 6.3.5).

**3.10**
**loose particulate material**
material consisting of separate, un-bound pieces of a substance

Note 1 to entry: Sand, gravel, bark and wood chips are examples of loose particulate materials.

**3.11**
**impact area**
area that can be hit by a user after falling through the falling space

**3.12**
**test zone**
subdivision of the impact area for the purpose of verification of impact attenuation. All test zones to be verified constitute the impact area of the equipment (see 5.2).

# 4 Test apparatus

## 4.1 Suitability

The same apparatus and recording procedures are used for the two methods of test described in this standard.

## 4.2 Components of the apparatus

### 4.2.1 General

The equipment comprises: a headform (4.2.2) fitted with one or more accelerometer(s) (4.2.2.3 a or b), optionally a signal conditioner (4.2.3), a release system for the headform (4.2.6), means for measuring the effective free fall height (4.2.5), a signal transmission system (4.2.7) and an impact measuring equipment (4.2.8).

If using a uniaxial accelerometer, a guidance system for the headform shall be provided (4.2.4).

Principle of apparatus see Figure A.1.

### 4.2.2 Headform

**4.2.2.1** The headform shall consist of either

a) an aluminium alloy ball; or

b) a hemispherical ended aluminium alloy missile.

**4.2.2.2** The headform shall have a diameter of 160 mm ± 5 mm, a mass of 4,6 kg ± 0,05 kg, with a maximum deviation from the hemispheric surface of 0,5 mm.

If the alloy from which the headform is made is too soft, deformation of the surface of the aluminium may occur when testing loose particulate materials like gravel or any other hard and rigid elements in the impact attenuating surface. This will result in unquantifiable errors in the measurement of gmax and HIC. When testing materials of this type, the impacting surface of the headform should be inspected frequently. If deformation of the headform surface is observed, the test is invalid.

In the case of a wired headform, the weight of any connector which is directly attached to or mounted on the headform and the weight of 1,5 m of the wire or cable shall be included in the determination of the mass of the headform.

**4.2.2.3** Accelerometer(s) shall be incorporated as follows:

a) accelerometer(s) aligned to measure 3 axes for free falling headform, mounted at the centre of gravity (±5mm in the vertical or horizontal axis) of the headform; or

b) a uniaxial accelerometer for guided headforms, aligned to measure in the vertical axis ±5° and located directly above the centre of mass.

**4.2.2.4** The impacting part of the headform below the mounting plane of the accelerometer shall be homogeneous and free from voids.

NOTE This is to avoid errors in measurement caused by vibrations.

### 4.2.3 Signal conditioner (optional)

Depending on the accelerometer technology employed, different methods of signal conditioning may be needed. Examples include: a charge amplifier, a Wheatstone bridge and amplifier, or an integrated electronic conditioner.

### 4.2.4 Guidance system

When using a uniaxial accelerometer, a vertical guidance for the headform shall be provided, including a means to measure the velocity of the headform immediately prior to impact (see 4.2.5.2).

### 4.2.5 Fall height measuring equipment

Methods for determination of the effective Free Height of Fall (FHF) of the headform when impacting the surface are:

**4.2.5.1** For the free-fall impact test, physical measuring of the drop height or calculating the drop height from the measured time between release and contact of the headform with the surface.

When calculating the drop height from the measured time between release and contact of the headform with the surface, special attention should be paid to possible time differences between the start of time measurement and the effective release of the headform (e.g. caused by permanent magnetism in a magnetic release system). A comparison of the measured height of fall and the calculated height of fall may be needed.

**4.2.5.2** For the guided impact test, measuring the velocity of the headform immediately prior to the impact and calculating the theoretical free fall drop height.

To allow for frictional losses, the velocity of the headform immediately prior to impact is recorded in order to calculate the equivalent drop height as if the headform had been in free fall.

In all cases, the effective Free Height of Fall (FHF) shall be recorded.

### 4.2.6 Release system

The release system for the free-fall impact test shall not create a significant rotation moment or any other forces on the headform, when released.

NOTE A rotation moment or other forces on the headform would cause additional accelerations at impact in the accelerometer, leading to an uncontrollable error of the resultant for the vertical measurement.

### 4.2.7 Signal transmission system

When using a signal cable for transmission, it shall not cause any significant restraining, pushing forces or unsteadiness of the headform.

### 4.2.8 Impact measuring equipment

**4.2.8.1** The impact measuring equipment shall consist of an accelerometer measurement system (4.2.8.2), a recording device (4.2.8.3) and a calculation program for the head injury criterion (HIC) (4.2.8.4).

**4.2.8.2** The accelerometer measurement system shall be capable of measuring all signal frequencies in the range 20 Hz to 1 000 Hz and having a sufficient response at all frequencies to keep amplitude errors below 5 %. It shall be capable of measuring, recording and displaying the acceleration and time duration of each complete impact (see 5.1.3).

For piezoelectric accelerometers, to have a sufficient response at low frequencies, the −3 dB lower limiting frequency should be less than or equal to 0,3 Hz to reduce the errors resulting from signal droop, which is most obviously visible in the form of baseline overshoot after the impact. Signal droop also results in underestimation of $g_{\mathrm{max}}$ and as a result HIC, particularly for longer pulse durations. Piezoelectric accelerometers with a time constant of 2 s or greater and appropriate signal conditioning will generally meet this requirement. Other accelerometers are not affected.

#### 4.2.8.3 Recording device

The recording device shall be capable of capturing and recording the acceleration/time signals produced throughout an impact with a minimum sampling rate of at least 20 kHz, including the maximum acceleration ($g_{max}$) experienced during each impact. Signal conditioning and filtering shall be compatible with the accelerometer and the data channel specified.

When the −3 dB upper frequency response of the accelerometer and its signal conditioning system is at a frequency greater than one-quarter of the sampling frequency, an anti-aliasing filter with an attenuation of at least 30 dB at half the sampling rate shall be employed.

**4.2.8.4 Program for calculating the HIC value** for the recorded acceleration time history of each impact, in accordance with Clause 5.

