PAS 170-1:2017

BSI Standards Publication

# Vehicle security barriers – Low speed impact testing

## Part 1: Trolley impact test method for bollards

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# Foreword

## Publishing information

This PAS was sponsored by the UK Government's Centre for the Protection of National Infrastructure (CPNI). Its development was facilitated by BSI Standards Limited and it was published under licence from The British Standards Institution. It came into effect on 31 July 2017.

Acknowledgement is given to the following organizations that were involved in the development of this PAS as members of the steering group:

- ATG Access;
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- Transport Research Laboratory (TRL Limited).



This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

The PAS process enables a standardization document to be rapidly developed in order to fulfil an immediate need in industry. A PAS can be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

**Assessed capability.** Users of this PAS are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.

**Test laboratory accreditation.** Users of this PAS are advised to consider the desirability of selecting test laboratories that are accredited to BS EN ISO/IEC 17025 by a national or international accreditation body.

## Use of this document

It has been assumed in the preparation of this PAS that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

## Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its methods are expressed as a set of instructions, a description, or in sentences in which the principal auxiliary verb is "shall".

*Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.*

### Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

**Compliance with a PAS cannot confer immunity from legal obligations.**

# Introduction

For many years, CPNI has been working in conjunction with BSI, impact test facilities and vehicle security barrier (VSB) manufacturers to develop technical specifications for the testing and deployment of a full range of VSBs. Such VSBs are a means of providing proportionate protection against vehicle borne threats to key infrastructure, secure events and crowded places. The technical specifications have been developed through an extensive programme of full-scale vehicle impact tests using commercially available vehicles from passenger cars to large goods vehicles at prescribed impact speeds.

The purpose of the PAS 170 series is to provide a quick and inexpensive way of evaluating a vehicle security barrier product, under dynamic impact from an impact trolley. The purpose of PAS 170-1 is for the testing of bollards designed to meet the vehicle threat posed by criminality and accidental impacts (from low speed passenger vehicles). Sites at which a bollard tested to this PAS might be installed are car parks and retail outlets, for example.

PAS 170-1 is not intended to replace any element of the full-scale vehicle impact test methods, e.g. IWA 14-1 or PAS 68. Test methods such as IWA 14-1 and PAS 68 have been created to be used for testing VSBs which have been designed to mitigate the terrorist vehicle-borne threat using unmodified commercially available vehicles. Critical national infrastructure sites are examples of where VSBs might be installed.

Where a test item is tested against PAS 170-1 and meets the specified requirements, it can:

a) provide reassurance that the test item design could offer impact resistance against a low speed N1G (2 500 kg) vehicle (as specified in IWA 14-1:2013), based on its performance against an impact trolley travelling at a low speed, which is acting as a surrogate (though this would not be a guarantee of performance); and

b) encourage the manufacturer to consider progressing to a full-scale vehicle impact test method (see **3.7**), e.g. those given in IWA 14-1 or PAS 68, to determine the impact resistance against higher speed vehicles than those speeds covered in PAS 170-1 (see **3.6**).

*NOTE PAS 69 and IWA 14-2 cover guidance for the selection, installation and use of VSBs, and their application, respectively.*

# 1 Scope

This PAS describes a method for testing the performance of a single bollard, when subjected to a single impact using a 2 500 kg impact trolley at a speed of $16^{+3}_{-1}$ km/h or $32^{+3}_{-1}$ km/h.

PAS 170-1 does not cover testing the performance of blockers, planters or street furniture.

It is not equivalent to a full-scale vehicle impact test method. It does not cover the performance of a test item or its control apparatus when subjected to: blast explosion, ballistic impact, manual attack with the aid of tools or electrical manipulation/attack through a control system.

This PAS is for use by manufacturers, distributers or specifiers of bollards.

*NOTE Full-scale vehicle impact test method is defined in **3.7**.*

# 2 Normative references

## Standards publications

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.

BS 8500-1:2015+A1:2016, *Concrete – Complementary British Standard to BS EN 206 – Part 1: Method of specifying and guidance for the specifier* [1)]

BS EN 206:2013+A1:2016, *Concrete – Specification, performance, production and conformity*

BS EN 10210-1:2006, *Hot finished structural hollow sections of non-alloy and fine grain steels – Part 1: Technical delivery requirements*

BS EN 12390-2, *Testing hardened concrete – Part 2: Making and curing specimens for strength tests*

BS EN ISO 14688-1:2002+A1:2013, *Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description* [1)]

BS EN ISO 14688-2:2004+A1:2013, *Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification* [1)]

## Other publications

[N1] SAE INTERNATIONAL. *SAE J211-1, Instrumentation for impact test – Part 1, Electronic instrumentation*. Warrendale: SAE International, 2014.

[N2] DEPARTMENT FOR TRANSPORT. *Manual of contract documents for highway works – Specification for highway works (Volume 1) – Series 800 – Road pavements – Unbound, cement and other hydraulically bound mixtures*. [2)] London: The Stationery Office, 2016.

# 3 Terms and definitions

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

**3.1 backfill**
material surrounding the test item or foundation with known composition

*NOTE See Annex C regarding soil properties and standard backfill.*

**3.2 ballast**
mass securely fixed to the impact trolley

*NOTE See also **3.20**.*

**3.3 bollard**
passive (static) or active (capable of operational movement) post/tube/section

**3.4 energy absorber**
material, or device, behind an impact bumper that is designed to absorb energy at a controlled rate during the trolley impact

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1) A revision of this standard is currently in development.

2) Available online: http://www.standardsforhighways.co.uk/ha/standards/mchw/index.htm.

**3.5 foundations**

**3.5.1 rigid foundation**
concrete, or equivalent material, constructed in the the test pit to rigidly hold the test item when subjected to a trolley impact

*NOTE A rigid foundation is the preferred method for the evaluation of test items because it provides a means of comparing a variety of different designs. See also **5.4.2**.*

**3.5.2 non-rigid foundation**
deformable material, constructed for site-specific deployment, which can be installed within the test pit

*NOTE See also **5.4.3**.*

**3.6 full-scale impact test vehicle**
commercially available vehicle with an unmodified chassis and frontal structure, used to evaluate the performance of a test item in a full-scale vehicle impact test

*NOTE "Commercially available vehicle" is a term used in PAS 68:2013 and IWA 14-1:2013.*

**3.7 full-scale vehicle impact test method**
method used to evaluate the performance of a vehicle security barrier (VSB) when subjected to impact from an unmodified commercially available vehicle

*NOTE "Commercially available vehicle" is a term used in PAS 68:2013 and IWA 14-1:2013.*

**3.8 guidance system**
equipment used to direct the impact trolley to the point of release

**3.9 impact angles**

**3.9.1 actual impact angle**
recorded angle created between the test item datum line and the longitudinal centre line of an impact trolley when the test item is aligned with the impact trolley approach path

**3.9.2 target impact angle**
angle planned to be created between the test item datum line and the longitudinal centre line of an impact trolley when the test item is aligned with the impact trolley approach path

**3.10 impact bumper**
structure at the front of the impact trolley that enables it to exert a uni-axial load on the test item

**3.11 impact heights**

**3.11.1 actual impact height**
recorded vertical distance from the ground to the point of impact on the test item

**3.11.2 target impact height**
vertical distance from the ground to the planned point of impact on the test item

**3.12 impact points**

**3.12.1 actual impact point**
recorded intersection between the longitudinal centre line of the impact trolley and the position on the test item where the impact occurred

**3.12.2 target impact point**
intersection between the longitudinal centre line of the impact trolley and the position on the test item at which the impact is planned to occur

**3.13 impact speeds**

**3.13.1 actual impact speed**
recorded velocity of the freely moving impact trolley at the point of impact

**3.13.2 target impact speed**
velocity of the freely moving impact trolley at the point of impact

**3.14 impact trolley**
rigid structure on wheels having a moving impact bumper and energy absorber

*NOTE 1 The impact trolley should, by design, be reusable.*

*NOTE 2 See also **3.20**.*

**3.15 impact trolley datum line**
vertical reference line passing across the leading edge of the impact bumper

*NOTE See item 4, Figure 1 and Figure 2.*

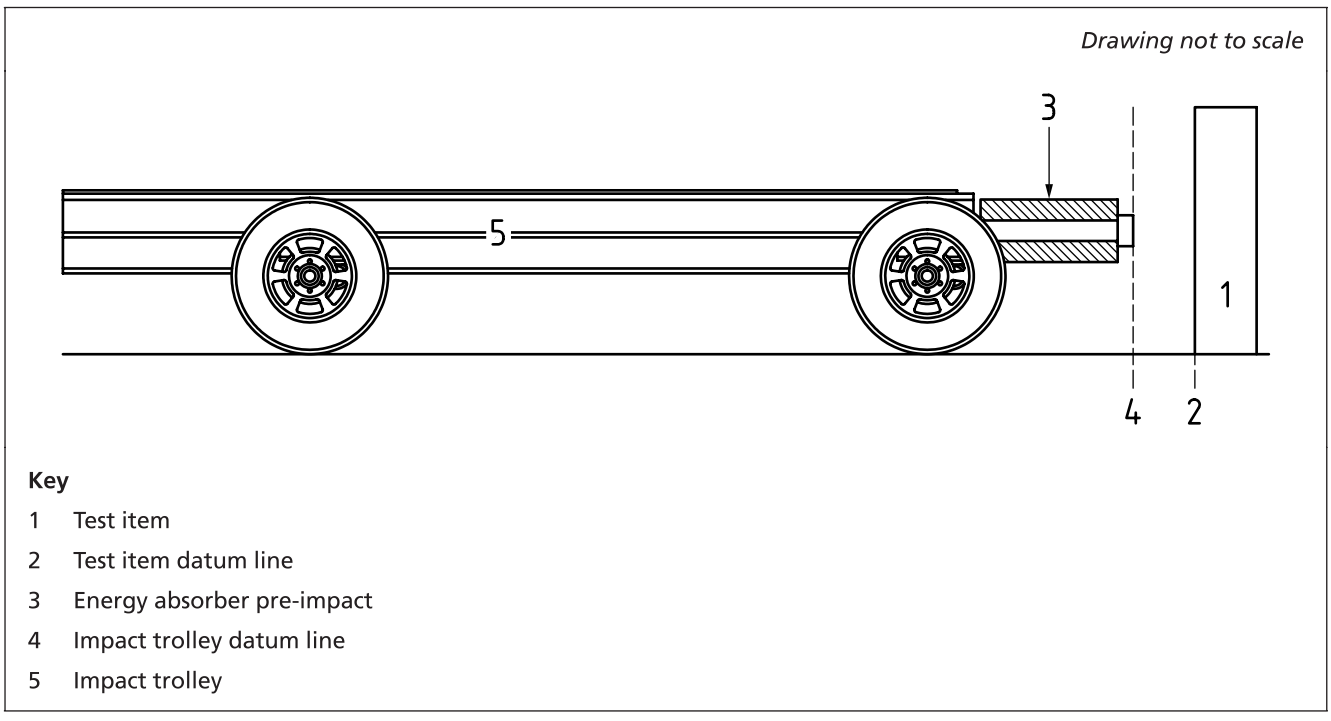
**3.16 initial contact point**
point at which the impact trolley and the test item impact face first engage

**3.17 penetration distance**
maximum distance between the impact trolley datum line and the test item datum line during or after the trolley impact

*NOTE 1 The maximum distance might occur during the trolley impact, i.e. dynamically, before the impact trolley rebounds from the test item.*

*NOTE 2 The penetration distance can be seen in Figure 2.*

Figure 1 **Pre-impact condition**



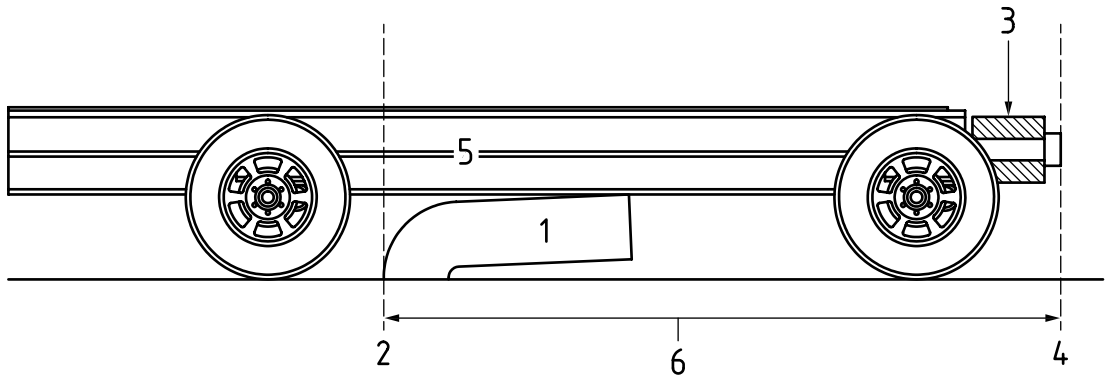

**Key**

1 Test item
2 Test item datum line
3 Energy absorber pre-impact
4 Impact trolley datum line
5 Impact trolley

Figure 2 **Post-impact condition**

*Drawing not to scale*




**Key**

1 Test item
2 Test item datum line
3 Energy absorber post-impact
4 Impact trolley datum line
5 Impact trolley
6 Penetration distance

**3.18 test item**
bollard, excluding foundation, which is subjected to a low speed trolley impact

**3.19 test item datum line**
horizontal reference line passing across the front face of the test item

**3.20 test mass**
combined mass of the impact trolley and the ballast

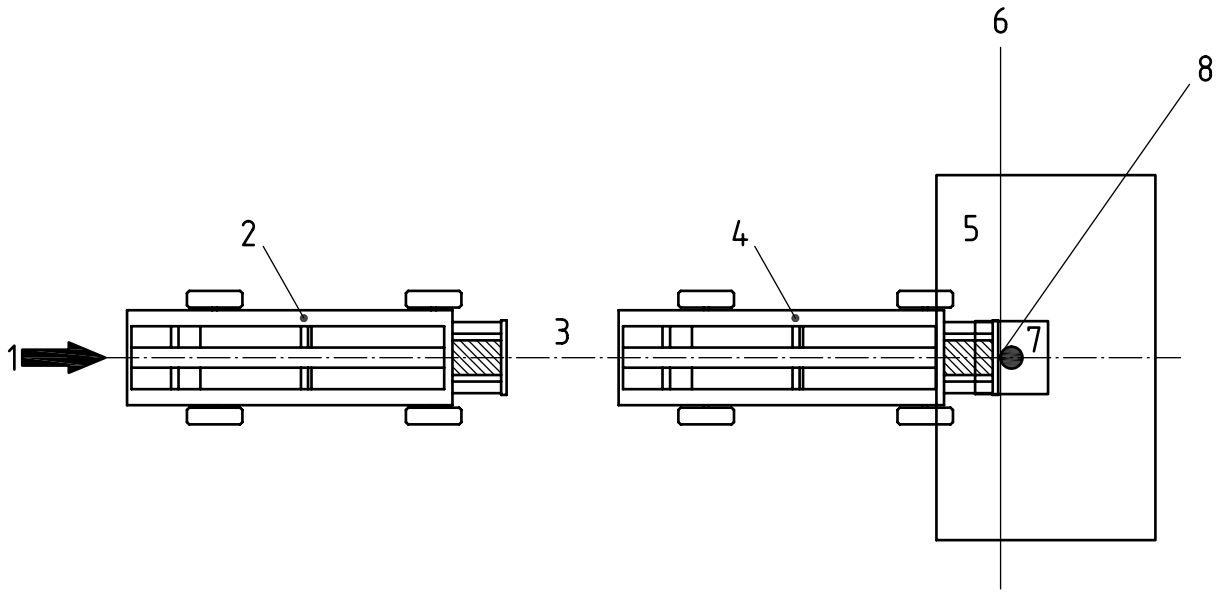
*NOTE See also **3.2** and **3.14**.*

**3.21 test pit**
purpose-built void, which can be filled with backfill and contains the test item

**3.22 trolley impact**
interaction between the impact trolley (primarily the impact bumper) and the test item at the chosen impact speed

*NOTE Figure 3 shows the impact trolley impacting during testing. It indicates an actual impact angle of 90°.*

Figure 3 **Trolley impact**




**Key**

1 Centre line of impact trolley
2 Impact trolley (pre-impact)
3 Impact trolley approach path
4 Impact trolley on impact
5 Test pit infill
6 Test item datum line (impact face)
7 Test item and foundation
8 Initial contact point

# 4 Principle

The test item and foundation, conforming to the test item documentation, are installed in the test pit. An impact trolley is connected to a method of propulsion, e.g. a winch, or similar apparatus, which is capable of accelerating and guiding the impact trolley into the test item and cameras and reference markers are set up to record the results. The selected face of the test item is subjected to a single trolley impact at the pre-selected target impact speed and target impact angle. A test report is generated, stating the outcome of the impact test or test series (where applicable).