## 4.3 Accuracy of apparatus

### 4.3.1 Calibration by a laboratory

**4.3.1.1** The apparatus shall be calibrated periodically, by a laboratory in accordance with EN ISO/IEC 17025.

**4.3.1.2** All parts of the acceleration measurement system including accelerometers and electronic part (analogue and numerical) shall be calibrated for the whole frequency range from 20 Hz to 1 000 Hz. Recalibration shall be carried out at time intervals recommended by the manufacturer of the accelerometer or at least every two years. Calibrations shall be documented (e.g. by calibration certificates) and uncertainties shall be indicated.

The uncertainty of the calibration of accelerometers shall not be greater than 5 %.

**4.3.1.3** Velocity measurement systems as well as algorithms for calculating the fall height shall be calibrated for the whole velocity range (up to 3.5 m drop height).

For free falling headforms the calculated fall height shall be compared with the physically measured effective fall height.

In all cases, the effective Free Height of Fall (FHF) shall be measured with an uncertainty of not more than ±1 %.

**4.3.1.4** The computer algorithm used for the calculation of HIC shall be checked, e.g. by imposing a half-sine curve and the result, when compared with an independent mathematical calculation of this curve, shall not deviate by more than ±1 %.

NOTE An example for verification is given in Annex C.

### 4.3.2 Checks by operators

**4.3.2.1** Operators shall verify the correct function of the apparatus they use at appropriate interval (depending on the frequency and type of use of the apparatus). The results of any checks shall be recorded during the life time of the apparatus (e.g. by using a monitoring log).

The tests given in 4.3.2.2 and 4.3.2.3 are for checking any deviations or anomalies in the components and neither replaces calibration nor the validation for compliance of the apparatus with this European Standard.

NOTE An example of a regime for checking the correct function of the apparatus is described in Annex F.

#### 4.3.2.2 Comparative testing on reference surfaces

Conduct the testing procedure for determination of the Critical Fall Height (CFH) (Clause 6 – Method 1) on a prefabricated reference surface with constant properties under conditions as described for laboratory tests (6.2.4.1).

Carry out a series of at least three consecutive drop tests on the same test position on the reference surface, using the same fall heights ±2cm for all drop tests. Record the results for HIC and $g_{max}$ of each drop test and determine the CFH.

The corresponding values for the CFH obtained shall not differ more than ±5 %.

In case of higher deviations, maintenance or re-calibration is required.

NOTE The reference surface can be any product giving constant properties under the range of drop heights tested.

#### 4.3.2.3 Uncertainty test on reference surfaces

Carry out a series of ten consecutive drops from the same drop height and on the same test position continually (within 15 min) on a reference surface.

Discard any obvious incorrect results and calculate the standard deviation of the calculated HIC and the measured $g_{max}$.

A standard deviation below 5 % of the ten calculated HIC and the ten measured $g_{max}$ values is considered satisfactory. If this is not the case, maintenance or calibration operations shall be conducted, and a verification performed.

# 5 Testing procedure

## 5.1 Principle of impact measurement

### 5.1.1 General

The surfacing to be tested is struck by the instrumented headform of the test apparatus (see 4.2.1) from different drop heights (drop test see 3.9). The signals emitted by the accelerometer(s) in the headform during each impact are processed to yield a severity from the measured impact energy, defined as head injury criterion (HIC) and to determine the peak acceleration ($g_{max}$) experienced.

Figure A.1 shows a scheme of a test rig for impact measurement.

In Method 1 the drop heights at which an HIC of max. 1 000 and a $g_{max}$ of 200 is obtained are used to define the Critical Fall Height of the surfacing, in Method 2 the drop heights for measuring HIC and $g_{max}$ are related to equipment installed and are used to verify the performance of the surfacing in that specific site location.

### 5.1.2 Time/acceleration curve

The time/acceleration trace for each impact of a drop test shall be displayed and examined for any anomalies before being processed and evaluated (see Figure B.1). If any single drop gives an anomalous result, investigate further by repeating the drop tests at the same test position or, in case of loose particulate material, at a new untested ground position for the part of the curve in question.

If high frequency components appear as a consequence of vibrations of the drop test headform, filtration of signals with a standardized filter will be necessary. Measure both with and without the filter and compare the HIC and $g_{max}$ values to decide if the collected data (time/acceleration curve(s)) are valid.

#### 5.1.3 Calculation of results

**5.1.3.1** The head injury criterion (HIC) value shall be calculated and recorded for each time/acceleration curve from the formula:

$$HIC = \left( \left( \frac{\int_{t_1}^{t_2} a \times dt}{t_2 - t_1} \right)^{2,5} \times (t_2 - t_1) \right) \max \qquad (1)$$

where (see also Figure B.1)

$t_{start}$ is the time, at the start of an impact event, when the acceleration of the headform first exceeds zero;

$t_{end}$ is the time, at the end of an impact event, when the acceleration of the headform first falls back to zero

$a$ is the acceleration experienced by the headform and expressed in $g$ (acceleration due to gravity);

$t_1$, $t_2$ are any two intermediate values of $t$ between $t_{start}$ and $t_{end}$, $t$ being the time expressed in milliseconds (ms).

The sampling rate from $t_{start}$ to $t_{end}$ shall be at least 20 kHz (see 4.2.8.3).

Experience has shown that an impact time greater than or equal to 3 ms, i.e. $(t_2 - t_1) \geq 3$ ms is expected for impacts within the limits defined for the HIC (≤ 1 000) and for the maximum value of $a$ ($g_{max} \leq 200g$). It has been observed that shorter impact times correspond to impacts with higher values of $g_{max}$ which tend to increase the risk, including injuries to the arms and legs; such surfacing shall be excluded when tested in accordance with this standard.

**5.1.3.2** For each time/acceleration curve the maximum acceleration ($g_{max}$) occurring shall be recorded for further processing.

### 5.2 Selection and definition of test positions

**5.2.1** Impact measurements shall be carried out in all relevant test zones (3.12) of the surfacing, as far as is practical, to determine the test positions having the lowest impact attenuation.

NOTE Requirements for the impact attenuation in impact areas are defined for the Free Height of Fall (FHF) and for forced movement on playground equipment in EN 1176 series (see EN 1176-1:2017, 4.2.8.1 and 4.2.8.5) or in other standards, where surfacing is required.

**5.2.2** The distance between any two test positions shall not be less than 250 mm and no position shall be closer than 250 mm from the edge of the test specimen, assembly or test frame.

NOTE These distances are to avoid influences on the test position from previous tests and from the edges at the perimeter of the test specimen.