# 5 Prior to testing

## 5.1 General

Test item documentation shall be issued with an easily identifiable and unique reference that is version controlled [see **5.2**c)].

## 5.2 Test item documentation

Test item documentation containing the following information shall be supplied to the party carrying out the impact test, prior to it being conducted:

a) test item manufacturer contact details;

b) whether the test item is a prototype or is in production;

c) test item;
   1) type;
   2) unique model code/reference;
   3) name;

d) parameters against which the test item is to be tested, including:
   1) target impact speed;
   2) target impact angle;
   3) which face of the test item is the front face (i.e. the face that makes contact with the impact bumper);

e) general arrangement of the test item and foundation, and, where applicable:
   1) detailed drawing(s) of test item; and
   2) installation drawings and installation instructions;

   *NOTE* *This should include the orientation of the test item.*

f) installation components list;

g) material specifications;

h) foundation specifications for site-specific conditions:
   1) reinforcement detail and bar-bending schedule;
   2) specified concrete strength (as per test item design);
   3) soil properties [i.e. using specified soil (see **C.3**) or alternative];

i) whether the test item to be tested is an active or a passive test item, and;

j) where the test item is active:
   1) whether it is to be operational for the test; and;
   2) the means of operation for the test (i.e. powered or manual).

## 5.3 Test item non-conformity to the test item documentation

Where a non-conformity is identified it shall be logged and reported to the party requesting the test.

The non-conformity shall be resolved before testing. The resolution of the non-conformity shall be recorded through the provision of either:

a) revised drawings [see **5.2**e)1)] demonstrating the modifications made to the design prior to completion of the test report (where the test item is correct but the test item documentation is not); or

b) a modified test item prior to continuation of an impact test or the test series (where the test item documentation is correct, but the test item is not).

Revised drawings shall be marked with an updated issue number. A copy of these revised drawings shall be provided to the party carrying out the test, together with a list of dated amendments (see **5.1**).

## 5.4 Foundations

### 5.4.1 General

Prior to undertaking impact testing, the test item installation shall be specified as requiring either a rigid foundation or a non-rigid foundation [see also **5.2**e) and **5.2**h)]. Where a rigid foundation is required, it shall conform to **5.4.2**. Where a non-rigid foundation is required, it shall conform to **5.4.3**.

### 5.4.2 Rigid foundation

The test item shall be fixed in the rigid foundation. Where the foundation is to be constructed from concrete, it shall be tested in accordance with **8.1.1**.

*NOTE It is recommended that the rigid foundation is a removable section that can be pre-cast with the test item, or manufactured such that it can be removed easily post-impact, and a new test item placed ready for testing, with the minimum time delay.*

On receipt of, and prior to installation of, the test item in the foundation, the test item shall be checked for conformity to the test item documentation and drawings provided in accordance with **5.2**.

### 5.4.3 Non-rigid foundation

On receipt of, and prior to the impact test being conducted, the test item and associated foundation shall be checked for conformity to the test item documentation and drawings provided.

The details of the soil properties shall be recorded in accordance with Annex **C**. Prior to the installation of the test item foundation, the test pit shall be prepared in accordance with the test item documentation [see **5.2**e) and **5.2**h)]. Where standard backfill is used, it shall conform to **C.1**.

## 6 Apparatus

**6.1** *Guidance system*, capable of keeping the impact trolley in line to achieve a compliant actual impact point (±100 mm of the target impact point) along the pre-defined approach path to the test item.

**6.2** *Equipment for measuring speed*, capable of measuring the impact speed along the trolley approach path (no more than 3 m before the initial contact point) in km/h and to within an accuracy of ±2 %.

*NOTE The determination of impact speed is an essential parameter and a minimum of two independent methods of recording speed should be used.*

**6.3** *Equipment for measuring the angle of impact*, capable of measuring to an accuracy of ±1°.

**6.4** *Equipment for measuring distance dynamically*, capable of measuring to an accuracy of ±0.05 m.

**6.5** Equipment for measuring distance statically, capable of measuring to an accuracy of ±0.005 m.

**6.6** *Equipment for measuring mass*, capable of measuring mass to an accuracy of ±5 kg.

**6.7** *Filming equipment*, incorporating a minimum of three high-speed video cameras (see **6.8**), which is capable of recording:

a) the impact trolley motion, pre- and post-impact;

b) the behaviour of the test item;

c) any motion of the ballast during impact; and

d) any movement and/or rotation of the foundation.

**6.8** *Three high-speed video cameras: Camera A, Camera B and Camera C*, capable of operating at a minimum of 200 frames per second, which can produce noise-free, correctly exposed results in year-round outdoor lighting conditions without resorting to the use of electronic gain or non-standard film processing to correct the exposure. The cameras shall be fitted with lenses of a flat field type in order to minimize any distortion of the image; these lenses shall be of a photographic quality capable of achieving the optimum sensor, or film resolution of the camera.

*COMMENTARY ON **6.8***
*"Correctly exposed" means checking that the brightness range of the area of interest is captured in its entirety. Camera lenses and their performance should meet the requirements of SAE J211-2 [1].*

*A higher recording frame rate, for example, 500 frames per second, gives greater detail of the trolley impact, but may decrease the resolution and requires increased light levels.*

*Additional high-speed video cameras may be used. Where more than three cameras are used, the subsequent cameras should be labelled "Camera D", "Camera E", and so forth. For high-speed video camera layouts, see **7.9**.*

**6.9** *Impact trolley*, comprising the elements shown in Figure A.1 and falling within the tolerances for dimensions and mass given in Table A.1.

*NOTE 1 The impact trolley should be of contrasting colour to the test item and the background to aid visibility in the camera footage.*

*NOTE 2 The impact trolley is representative of the 2 500 kg N1G full-scale impact test vehicle specified in IWA 14-1:2013, Table 1, and PAS 68:2013, Table 3. It is important that the impact trolley specification falls within the parameters given in Table A.1 so that results yielded are comparable and consistent.*

*NOTE 3 It is recommended that the structure of the impact trolley is of a robust and sound nature such that it can be re-used.*

**6.10** *Photographic equipment*, capable of taking still photographs.

*NOTE A DSLR camera, with a variable zoom lens, automatic focus and aperture to minimize the use of flash photography, which might cause unwanted glare is an example of suitable photographic equipment.*

**6.11** *Winch, towing cable and guidance system*, or alternative method of delivering the impact trolley to the test item at the specified impact speed and target impact angle.

*COMMENTARY ON **6.11***
*The impact trolley delivery method should be capable of:*

- *accelerating the impact trolley in a stable manner;*
- *accelerating the impact trolley in a straight line and as close as is practicable to the target impact point; and*
- *allowing the impact trolley to travel freely on release.*

*A stable manner is one generating negligible roll, pitch and yaw for the impact trolley.*

# 7 Apparatus set-up and test preparation

## 7.1 General

The apparatus shall be set up and the test prepared in accordance with **7.2** to **7.12**.

## 7.2 Impact trolley

The impact trolley shall conform to Annex **A**. The impact trolley shall be checked for correct dimensions, wheel alignment and mass. Where a non-conformity is identified as a result of these checks, corrections shall be undertaken until the impact trolley conforms to Annex **A**.

When the impact trolley mass has been confirmed as conforming to Table A.1, the mass shall not be modified. This mass shall be recorded as the impact trolley test mass to within an accuracy of ±5 kg.

Prior to testing, a calibration test of the impact trolley shall be conducted in accordance with Annex **B**.

*NOTE The purpose of the calibration test is to test the reliability and consistent performance of the impact trolley.*

## 7.3 Energy absorber

The energy absorber shall be tested in accordance with Annex **B** and conform to force/displacement profile limits given in Table B.1.

## 7.4 Ballast

All ballast shall be evenly distributed and secured for the duration of the trolley impact, such that the centre of gravity of the impact trolley falls within the location specified in Table A.1.

## 7.5 Reference markings

Reference markings on the impact trolley, the test item, datum lines, and the test site ground shall be created, as required, and visible to the relevant high speed video cameras.

*NOTE See also **7.9** for high-speed video camera layouts.*

## 7.6 Target impact height

Prior to carrying out the impact test, the target impact height shall be set in accordance with Table A.1.

## 7.7 Impact speed

The impact speed shall be selected from one of the following impact speeds:

a) $16^{+3}_{-1}$ km/h;

b) $32^{+3}_{-1}$ km/h.

## 7.8 Test site

The test site ground shall be flat and even, and have a gradient not exceeding 2.5% in any plane.

The test site ground used for the trolley impact, the test item and the foundation shall be clear of standing water (e.g. puddles), ice and/or snow at the time of the test.

Measures shall be taken in order to minimize dust or water spray generated from the test site ground and the impact trolley during the test so that the trolley impact is not obscured in any way and photographic and film records are not affected.

The test site ground shall extend for at least 5 m beyond the rear face of the test pit. The test site ground shall be firm and free from obstructions, such as equipment or stored materials, such that the impact trolley movement is not restricted.

The test site ground shall have reference markings to indicate the test item datum line and marked for the post-impact measurement of the penetration distance.

*COMMENTARY ON **7.8***
*The test site should be such that the impact trolley can be:*

*a) accelerated to the required impact speed;*

*b) guided stably along the approach path;*

*c) released from a steady state to travel freely into the test item; and*

*d) allowed to freely travel so that the penetration distance can be assessed in accordance with Clause **9** (see also Figure 2).*

*Markings on the test site ground should be in a contrasting colour. Examples of methods of marking include painting lines and using grids or target markers. Markings indicating nominal distances beyond the test item datum line (e.g. 1 m, 2 m, 3 m;), can be used as a visual aid for setting up an overhead camera (Camera C; **7.9.4**) and for assisting in the measurement of the penetration distance.*

## 7.9 High-speed video camera layout

### 7.9.1 General

Three high-speed video cameras, Camera A, Camera B and Camera C, conforming to **6.8**, shall be placed in the layout shown in Figure 4 and conform to **7.9.2**, **7.9.3**, and **7.9.4** respectively.

*NOTE Cameras and lenses should be selected that are capable of providing the specified coverage whilst minimizing distortion. This can be achieved by positioning the cameras a minimum of 4 m from the impact test point and selecting an appropriate lens such that the areas stated in Figure 4 are in their field of views.*

### 7.9.2 Camera A

Camera A shall be static (see Figure 4, Camera A). It shall be ground based in line with the test item datum line and it shall have an unobstructed view of the test item impact face. It shall also be capable of recording the impact trolley motion for a minimum of 3 m prior to the test item datum and 3 m beyond the test item datum in the direction of impact. Where Camera A is used to determine the impact speed, it shall be calibrated for this purpose.

*NOTE Camera A records the motion of the impact trolley pre- and post- impact, and during the trolley impact. It can be used to determine the actual impact height and actual impact speed.*

### 7.9.3 Camera B

Camera B shall be static (See Figure 4, Camera B). It shall be ground based in line with the centre line of the impact trolley facing the trolley approach path and it shall be capable of recording the impact trolley motion for a minimum of 3 m prior to the test item datum line and 3 m beyond the test item datum line in the direction of impact.

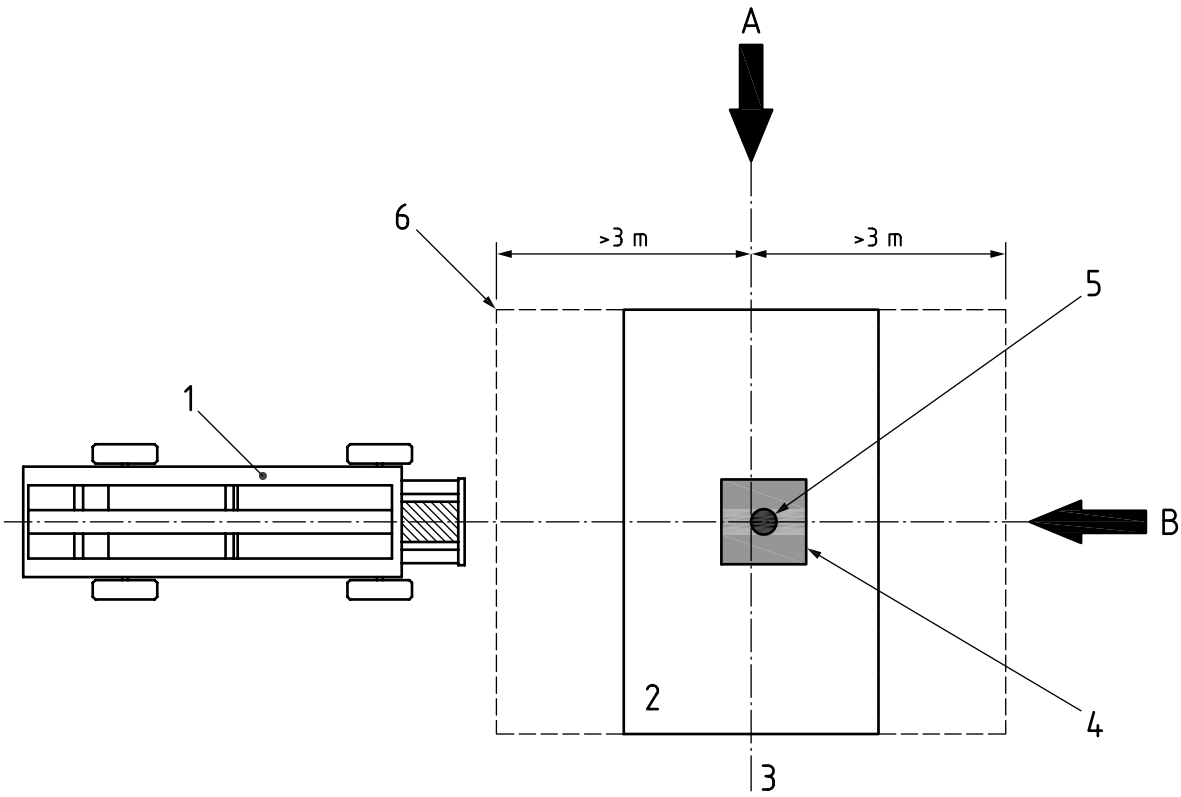
*NOTE Camera B can be used to determine the actual impact point.*

### 7.9.4 Camera C

Camera C shall be static. It shall be located directly overhead and in line with the test item datum (see Figure 4, item 6). It shall be positioned such that it covers the impact trolley motion from a minimum distance of 3 m before the test item datum line and a minimum distance of 3 m beyond the test item datum line and full width of the test pit. Where Camera C is used to determine the impact speed, it shall be calibrated for this purpose.

*NOTE Camera C can be used to determine dynamic penetration distance and actual impact speed.*

Figure 4 **High speed video camera layout**




**Key**

1 Impact trolley
2 Test pit
3 Test item datum line
4 Test item foundation
5 Test item
6 Field of view from Camera C (see **7.9.4**)

A Camera A
B Camera B

## 7.10 Test item preparation

### 7.10.1 General

Photographs shall be taken to record:

a) the preparation and installation of the test item; and

b) the foundation or the ground fixing arrangement of the test item.

*NOTE The test item should be of contrasting colour to the impact trolley and the background to aid the review of the trolley impact using the camera images.*

### 7.10.2 Installation

The test item shall be installed in accordance with the accompanying detailed drawings and installation instructions provided [see **5.2**e)]. Any non-conformity shall be addressed in accordance with **5.3**.

*NOTE The test item should be installed in the orientation specified in the test item documentation [see **5.2**e)].*

### 7.10.3 Backfill material

The backfill material surrounding a test item shall conform to Annex **C**.

### 7.10.4 Test pit

The test pit shall be of an area large enough such that it shall:

a) contain a rigid foundation; or

b) contain a non-rigid foundation and conform to **7.10.6**.

### 7.10.5 Rigid foundation

The rigid foundation shall be located within the test pit such that it conforms to **3.5.1**.

### 7.10.6 Non-rigid foundation

Where a non-rigid foundation design is to be evaluated then the test pit dimensions shall be such that when the test item and foundation are placed in the pit a minimum of 500 mm of specified soil can be accommodated around and beneath the test item.