**5.2.3** The precise location of each test position shall be referenced to the test specimens or material as related to the structure and/or geometry of the surfacing and indicated in the test report (see also Clause 8 and Annex D).

# 6 Test Method 1 – Determination of Critical Fall Height (CFH)

## 6.1 Principle

**6.1.1** Impact measurements shall be carried out according to the testing procedure in 5.1 by conducting a drop test on each selected test position to the procedures as defined for testing in the laboratory (6.2) and on site (6.3).

**6.1.2** Each drop test shall be completed within 15 min. The values for HIC and $g_{max}$ for each drop test shall be recorded.

## 6.2 Testing in the laboratory

**6.2.1** Testing shall be carried out at a temperature of 23 °C ± 5 °C.

**6.2.2** Testing shall be carried out on a flat, rigid concrete, or equivalent substrate of sufficient mass, density and thickness that its deformation during the test makes no significant contribution to the test result.

Substrates other than the flat, rigid substrate are likely to contribute to the impact attenuation of the material being tested and are applicable for test reports only with clearly defined limitations.

**6.2.3 Selection of data for determination of critical fall height**

**6.2.3.1** The results for HIC and $g_{max}$ (see 5.1.3) of each impact shall be plotted and curves from HIC and $g_{max}$ against the corresponding drop height shall be produced for each test position of each test zone.

**6.2.3.2** To determine the Critical Fall Height (CFH), interpolate the curves to obtain the drop height equivalent to a HIC of 1 000 and the drop height equivalent to a $g_{max}$ of 200$g$, using impact measurements with at least two values giving HIC and $g_{max}$ values below and at least two giving HIC and $g_{max}$ values above these target values.

The Critical Fall Height is the lower of these two drop heights.

Whenever it is possible the drop heights should be chosen to obtain the HIC values given in Table 1, subject to the following constraints:

**Table 1 — HIC values**

| Impact number | Targeted HIC value |
|---|---|
| Impact 1 → $m_1$ | 700 to 800 |
| Impact 2 → $m_2$ | 850 to 950 |
| Impact 3 → $m_3$ | 1050 to 1150 |
| Impact 4 → $m_4$ | 1200 to 1300 |

NOTE An example of correct curves is illustrated in Figure B.2 (HIC and $g_{max}$).

**6.2.3.3** For materials giving HIC values lower than 1 000 and $g_{max}$ lower than 200$g$ at the maximum test height, the Critical Fall Height shall be quoted as > M (where M is the greatest drop height measured).

NOTE The maximum Free Height of Fall (FHF) on playground equipment conforming with EN 1176-1 is 3 m (see EN 1176-1:2017, 4.2.8.1).

### 6.2.4 Procedures for specific types of product

#### 6.2.4.1 Testing tiles, slabs or other pre-fabricated surfacing products

At least four test specimens with a minimum total dimension of 1 m × 1 m shall be installed according to the manufacturer's instructions, including all connecting and site fixing elements used for installation in the playground.

At least nine drop tests, each from at least 4 increasing drop heights shall be conducted and reported, each drop test at a different test position on the test specimens (see also 5.2).

Conduct the drop tests in the following test positions:

a) in the centre of the tiles;

b) in the centre of a joint between two adjoining tiles;

c) at the junction where the greatest number of tiles meet;

d) at any other point of inhomogeneity or discontinuity, to obtain the lowest value for the critical fall height anywhere on the assembly;

e) if the tile has a moulded structure in which the wearing surface is not uniformly supported, test the test positions where the surface has the greatest and the least support.

#### 6.2.4.2 Testing surfacing intended to be manufactured on site

Either of the following shall be prepared without seams or joints:

a) at least one test specimen with a minimum total dimension of 1 m × 1 m, prepared in accordance with the manufacturer's instructions; or

b) at least nine separate specimens, each not less than 500 mm × 500 mm, prepared in accordance with the manufacturer's instructions.

At least nine drop tests, each from at least 4 increasing drop heights shall be conducted and reported, each drop test at a different test position on the test specimens (see also 5.2), if applicable in test positions as required in 6.2.4.1.

#### 6.2.4.3 Testing products consisting of more than one component

The entire system, surfacing with under layer with a minimum total dimension of 1 m × 1 m, shall be tested and reported as a composite product which allows reproducibility of the test.

At least nine drop tests, each from at least 4 increasing drop heights shall be conducted and reported, each drop test at a different test position on the product (see also 5.2).

#### 6.2.4.4 Testing products designed to be installed in combination with natural materials

Products installed in combination with natural materials intended to influence their performance (e.g. rubber mats with grass or sand) cannot be meaningfully tested in the laboratory and cannot be subject to a test report according to 8.2 or 8.3. The critical fall height of such products can only be determined individually by an on-site test, on a mature, fully established installation and will likely vary over time or with climatic conditions.

#### 6.2.4.5 Testing loose particulate material and natural surfaces

**6.2.4.5.1** A test frame without a base shall be used, having internal dimensions not less than 1 m × 1 m.

NOTE 1 The dimensions stated above are usually adequate to avoid any influence of containment on particulate materials.

Loose particulate materials shall be placed in the test frame above the flat rigid substrate and uniformly distributed within the frame to a depth specified by the supplier.

Compact the material in accordance with the method given in Annex E.

When testing sand or gravel, determine the particle size distribution by carrying out a sieve test in accordance with EN 933-1 and record the result for the "uniformity coefficient" (see EN 1176-1:2017, Table 4 and Annex G)

If it is suspected that the impact attenuation of the material could be influenced by moisture (e.g. sand), the moisture content at the time of testing shall be measured and reported together with the test method used.

NOTE 2 The impact attenuation of some loose particulate material can be significantly influenced by its moisture content.

**6.2.4.5.2** A drop test on each selected test position shall be conducted and reported by one impact measurement from a determined drop height. After compaction in the test frame according to Annex E, drop the headform from at least 4 increasing drop heights, each at a previously untested position (see also 5.2.2).

If more than one depth is specified for the same product, the frame shall be refilled to each depth separately. Previously tested material shall be removed from the frame and may be reused at the new depth.

### 6.3 Testing on site

**6.3.1** Testing shall only be carried out when the temperature of the surface is between 5 °C and 55 °C. Temperature as well as all relevant climatic conditions existing throughout the test, e.g. humidity, moisture, etc., shall be measured and recorded.