*NOTE Having the internal sides of the test pit located at least 500 mm from the test item reduces the likelihood of the test pit affecting the performance of the test item.*

Where soil is used to form the non-rigid foundation, the soil grade and bearing capacity, and compaction and moisture content shall conform to Annex **C**.

### 7.10.7 Reference markers

A marker shall be applied at the target impact height on the test item so as to be visible by Camera A (see **7.9.2**).

A central marker shall also be placed on the rear of the test item (visible from Camera B) to enable the accuracy of the actual impact point to be determined (see **7.9.3**).

A central marker shall also be placed on the top face of the test item (visible from Camera C) to enable the accuracy of the actual impact point to be determined (see **7.9.4**).

## 7.11 Impact angle

The target impact angle shall be agreed between all parties prior to testing (e.g. test house/party conducting the testing, client, designer, specialist).

The target impact angle shall be either:

a) 90° to the test item datum line; or

b) the angle to the test item datum line that on testing is most likely to cause failure up to 45° in 5° increments.

Following the test procedure in accordance with Clause **8**, the actual impact angle shall be within ±2° of the target impact angle.

### 7.12 Impact point

Following the test procedure in accordance with Clause **8**, the actual impact point shall be achieved within ±100 mm of the initial contact point.

# 8 Test procedure

## 8.1 Pre-impact test data

### 8.1.1 Foundations

#### 8.1.1.1 General

Where the test item system is installed in, or on, a rigid foundation made of cast concrete foundations, record the pre-impact test data, including the:

a) date the foundation was cast;

b) results of tests undertaken with concrete cubes (see **8.1.1.2**);

c) concrete delivery certificate/note detailing its specification;

d) still photographs of the reinforcement in the foundation prior to concrete being poured;

e) still photographs of the foundations being poured.

#### 8.1.1.2 Concrete testing

Where concrete foundations are used, test the concrete in accordance with BS EN 12390-2 and test the concrete at the intervals given in Table 1.

*NOTE 1 Conducting and recording the result from a slump test on the concrete prior to pouring is also recommended as this provides data on the water content of the concrete at the time of pour.*

Test a sample within ±24 h of the specified day of the impact test.

Record the concrete strength of the sample taken within ±24 h of the test day along with the number of days that have passed since the concrete was initially poured.

*NOTE 2 If the concrete strength recorded on the test day is lower than that specified by the manufacturer, consideration should be given to how this could affect the test item's performance during the test.*

Table 1 **Concrete sample testing**

| **Time between concrete pour and test day** | **Day sample is tested** | | | |
|---|---|---|---|---|
| Days | Day 7 | Day 14 | Day 28 | Test day |
| 0–7 | | | | ✓ |
| 8–14 | ✓ | | | ✓ |
| 15–27 | ✓ | ✓ | | ✓ |
| ≥28 | ✓ | ✓ | ✓ | ✓ |

*NOTE Samples are tested at intervals after the installation date (i.e. after the concrete has been poured) to determine the concrete strength, for example:*

*i) if testing ≥28 days after the concrete is poured, samples are tested on day 7, day 14, day 28 (to allow the curing rate to be monitored), and on the day of the test;*

*ii) if the test day is on day 11 after the concrete has been poured, samples are tested on day 7 and day 11 (the day of the test);*

*iii) if the test day is on day 5 after the concrete has been poured, a sample is only tested on day 5 (the day of the test).*

### 8.1.2 Test item

Record the following information about the test item:

a) height and inclination (from horizontal, parallel and perpendicular to the test item datum line);

b) actual impact height;

c) actual impact angle;

d) location within the foundation (including depth) or on the ground (with fixing depth, where applicable);

e) for an active test item, the operating cycle and its state (active or passive) during the test;

f) photographs (including views taken from the impact trolley approach path and at each increment of 90°);

g) any specific design features of the test item.

*NOTE For an active test item, the operating cycle and its state (active or passive) during the test should also be recorded using real-time video.*

### 8.1.3 Impact trolley

Record the following information about the impact trolley:

a) specification of the impact head, e.g. material specification, design strength, dimensions;

b) height of the impact head (in accordance with Table A.1);

c) photographs including views taken from the impact trolley approach path and at each increment of 90°, as a minimum, taken using photographic equipment (see **6.10**).

## 8.2 Impact

**8.2.1** Subject the test item to a single trolley impact at the pre-defined parameters (see **7.4**, **7.6**, **7.7**, **7.11** and **7.12**).

**8.2.2** Photographically record the impact test sequence using the specified equipment in accordance with **6.10**.

**8.2.3** Record the:

a) impact speed (in km/h) using the equipment for measuring speed in accordance with **6.2** at no more than 3 m before impact;

b) actual impact angle (in degrees) using the equipment for measuring the angle of impact in accordance with **6.3**;

c) actual impact point using the equipment for measuring distance dynamically in accordance with **6.4**;

d) dynamic penetration, using the equipment for measuring distance dynamically in accordance with **6.4**;

e) final position of the impact trolley with respect to the test item datum line using the equipment for measuring distance statically in accordance with **6.5**.

**8.2.4** The impact trolley, including the ballast, shall conform to the pre-impact configuration at the point of impact. Where this is not the case, the test shall be invalidated.

### 8.3 Post-impact test data

Record the following:

a) penetration distance, dynamic or static, using either the equipment for measuring distance dynamically or the equipment for measuring distance statically, as applicable (see **6.4** or **6.5**);

b) damage/distortion/crush to:

   1) test item:

      i) including irregular gaps with the foundation/ground;

      ii) angle of inclination (from the vertical, parallel and perpendicular to the test item datum line);

   2) foundation/ground and connection to fixings;

   3) impact trolley, including the impact head;

c) static photographic views using the photographic equipment (see **6.10**) taken from the impact trolley approach path and at each increment of 90° to show:

   1) all faces of the test item; and

   2) foundation/ground and connection to fixings;

d) impact trolley, including:

   1) impact head;

   2) other structural elements, e.g. chassis, axles;

   3) position of the ballast;

e) for an active test item, the operation cycle:

   1) with the impact trolley in place;

   2) without the impact trolley, i.e. removed;

   3) without the impact trolley, the determined damage and deformation of the test item.

## 9 Performance rating

Where the test item is recorded as having a penetration distance of 2.0 m or less, it shall be given a performance rating, for example:

PAS 170-1:2017 Bollard IT/2500/32/90:1.4

This performance rating shall be configured based on the criteria given in Table 2.

*NOTE Measurements should be rounded to one decimal place.*

Table 2 **Performance classification example**

| Parameter | Rating | Explanation |
|---|---|---|
| Standard | PAS 170-1:2017 | Test method document |
| Test item | Bollard | Test item type |
| Test type | IT | Impact trolley |
| Impact trolley mass (kg) | 2 500 | 2 500 kg |
| Impact speed (km/h) | 32 | $32^{+3}_{-1}$ km/h |
| Actual impact angle (°) | 90 | 90° respectively to the test item datum line |
| Penetration distance (m) | 1.4 | The impact trolley datum penetrated a maximum of 1.4 m beyond the test item datum line |

Where the impact trolley datum line does not travel beyond the test item datum line, there is no penetration and 0.0 m shall be stated in the performance rating, for example:

PAS 170-1:2017 Bollard IT/2500/32/90:0.0

Where the impact trolley penetrates a distance greater than 2.0 m, no performance rating shall be issued.

# 10 Further impact tests

Where additional actual impact angles and/or impact speeds are to be assessed, the impact test shall be repeated (Clause **5** to Clause **9**) for the required test specification.

The test item, including its foundation and/or ground fixings, and the test site shall be checked for their suitability for re-testing prior to the subsequent trolley impact.

The condition of the impact trolley shall be inspected after each trolley impact to check that it is structurally sound and able to perform consistently during another test.

*COMMENTARY ON CLAUSE **10***
*It is advisable that a new test item is used for each trolley impact, unless all parties involved in the testing are in agreement that the tested test item is fit for further testing.*

*The foundation and/or ground fixings might not be fit for further testing due to damage incurred in previous testing. If re-testing is to take place, all parties should be in agreement that the foundation or ground is fit for further testing.*

*It is recommended that an inspection of the impact trolley is periodically conducted to check its conformity to Annex A.*

*It is recommended that an impact trolley calibration is periodically conducted in accordance with Annex B.*

# 11 Test report

## 11.1 General

A test report shall be prepared for each impact test or test series.

Where a test series has been conducted, a summary of the results shall be reported for each individual test.

Any modifications between multiple tests shall be stated in pre-test data [see **11.2**b)].

*COMMENTARY ON CLAUSE **11.1***
*A test series may consist of a single test or several tests using an identical or similar test item designs whilst varying the test parameters and recording the results.*

*A test report should not be released without containing all of the information required in accordance with Clause **5**.*

*If a test item is made available for sale after testing, it is advisable that the following information is contained within the product information to assist traceability of the test item:*

*a) test item product name (type and model);*

*b) reference to PAS 170-1:2017;*[3)]

*c) the performance rating in accordance with Clause **9**.*

*This information could be provided in the form of printed material, or on the manufacturer's website, for example.*

## 11.2 Content

The test report shall include, as a minimum:

a) summary of results, including:

1) name or trademark, where applicable, and address of the test item manufacturer;

2) name of client (where different to the test item manufacturer);

3) name(s) and address(es) of the test house or party carrying out testing and relevant accreditation/qualification status, if applicable;

4) date(s) testing was undertaken;

5) test item product name, including type and model, and unique model/reference;

6) reference to this part of PAS 170, i.e. PAS 170-1:2017[3)];

7) performance rating in accordance with Clause **9**;

b) pre-test data, including:

*NOTE Pre-test data that is common across multiple tests should not feature multiple times.*

1) date and result of current impact trolley calibration test, including graphical output in accordance with **B.4.1**;

2) test item documentation (see **5.2**);

3) test item foundation (where applicable), including:

i) concrete/steel (rigid) or soil (non-rigid);

ii) for a rigid foundation, prescribed strength of concrete/steel;

iii) for a rigid foundation, specified concrete strength results e.g. 7 day, 14 day, and test day strength of concrete (to zero decimal places) (see Table 1);

iv) condition (e.g. newly installed, previously used);

v) soil properties;

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[3)] Marking PAS 170-1:2017 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standardization document. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

4) ground fixing detail (where applicable), including:
    i) method;
    ii) depth;
    iii) material specification;
    iv) condition (e.g. newly installed, previously used);
5) impact trolley, including:
    i) manufacturer;
    ii) supplier;
    iii) test mass in kilograms (kg), to zero decimal places;
    iv) centre of gravity [dimensions in millimetres (mm)], to zero decimal places;
6) test specification, including:
    i) target impact point in millimetres (mm);
    ii) target impact angle in degrees (°);
    iii) target impact speed in kilometres per hour (km/h);
    iv) target impact height in millimetres (mm);

c) post-test data results, including:
    i) actual impact point in millimetres (mm);
    ii) actual impact angle in degrees (°);
    iii) actual impact speed in kilometres per hour (km/h);
    iv) actual impact height in millimetres (mm);
    v) whether the impact trolley was restrained;
    vi) penetration distance in metres (m), to one decimal place;
    vii) PAS 170-1:2017 Low speed impact testing performance rating (in accordance with Clause **9**).

# Annex A (normative) Impact trolley

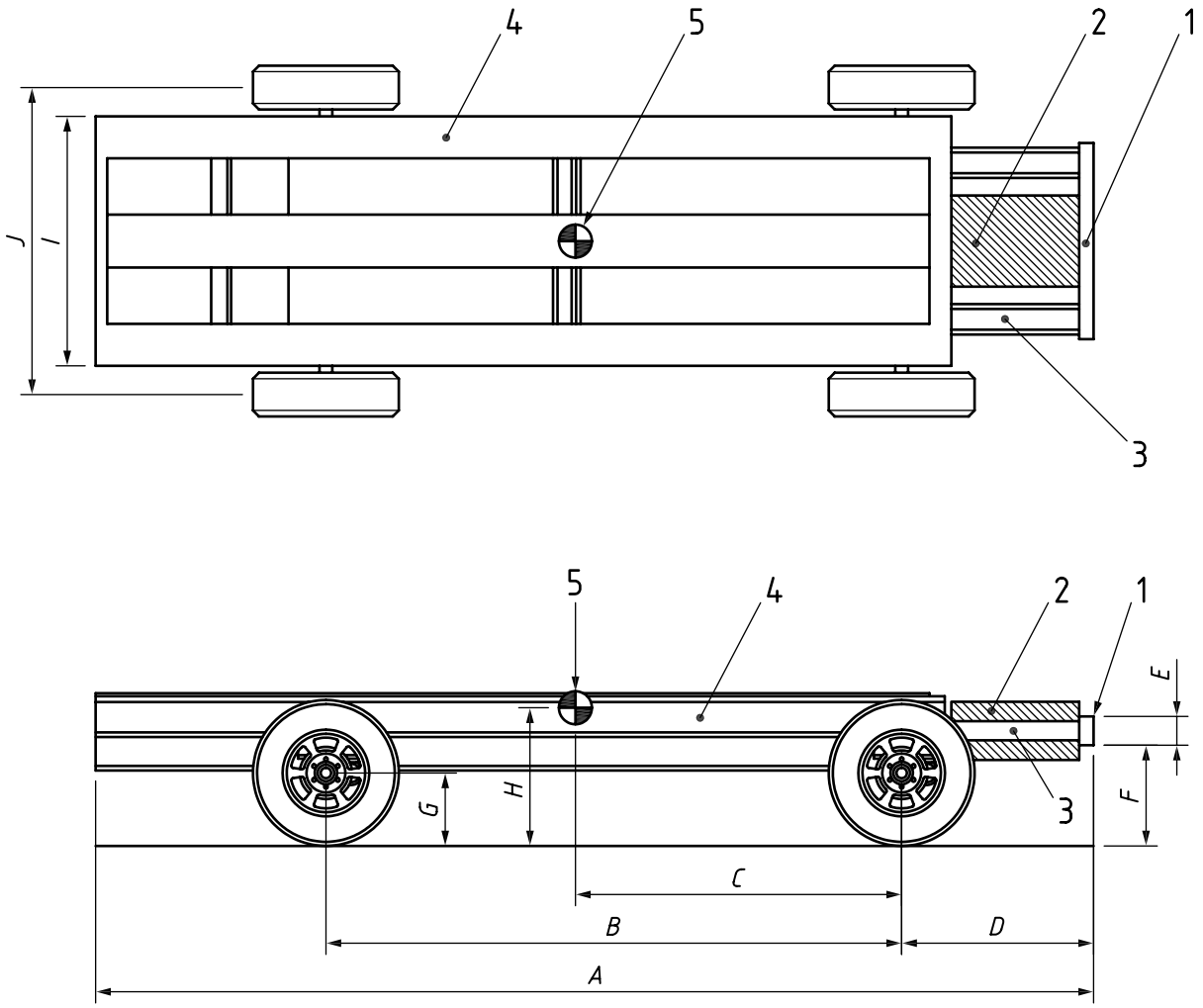
## A.1 Impact trolley

The impact trolley shall comprise, as a minimum, the elements shown in Figure A.1.

*NOTE* *See also* ***6.9****.*

Figure A.1 **Impact trolley schematic**

*Drawings not to scale*




**Key**

1 Impact bumper
2 Energy absorber (see Annex B)
3 Means of supporting impact bumper which is limited to horizontal movement
4 Rigid chassis
5 Centre of gravity

*A* Impact trolley length
*B* Wheelbase
*C* Centre of gravity, horizontal from front axle
*D* Front overhang
*E* Vertical thickness of impact bumper
*F* Height from lower edge of impact bumper to ground
*G* Tyre radius
*H* Centre of gravity, vertical
*I* Chassis width, outer edges
*J* Wheel track

The impact trolley specification for the 2 500 kg trolley shall conform to Table A.1.

Table A.1 **Impact trolley specification (dimensions and mass)**

| Item | Impact trolley IT 2500 | Specification |
|---|---|---|
| — | Impact trolley test mass | 2 500 kg ± 50 kg |
| *A* | Impact trolley length* | 5 000 mm ± 600 mm |
| *B* | Wheelbase | 3 000 mm ± 300 mm |
| *C* | Centre of gravity, horizontal from front axle* | 1 700 mm ± 100 mm |
| *D* | Front overhang* | 1 250 mm ± 200 mm |
| *E* | Vertical thickness of impact bumper | 150 mm ± 25 mm |
| *F* | Height from lower edge of impact bumper to ground | 525 mm ± 50 mm |
| *G* | Tyre radius | 380 mm ± 50 mm |
| *H* | Centre of gravity vertical* | 720 mm ± 50 mm |
| *I* | Chassis width, outer edges | 1 300 mm ± 50 mm |
| *J* | Wheel track | 1 600 mm ± 50 mm |

** Measured with impact bumper in pre-test condition.*

# Annex B (normative) Impact trolley calibration

## B.1 General

In order to demonstrate the reliability of the impact trolley and its consistent performance, an impact trolley calibration test procedure shall be conducted in accordance with **B.2**.