**6.3.2** Testing shall not be carried out on surfaces that are saturated with water.

**6.3.3** Tests shall not be conducted on a test zone if it is inclined at an angle of > 10° to the horizontal.

NOTE Guided systems will give invalid results on inclined surfaces and free falling headforms can experience excessive rotation forces.

**6.3.4** If different types and/or layer thickness of substrate and/or surfacing are known to exist within the impact area, each variation shall be considered as a separate test zone and tested separately.

For surfacing manufactured on site the drop tests shall be carried out on each test zone identified.

**6.3.5** Drop the headform from at least 4 increasing drop heights, each at a previously untested position without compaction, ensuring that the material is present at the same layer depth at each test position, and report the results.

NOTE When testing sand or gravel on site, it is not necessary to determine the particle size distribution.

**6.3.6** When testing on site, a variety of test positions shall be selected to ensure the worst case situation is included (e.g. access/exit areas of the equipment) (see also 5.2.1).

**6.3.7** Reports of tests carried out on site shall be prefaced with the statement:

"As the performance of some products can be greatly influenced by the prevailing conditions, the results in this report cannot be used to indicate the performance of the same product under other conditions or in other locations."

# 7 Test Method 2 – Determination of Impact Attenuation on site

## 7.1 Principle

**7.1.1** Impact measurements shall be carried out according to the testing procedure in 5.1 by conducting a drop test on each selected test position of the surfacing in order to verify its compliance with the impact attenuation requirements for equipment, beneath which the surfacing is installed.

**7.1.2** This method does not determine the Critical Fall Height.

NOTE This test is for verification of the specific installation on site under the particular climatic and site conditions and is not representative for other installations. It can be used to check the final installation of surfacing prior to use (e.g. for playgrounds as in EN 1176–1:2017, 5.2) as well as to make subsequent checks on impact attenuating surfacing in use (e.g. for periodical inspections or for inspections after changes of playground installations).

## 7.2 Selection and recording of test positions

**7.2.1** The surfacing within the impact area is examined to determine whether it is intended to be uniform or to include zones of different impact performance. Zones designed to have different impact performance shall be treated as separate test zones (see also 5.2.1).

**7.2.2** For specific playground equipment selection of test positions shall be in accordance with the examples given Annex D. For any equipment not described in Annex D at least one test shall be conducted on every 10 $m^2$ within its impact area, in both cases it shall include testing at the position identified in 7.2.3.

For equipment with an impact area bigger than 100 $m^2$ one test shall be conducted on every 20 $m^2$.

**7.2.3** Each test zone shall be further examined to identify points of heaviest wear, any signs of deterioration or damage. Where possible, a thin probe may be used to measure the thickness of the surfacing and to identify the thinnest area. The purpose of these examinations is to ensure, as far as practical, that testing is carried out at the position likely to provide the least protection (worst case).

**7.2.4** The location of each test position within a test zone shall be precisely identified by any suitable means, e.g. by measurement from specific points on the playground equipment, by marked photographs, etc. and recorded.

### 7.3 Carrying out the test

**7.3.1** In each selected test position one drop test shall be conducted from the drop height at least equal to the actual Free Height of Fall (FHF) of the equipment or such other requirements laid down in the standards (see also 5.2.1).

**7.3.2** Measurement of the Free Height of Fall (FHF) on site is recommended, as experience has shown that the measured Free Height of Fall (FHF) on site may differ from that expected from the manufacturer of equipment due to the method of installation.

**7.3.3** Repeat the test at the appropriate number of test positions within the test zones.

### 7.4 Results

**7.4.1** Both the head injury criterion (HIC) value and the peak acceleration $g_{\mathrm{max}}$ of the impact event shall be recorded for each test position documented.

**7.4.2** If the result of a drop test shows an HIC of between 950 and 1 050 or a peak acceleration $g_{\mathrm{max}}$ between 195 and 205, conduct 3 further drop tests on 3 further test positions (each min. 250 mm away), each from the same drop height and calculate the mean of the 3 highest results for HIC or $g_{\mathrm{max}}$ as the result of the test.

## 8 Reports

### 8.1 General

Test reports shall be issued only for clearly defined surfacing materials, sub-structures and test conditions, when tested in accordance with Method 1 of this standard (see 8.2 and 8.3). For Method 2 an Inspection Report shall be issued (see 8.4).

### 8.2 Tests carried out in the laboratory with Method 1

The test report for laboratory testing shall include the following:

a) number and date of this European Standard, i.e. EN 1177:2017, Method 1;

b) a full description of the product tested, the dimensions, the weight, the density, mass/unit area and any other properties likely to influence the critical fall height of the material; or for loose particulate materials the layer depth, particle size and the result of a sieve test in accordance with EN 933-1 (for sand or gravel);

c) a photograph of the material tested, with an indication of the scale of loose particulate material;

d) the method of fixing used to retain the samples or the internal dimension of the test container used and the layer thickness for loose particulate material;

e) a diagram showing all the test positions;

f) the condition of the surfacing at the time of the test, including the temperature, expressed in degrees Celsius, and the moisture content, if relevant (e.g. for sand), including the test method used;

g) the results from each drop test, giving all drop heights used and the corresponding HIC and $g_{\mathrm{max}}$ values for each;

h) the critical fall height for the surfacing tested, expressed in metres to two decimal places and stating an uncertainty of ±7 %;

NOTE 1 This uncertainty is based on the findings of the round robin test performed in 2011.

i) the curves of HIC and $g_{\mathrm{max}}$ vs. drop height from which the critical fall height of the surfacing was determined;

j) either the time/acceleration curve of one impact with HIC equal to or greater than 1 000 or $g_{\mathrm{max}}$ equal to or greater than 200$g$ or, for maximum HIC values below 1 000 and $g_{\mathrm{max}}$ below 200$g$, the highest value measured.

NOTE 2 Method 1 is intended to measure critical fall height of the surfacing under the least favourable conditions. Test reports can be used as the basis for the selection of surfacing for any situation under normal climatic condition.

## 8.3 Tests carried out on site in accordance with Method 1

The test report for tests carried out on site shall include the following statement as a preface to the report:

"This test was carried out on site with the particular climatic and site conditions occurring on the day of test. The results cannot be used to indicate the performance of the product under any other conditions or in other locations."