*NOTE 1 It is recommended that an impact trolley calibration test is conducted at regular intervals to test its performance, or when characteristics of the impact trolley have changed. The frequency of checks is likely to be dependent on the frequency with which the impact trolley is used for testing.*

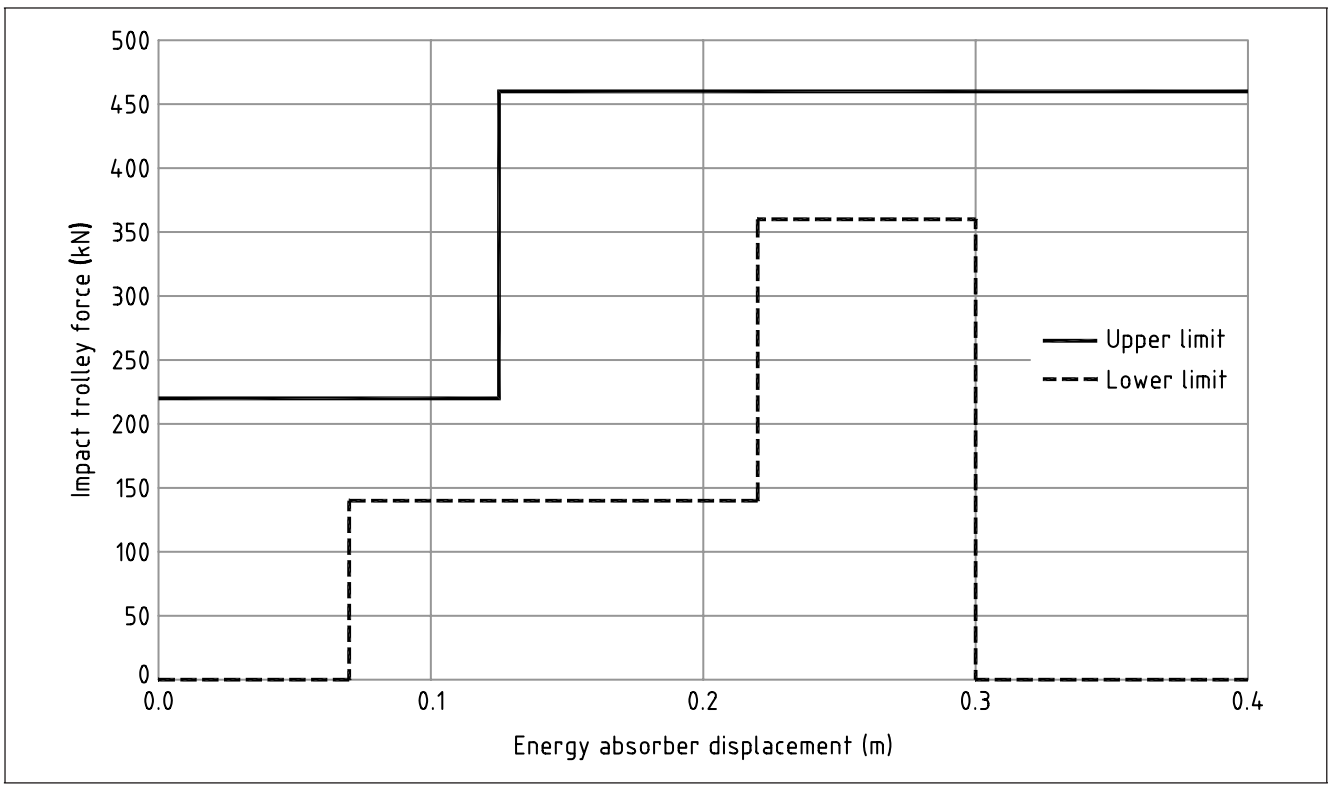
When tested in accordance with **B.2**, the required longitudinal force/deflection characteristic of the impact trolley shall conform to Table B.1 and be represented graphically, an example of this is shown in Figure B.1.

*NOTE 2 Figure B.1 can be used to demonstrate conformity with the impact trolley calibration requirements in B.1 and the overall force/deflection profile of the impact trolley as the results can be shown to fall clearly within the corridor created by the results.*

Table B.1 **Longitudinal force/displacement corridor limits**

| | **Upper limit** | | | | |
|---|---|---|---|---|---|
| Energy absorber displacement (m) | -- | 0 | 0.125 | 0.125 | 0.4 |
| Impact trolley force (kN) | -- | 220 | 220 | 460 | 460 |
| | **Lower limit** | | | | |
| Energy absorber displacement (m) | 0.07 | 0.07 | 0.22 | 0.3 | 0.3 |
| Impact trolley force (kN) | 0 | 140 | 140 | 360 | 0 |

Figure B.1 **Impact trolley longitudinal force/displacement corridor (visual example using data from Table B.1)**



The test shall be conducted using:

a) a target impact speed of $32^{+3}_{-1}$ km/h; and

b) at a target impact angle of 90°.

The test shall be conducted in a rigid foundation, using a concrete grade of RC32/40 conforming to BS EN 206:2013+A1:2016 and BS 8500-1:2015+A1:2016. The test shall be conducted a minimum of 28 days after the concrete has been poured and tested in accordance with **8.1.1.2**.

*NOTE 3 Testing an impact trolley at $32^{+3}_{-1}$ km/h can also be used to provide assurance of performance of the impact trolley at $16^{+3}_{-1}$ km/h. See also Clause **11** regarding inclusion of the impact trolley calibration test results in the test report.*

Where the energy absorber specification conforms to Table B.2, the energy absorber shall be replaced after each trolley impact.

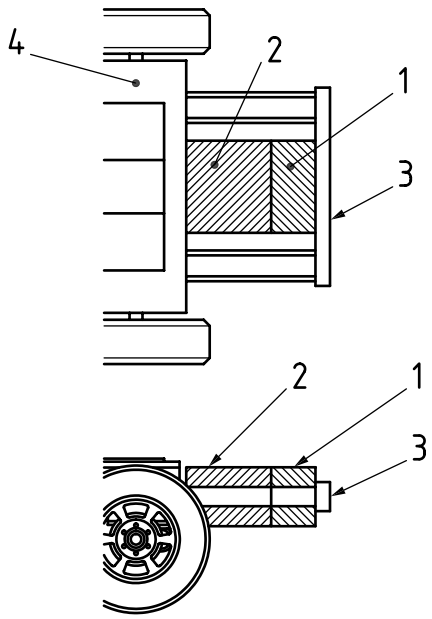
*NOTE 4 The energy absorber is a critical element of the impact trolley that replicates a surrogate N1G (2 500 kg) vehicle at low speed (see also the introduction). The constituent parts of an energy absorber are shown in Figure B.2. The specification for the energy absorber and its characteristics may conform to Table B.2, or a specification with an equivalent force/displacement profile as alternative methods of energy absorption might be available.*

Table B.2 **Example of an energy absorber specification**

| **Nominal properties** | **Part 1** | **Part 2** |
|---|---|---|
| Depth (front to back) | 170 mm | 300 mm |
| Width (parallel to test item datum line) | 330 mm | 330 mm |
| Height (perpendicular to ground) | 200 mm | 200 mm |
| Material | Aluminium honeycomb | Aluminium honeycomb |
| Compressive strength | 2.2 MPa | 5.5 MPa |

Figure B.2 **Example of energy absorber constituent parts**

*Drawings not to scale*




**Key**

1 Energy absorber part 1
2 Energy absorber part 2
3 Impact bumper
4 Rigid chassis

Where the energy absorber specification does not conform to Table B.2, it shall conform to **B.1** and shall display consistent performance.

When tested in accordance with **B.2**, the required force/deflection characteristic of the impact trolley shall conform to Table B.1 and be represented graphically (an example of this graphical representation is shown in Figure B.1).