The test report shall include the following:

a) number and date of this European Standard, i.e. EN 1177:2018; Method 1;

b) the location of the site (e.g. postal address) and, if relevant, the substrate on which the surfacing was tested;

c) a description of the product tested and any reference applicable for its identification;

d) a photograph of the material tested, with an indication of the scale for loose particulate materials;

e) the layer thickness for loose particulate material and for *in situ* formed products;

f) identification and location of each test position;

g) the condition of the surfacing at the time of the test, including the temperature and humidity, the age of the product (if known) and any other factors that may be considered to have influenced the result, e.g. the moisture content (in the case of loose particulate materials);

h) the results from each drop test, giving all drop heights used and the corresponding HIC and $g_{\mathrm{max}}$ values for each;

i) the critical fall height for the surfacing on each test position, expressed in metres to two decimal places, followed by the statement: "The uncertainty of this result under controlled laboratory conditions is ±7 %. Under site conditions the uncertainty may be greater."

NOTE This uncertainty is based on the findings of the round robin test performed in 2011. However, it will be noted that the round robin tests were carried out under controlled laboratory conditions and therefore these site specific test results could have an even greater variance

j) the curves of HIC and $g_{\max}$ vs. drop height from which the critical fall height of the surfacing was determined for each test location; and

k) either the time/acceleration curve of one impact with HIC equal to or greater than 1 000 and $g_{\max}$ equal to or greater than 200$g$ or, for maximum HIC values below 1 000 and $g_{\max}$ below 200$g$, the highest value measured.

## 8.4 Tests carried out on site in accordance with Method 2

The report for tests carried out on site according to Method 2 shall include the following statement as a preface to the report:

“This test was carried out on site under the particular climatic and site conditions occurring on the day of test, therefore it should not be assumed that the same results would be obtained under other conditions.”

The report shall include the following:

a) number and date of this European Standard, i.e. EN 1177:2017; Method 2;

b) the location of the site (e.g. postal address) and, if relevant, the substrate on which the surfacing was tested;

c) a description of the product(s) tested and any reference, if applicable, for its identification;

d) a photograph of the material tested, with an indication of the scale for particulate materials;

e) the layer thickness for loose particulate material and for *in situ* formed products;

f) identification and location of each test position and details of equipment and its Free Height of Fall (FHF) or such other requirements laid down in the standards;

g) the condition of the surfacing at the time of the test, including the surface temperature and humidity, the age of the product (if known) and any other factors that may be considered to have influenced the result;

h) the results from each drop test, giving all drop heights used and the corresponding HIC and $g_{\max}$ values for each;

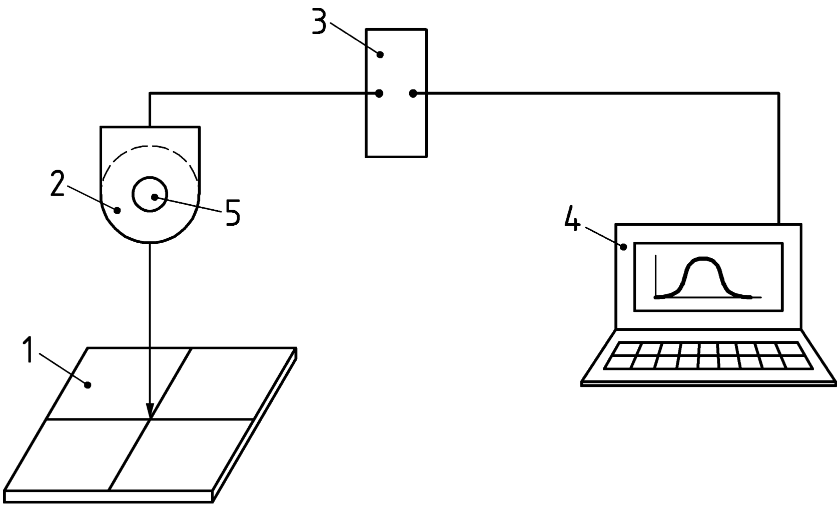
i) the time/acceleration curve of one of the impacts on the site.

j) Include the statements:

“Impact attenuating surfacing shall have an HIC of equal to or less 1 000 and a $g_{\max}$ of no more than 200 from a drop equal to the Free Height of Fall (FHF) of equipment above it. This report can only be used to confirm the performance of the surfacing in the specific situation at the time of the test.”

# Annex A
(informative)

## Test rig for determination of impact attenuation




**Key**

1 test specimen

2 headform

3 signal conditioner (as required)

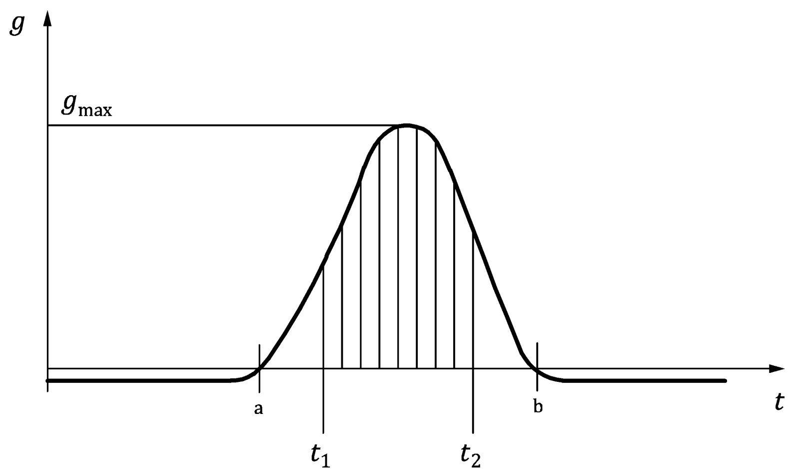
4 computer

5 accelerometer

**Figure A.1 — Test rig for determination of critical fall height**

# Annex B
(informative)

## Typical examples of trace of acceleration against time and curve of HIC and $g_{max}$ values against drop height




**Key**

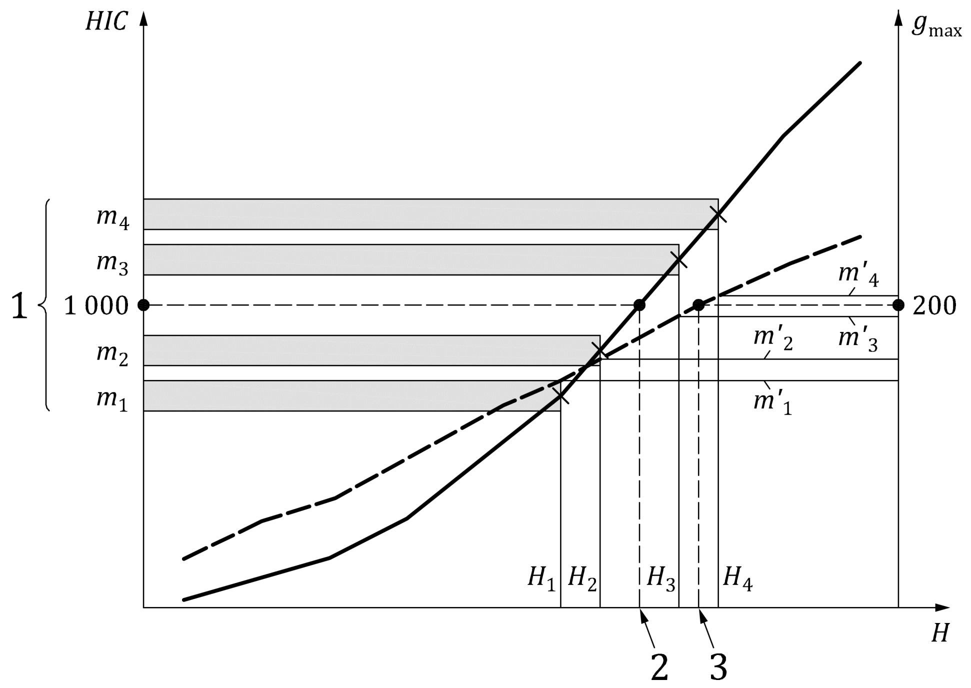
a $t_{start}$

b $t_{end}$

*a* acceleration [*g*]

*t* time [ms]

**Figure B.1 — Typical trace of acceleration against time**




**Key**

| | |
|---|---|
| 1 | impact measurements $m_1$ to $m_4$ in HIC at drop heights $H_1$ to $H_4$ |
| 2 | critical fall height at HIC = 1 000 |
| 3 | critical fall height at $g_{max}$ = 200 |
| $m_1$ | HIC = 700 to 800 |
| $m_2$ | HIC = 850 to 950 |
| $m_3$ | HIC = 1050 to 1150 |
| $m_4$ | HIC = 1200 to 1300 |
| $m'_1$, $m'_2$, $m'_3$, $m'_4$ | impact measurements $m'_i$ in $g_{max}$ at drop heights $H_i$ |
| $H_1$, $H_2$, $H_3$, $H_4$ | drop heights $H_1$ to $H_4$ [m] |

Figure B.2 — Example of typical curves from a test on rubber tiles for HIC and $\boldsymbol{g_{max}}$ values against drop height

# Annex C
(informative)

# Verification of computer algorithm used for the calculation of HIC (see 4.3.1.4)

For a complete verification, the calculations should be verified. This verification is done using the following formula:

$$V = \frac{A}{2}\left(1 - \cos\left(\frac{2\pi t}{T}\right)\right) \tag{C.1}$$

where

| | |
|---|---|
| $V$ | is the output voltage from a conditioner to simulate an impact |
| $A$ | is the full amplitude (±) of the signal; |
| $t$ | is the time [ms]; |
| $T$ | is the period [ms]. |

NOTE For calculation of formula (C.1) the signal injected to simulate an impact is measured in Volts *(V)* corresponding to the measured acceleration *a* (in *g*), depending on the accelerometer technology employed.

The table below is generated, for a 20 kHz frequency, by varying parameters *A* and *T*. This makes it possible to simulate three "standard" curves for an impact. The calculation software shall, to within the rounding-off error, find the "target" values of the HIC index and of $\Delta t$ $(t_2 - t_1)$.

The HIC index and $\Delta t$ validation intervals have been defined by taking into account an uncertainty of 1 % on the amplitude and frequency of the audio generator.

**Table C.1 — Calculation of the output voltage for a 20 kHz frequency**

| **Period** $T$ <br> *ms* | **Amplitude** | **HIC index** | $\Delta t$ <br> $(t_2 - t_1)$ |
|---|---|---|---|
| 10 | 100 | 295 to 311 | 5,03 – 5,14 |
| 10 | 150 | 814 to 856 | 5,03 – 5,14 |
| 10 | 200 | 1 671 to 1 756 | 5,03 – 5,14 |

# Annex D
(normative)

# Procedure for selection of test positions in playgrounds for Method 2 (see Clause 7)

## D.1 Principle

The aim is to determine, in the impact area of each equipment item, the test zones and a minimum number of test positions to be checked according to test Method 2 (see 7.2).

The tables below show for specific play elements (as referred to the EN 1176 series) where and how many test positions on the impact area shall be chosen for testing. Other play elements not covered by this table should be tested following the same principle described. In all cases measurements shall be carried out at positions of the lowest measured thickness of the surface material in relation to the Free Height of Fall (FHF) of the corresponding play element.

## D.2 Criteria for selection of test zones (3.12)

The location of test zones depends on the installed equipment and the reasonably foreseeable fall.

Depending on the type of equipment, it is necessary to distinguish the test zones in the impact attenuating surfacing (IAS) for the different free heights of fall from the play elements that constitute the equipment.

Each test zone identified will be subjected to at least one test using Method 2.

At least 3 thickness measurements shall be made in each test zone, and the test shall be performed at the point corresponding to the minimum measured thickness.

The thickness at the point under test as well as its location in relation to the equipment will be reported (see 7.2.2 and 7.2.3).

The measured thickness is for information. The uncertainty on this measurement is mainly associated with the nature of the substrate (e.g. unbound material).

The Tables D.1 to D.4 show examples for impact areas to be considered for specific equipment types and the minimum number of test zone to be tested.