## B.2 Impact trolley calibration test procedure

### B.2.1 Calibration test item

The calibration test item shall be a circular hollow section and have:

a) an overall diameter of 219 mm ±2 mm;

b) a wall thickness of 19 mm ±1 mm;

c) a height of 1 000 mm ±50 mm above ground; and

d) a depth of 600 mm ±50 mm below ground.

The calibration test item shall be made from steel grade S355 in accordance with BS EN 10210-1:2006, or equivalent.

The calibration test item shall be mounted in a rigid foundation in accordance with **5.4.2**. When installed, the calibration test item shall be 90° ±1° from the horizontal plane when measured using the measuring equipment conforming to **B.2.2**.

### B.2.2 Apparatus

#### B.2.2.1 General

The apparatus given in Clause **6** shall be used. In addition, the apparatus given in **B.2.2.2** to **B.2.2.4** shall be used for the impact trolley calibration procedure.

**B.2.2.2** *Measuring equipment for measuring the test item angle*, capable of measuring the angle of the installed test item with a minimum accuracy of ±0.5°.

**B.2.2.3** *Data acquisition system*, capable of recording the accelerometer data in accordance with SAE J211-1 [N1].

**B.2.2.4** *Accelerometer*, capable of measuring acceleration in the longitudinal direction and producing outputs in accordance with SAE J211-1 [N1].

### B.2.3 Impact trolley calibration test method

The impact trolley shall be set-up and prepared in accordance with Clause **7**.

The impact trolley calibration test procedure shall be set up in accordance with **8.1**. The accelerometer shall be securely fixed to the impact trolley longitudinal centre of gravity and on its centreline (±50 mm).

*NOTE The accelerometer should be mounted using an interface which reduces high frequency resonance within the impact trolley.*

With the exception of **8.2.3**d) and **8.2.3**e), the impact trolley calibration test shall be carried out in accordance with **8.2**.

## B.3 Impact trolley calibration test analysis

To demonstrate that the force/displacement profile of the impact trolley falls within the acceptable limits, the accelerometer data shall be processed in accordance with SAE J211-1 [N1], and the following procedure shall apply.

a) The accelerometer data shall be double integrated to generate the raw impact trolley displacement data. A channel frequency class of 180 (CFC 180) digital filter shall be applied to the data to produce the impact trolley displacement.

b) The accelerometer data shall be multiplied by the impact trolley test mass [see **11.2**b)] to generate the raw impact trolley force. A channel frequency class of 60 (CFC 60) digital filter shall be applied to the data to produce the impact trolley force.

*NOTE The calculations for a) and b) can be used for comparison with the impact trolley force/displacement corridor (Figure B.1).*

The impact trolley displacement and force data shall be compared to the corridor limits defined in Table B.1 and shown in Figure B.1.

## B.4 Impact trolley calibration test report

### B.4.1 General

A calibration test report shall be produced to record the results of the impact trolley calibration test. It may be used to demonstrate that the impact trolley force/displacement profile fits within the lower and upper limits of the force/displacement corridor, Figure B.1.

A graphical summary of the result shall be included in the standard test report [see **11.2**b)1)].

### B.4.2 Test characteristics

The following calibration test characteristics shall be stated in the calibration test report:

a) name(s) and address(es) of the test house or party carrying out testing and relevant accreditation/qualification status, if applicable;

b) date the test was undertaken;

c) calibration test item (see **B.2.1**);

d) impact speed:

   1) target impact speed (i.e. km/h);

   2) actual impact speed;

e) impact trolley test mass:

   1) target test mass;

   2) actual test mass;

f) energy absorber specification (see Table B.2 or state equivalent means);

g) graphical output of calibration test data (see **B.3**) plotted on to an impact trolley force/displacement corridor (see Figure B.1);

h) result of the calibration test (i.e. compliant/non-compliant).

# Annex C (normative) Soil properties and standard backfill

## C.1 Standard backfill for test pit

Test items requiring a standard soil shall be surrounded by a uniformly graded Type 1B granular backfill in accordance with the Department for Transport publication, *Manual of contract documents for highway works (MCHW) – Specification for highway works (Volume 1) – Series 800 – Road pavements – Unbound, cement and other hydraulically bound mixtures* [N2], which is free from organic material, having a particle size conforming to Table C.1. The soil grade and bearing capacity shall be measured and recorded.

*NOTE Example soil specifications are given in: ASTM F2656, AASHTO's Standard specification for materials for aggregate and soil-aggregate sub-base, base, and surface courses [2], and BS EN 12767:2007, Annex A.*

The particle size of the soil shall also conform to Table 6/2 of the Department for Transport publication, *Specification for highway works (Volume 1) – Series 800 – Road pavements – Unbound, cement and other hydraulically bound mixtures* [N2].

Table C.1 **Particle size of soil**

| **Sieve size** | **Soil passing through sieve** |
|---|---|
| mm | % |
| 63.000 | 100 |
| 31.500 | 75–99 |
| 16.000 | 43–81 |
| 8.000 | 23–66 |
| 4.000 | 12–53 |
| 2.000 | 6–42 |
| 1.000 | 3–32 |
| 0.063 | 0–9 |

*NOTE Table C.1 aligns with the Type 1 granular sub-base soil particle sizes given in Table 8/5 of the Department for Transport publication,* Manual of contract documents for highway works (MCHW) – Specification for Highway Works (Volume 1) – Series 800: Road pavements – Unbound, cement and other hydraulically bound mixtures *[N2].*

## C.2 Compaction and moisture content

When using soil for backfill, the soil shall be in a thawed state when placing and compacting. The soil shall not be placed on frozen substrate.

With the exception of chalk, any material or combination of materials, may be used within the soil.

The soil shall be placed in layers not exceeding 150 mm in depth. Each layer shall be thoroughly compacted by means of packers or mechanical tampers to a relative compaction of not less than 95% standard proctor density for the soil at optimum moisture content.

A minimum of 72 h before the test, the moisture content and compaction of the soil shall be measured and recorded.

At the time of compaction, the moisture condition value (MCV) of the soil shall be at an appropriate moisture content between +1% and –2% of the optimum moisture content.

*NOTE 1 The soil compaction can be recorded by nuclear density testing or the California Bearing Ratio (CBR). CBR can be calculated by using a dynamic cone/drop weight penetrometer, for example. For information regarding methods of compaction, see Table 6/4 of the DfT publication,* Manual of contract documents for highway works (MCHW) – Specification for Highway Works (Volume 1) – Series 800: Road pavements – Unbound, cement and other hydraulically bound mixtures *[N2]. Density of fill can be measured using methods stated in BS 1377-4:1990.*

*NOTE 2 A moisture meter can be used to measure the soil moisture content.*

*NOTE 3 The soil MCV is referenced in accordance with the vibrating hammer method given in BS 1377-4:1990,* ***3.7****.*

## C.3 Specified soil

Where it is deemed necessary to test the test item in a soil different to standard backfill, the specified soil shall be classified, identified and described in accordance with BS EN ISO 14688-1:2002+A1:2013 and BS EN ISO 14688-2:2004+A1:2013.

Shear, bearing, compaction and moisture content values of the specified soil shall be measured and recorded not more than 48 h before the test. Results to all tests shall be documented and referenced in the test report in accordance with Clause **11**.

# Bibliography

## Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASTM F2656, *Standard test method for crash testing of vehicle security barriers*

BS 1377-4:1990, *Methods of test for soils for civil engineering purposes – Part 4: Compaction-related tests*

BS EN 12767:2007, *Passive safety of support structures for road equipment – Requirements, classification and test methods* [4)]

BS EN ISO 9000, *Quality management systems – Fundamentals and vocabulary*

BS EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories* [4)]

IWA 14-1:2013, *Vehicle security barriers – Part 1: Performance requirement, vehicle impact test method and performance rating*

IWA 14-2:2013, *Vehicle security barriers – Part 2: Application*

PAS 68:2013, *Impact test specifications for vehicle security barrier systems*

PAS 69:2013, *Guidance for the selection, installation and use of vehicle security barrier systems*

**Other publications**

[1] SAE INTERNATIONAL. *SAE J211-2, Instrumentation for impact Test – Part 2: Photographic instrumentation*. Warrendale: SAE International, 2014.

[2] AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO). *M147, Standard specification for materials for aggregate and soil-aggregate subbase, base and surface courses.* Washington: AASHTO, 1965.

[4)] A revision of this standard is currently in development.

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