**Table D.1 — Example for test zones – Swings**

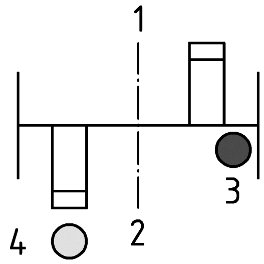
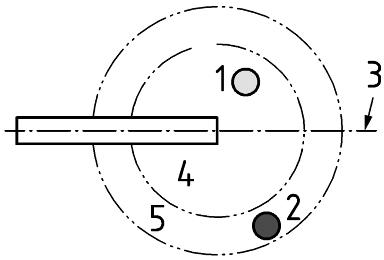
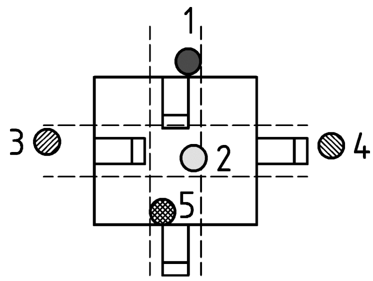
| Swings | Location and number of test positions | Illustration |
|---|---|---|
| **Type 1:**<br>One rotation axis | One test position per seat (3 and 4)<br>Chosen on the minimum measured thickness of IAS whether on the rear or the front side of the seat.<br>1: rear side<br>2: front side | <br>**Figure D.1** |
| **Type 2:**<br>Several rotation axes | Same as for Type 1 | |
| **Type 3:**<br>One hanging point | Test positions on each side of the axis:<br>1: one position in range A (4)<br>2: one position in range B (5)<br>Chosen on the minimum measured thickness of IAS<br>3: axis<br>4: range A see EN 1176-2 § 4.10.2.1<br>5: range B or C see EN 1176-2 § 4.10.2.1 | <br>**Figure D.2** |
| **Type 4:**<br>Contact swings | One test position in the central test zone 2<br>One test position for each seat 1, 3, 4 and 5 chosen on the minimum measured thickness of IAS | <br>**Figure D.3** |

**Table D.2 — Example for test zones – Slides and cableways**

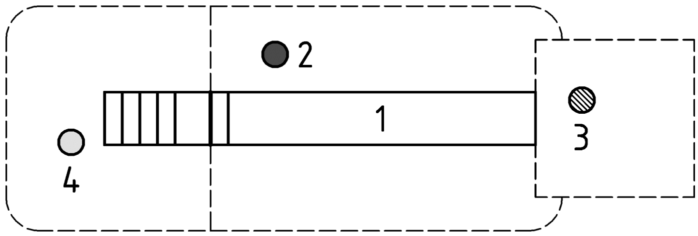
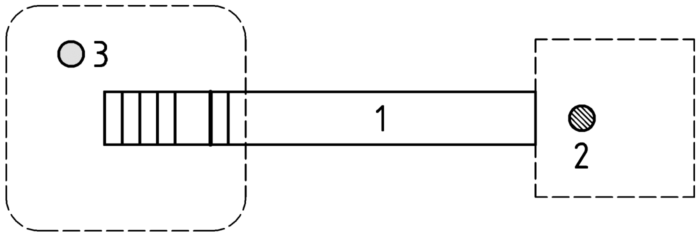
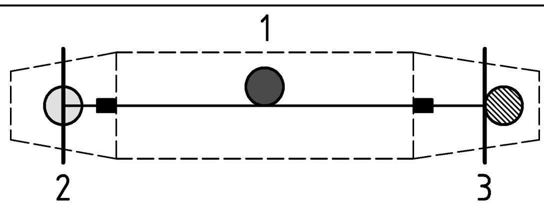
| Slides | Location and number of test positions | Illustration |
|---|---|---|
| **Type 1:**<br>Open slide | 1: Slide<br>2: Test zone below slide<br>3: Run out test zone<br>4: Test zone below access<br>One test position in each test zone 2, 3 and 4 chosen on the minimum measured thickness of IAS | <br>**Figure D.4** |
| **Type 2:**<br>Tunnel slide | 1: Tunnel slide<br>2: Run out test zone<br>3: Test zone below access<br>One test position in each test zone 2 and 3 chosen at the minimum measured thickness of IAS | <br>**Figure D.5** |
| **Type 3:**<br>Cableways | 1: Suspension area: One test zone<br>2: Starting area: One test zone<br>3: Terminus: One test zone<br>One test position in each test zone 1, 2 and 3 chosen at the minimum measured thickness of IAS | <br>**Figure D.6** |

**Table D.3 — Example for test zones – Carousels**

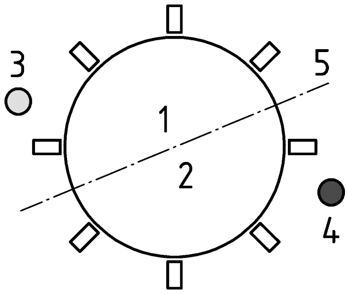
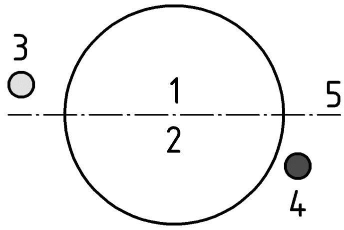
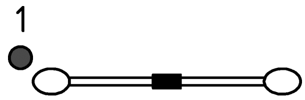
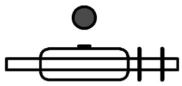
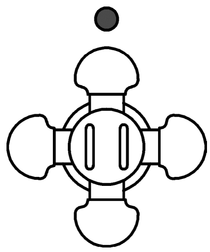
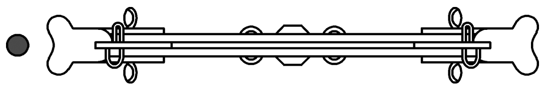
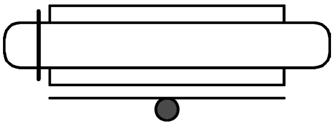
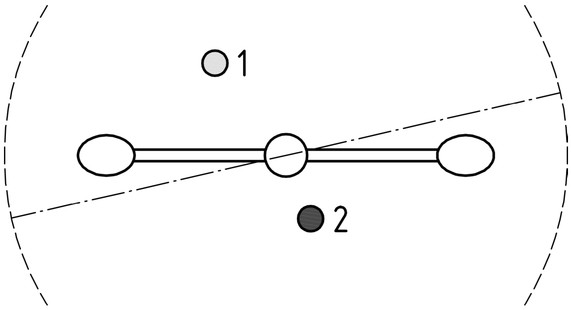
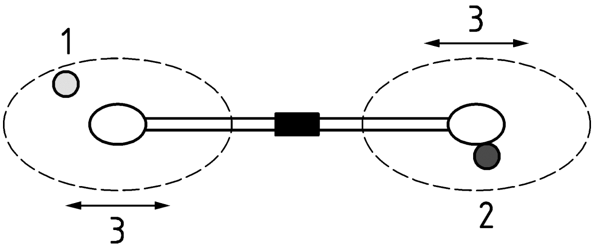
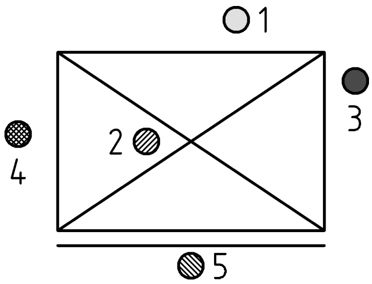
| Carousels | Location and number of test positions | Illustration |
|---|---|---|
| **Type 1:**<br>Spinning mushroom | 3 and 4: two test positions on each side of an identified axis outside the carousel<br>One test position in each test zone 3, and 4 chosen at the minimum measured thickness of IAS<br>1: upper<br>2: lower<br>5: axis to be identified | <br>**Figure D.7** |
| **Type 2:**<br>Giant revolving disks | 3 and 4: two test positions on each side of an identified axis outside the carousel<br>One test position in each test zone 3, and 4 chosen at the minimum measured thickness of IAS<br>1: upper<br>2: lower<br>5: axis to be identified | <br>**Figure D.8** |

**Table D.4 — Example for test zones – Rocking equipment and spatial nets**

| Rocking equipment | Location and number of test positions | Illustration |
|---|---|---|
| **Type 1:**<br>Axial seesaw | 1 test position in the selected test zone at the minimum measured thickness of the IAS after a sounding under both sites. | <br>**Figure D.9** |
| **Type 2:**<br>Single point rocking equipment | One test position in the impact area | <br>**Figure D.10**<br><br>**Figure D.11** |
| **Type 3:**<br>Multi-point rocking equipment<br>(With or without multidirectional movement) | Proceed as for type 1 | <br>**Figure D.12** |

| Rocking equipment | Location and number of test positions | Illustration |
|---|---|---|
| **Type 4:** Rocking seesaw | One test position in the impact area |  **Figure D.13** |
| **Type 5:** Sweeping seesaw, 1 hanging point | Two test positions (1 and 2): one on each side of an identified axis<br>Chosen at the minimum measured thickness of IAS |  **Figure D.14** |
| **Type 6:** Overhead single-axis seesaw | Test position 1 and 2:<br>One test position per seat<br>Chosen at the minimum measured thickness of IAS in each test zone<br>(the arrows 3 show the transversal movement) |  **Figure D.15** |
| Spatial nets | One test position outside the structure on each face (1, 3, 4 and 5)<br>One test position inside the structure (2)<br>Chosen at the minimum measured thickness of IAS |  **Figure D.16** |

# Annex E
(normative)

# Method for compaction of loose particulate impact attenuating material (see 6.2.4.5.1)

## E.1 General

The performance of some particulate loose particulate materials or systems containing loose particulate material can be significantly influenced by compaction in normal use. This procedure describes how such materials shall be compacted prior to testing. The method is applicable to laboratory testing according to Method 1.

Testing on site is carried out at the surface as found with no preparation for both Method 1 and Method 2.

## E.2 Measurement of layer thickness

Lightly rake the surface of the material at the test position to create a uniformly flat layer.

Measure the layer thickness for example by placing a rigid circular board, at least 200 mm in diameter, of known thickness on the prepared surface and measure the layer thickness from the underside of the board to the substrate e.g. by means of a calibrated rod probe not more than 3 mm in diameter.

## E.3 Compaction procedure

Place a rigid circular board of at least 200 mm diameter on the sample. Apply a pressure of (2 ± 0,1) $N/cm^2$ to the board for (3 ± 1) s. Repeat the application of the same load 4 more times, such that the full sequence is completed within 1 min.

The dimension of the board can be chosen to suit the weight of the tester. Within the limit of (2 ± 0,1) $N/cm^2$ board diameters with 5 mm increments permit them to be used with body masses in accordance with Table E.1.

**Table E.1 — Dimension of board sizes that can be used by different weight testers**

| **Diameter of the board**<br>mm | **Weight of the tester**<br>kg |
|---|---|
| 200 | 59,7 to 66,0 |
| 205 | 62,7 to 69,3 |
| 210 | 65,8 to 72,7 |
| 215 | 69,0 to 76,2 |
| 220 | 72,2 to 79,8 |
| 225 | 75,5 to 83,5 |
| 230 | 78,9 to 87,2 |
| 235 | 82,4 to 91,1 |
| 240 | 86,0 to 95,0 |
| 245 | 89,6 to 99,0 |
| 250 | 93,3 to 103,1 |
| 255 | 97,0 to 107,2 |
| 260 | 100,9 to 111,5 |
| 265 | 104,8 to 115,8 |
| 270 | 108,8 to 120,2 |

# Annex F
(informative)

## Example of a regime for checking the function of an HIC test apparatus

**Table F.1 — Example of a regime for checking the correct function of an HIC test apparatus used weekly**

| Internal/External | Kind of test | Period |
|---|---|---|
| Self-checking | Comparative testing on reference surfaces | **March year 1** |
| Self-checking | Uncertainty test | **March year 1** |
| Self-checking | Comparative testing on reference surfaces | **June year 1** |
| Self-checking | Uncertainty test | **June year 1** |
| Self-checking | Comparative testing on reference surfaces | **September year 1** |
| Self-checking | Uncertainty test | **September year 1** |
| Calibration by a laboratory (see 4.3.1) | Acceleration measurement system<br>Velocity measurement systems<br>Computer algorithm | **December year 1** |
| Self-checking | Comparative testing on reference surfaces | **March year 2** |
| Self-checking | Uncertainty test | **March year 2** |
| Self-checking | Comparative testing on reference surfaces | **June year 2** |
| Self-checking | Uncertainty test | **June year 2** |
| Self-checking | Comparative testing on reference surfaces | **September year 2** |
| Self-checking | Uncertainty test | **September year 2** |
| Calibration by a laboratory (see 4.3.1.1) | Acceleration measurement system<br>Velocity measurement systems<br>Computer algorithm | **December year 2** |