BS EN 1097-2:2010

BSI Standards Publication

Tests for mechanical and physical properties of aggregates

Part 2: Methods for the determination of resistance to fragmentation

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National foreword

This British Standard is the UK implementation of EN 1097-2:2010. It supersedes BS EN 1097-2:1998 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/502, Aggregates.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Tests for mechanical and physical properties of aggregates - Part 2: Methods for the determination of resistance to fragmentation

Essais pour déterminer les caractéristiques mécaniques et physiques de granulats - Partie 2 : Méthodes pour la détermination de la résistance à la fragmentation

Prüfverfahren für mechanische und physikalische Eigenschaften von Gesteinskörnungen - Teil 2: Verfahren zur Bestimmung des Widerstandes gegen Zertrümmerung

This European Standard was approved by CEN on 21 February 2010.

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Foreword

This document (EN 1097-2:2010) has been prepared by Technical Committee CEN/TC 154 "Aggregates", the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by September 2010, and conflicting national standards shall be withdrawn at the latest by September 2010.

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

This document supersedes EN 1097-2:1998.

This standard forms part of a series of tests for mechanical and physical properties of aggregates. Test methods for other properties of aggregates are covered by the following European Standards:

— EN 932 (all parts), *Tests for general properties of aggregates*

— EN 933 (all parts), *Tests for geometrical properties of aggregates*

— EN 1367 (all parts), *Tests for thermal and weathering properties of aggregates*

— EN 1744 (all parts), *Tests for chemical properties of aggregates*

— EN 13179 (all parts), *Tests for filler aggregate used in bituminous mixtures*

EN 1097, *Tests for mechanical and physical properties of aggregates*, consists of the following parts:

— *Part 1: Determination of the resistance to wear (micro-Deval)*

— *Part 2: Methods for the determination of resistance to fragmentation*

— *Part 3: Determination of loose bulk density and voids*

— *Part 4: Determination of the voids of dry compacted filler*

— *Part 5: Determination of the water content by drying in a ventilated oven*

— *Part 6: Determination of particle density and water absorption*

— *Part 7: Determination of the particle density of filler — Pyknometer method*

— *Part 8: Determination of the polished stone value*

— *Part 9: Determination of the resistance to wear by abrasion from studded tyres — Nordic test*

— *Part 10: Determination of water suction height*

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

1 Scope

This European Standard describes the reference method, the Los Angeles test, used for type testing and in case of dispute (and an alternative method, the impact test) for determining the resistance to fragmentation of coarse aggregates and aggregates for railway ballast (Annex A). For other purposes, in particular factory production control, other methods may be used provided that an appropriate working relationship with the reference method has been established.

This European Standard applies to natural, manufactured or recycled aggregates used in building and civil engineering.

2 Normative references

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

EN 932-1, *Tests for general properties of aggregates — Part 1: Methods for sampling*

EN 932-2, *Tests for general properties of aggregates — Part 2: Methods for reducing laboratory samples*

EN 932-5, *Tests for general properties of aggregates — Part 5: Common equipment and calibration*

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

EN 933-2, *Tests for geometrical properties of aggregates — Part 2: Determination of particle size distribution — Test sieves, nominal size of apertures*

EN 1097-6:2000, *Tests for mechanical and physical properties of aggregates — Part 6: Determination of particle density and water absorption*

EN 10025-2:2004, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

3 Terms and definitions

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

3.1
Los Angeles coefficient
LA
percentage of the test portion passing a pre-determined sieve after completion of the test

3.2
impact value
SZ
value SZ which gives a measure of the resistance of aggregates to dynamic crushing, and is equal to one fifth of the sum of the mass percentages of the tested sample passing through five specified test sieves when tested in accordance with Clause 6

3.3
test specimen
sample used in a single determination when a test method requires more than one determination of a property

3.4
test portion
sample used as a whole in a single test

3.5
laboratory sample
reduced sample derived from a bulk sample for laboratory testing

3.6
constant mass
successive weighings after drying at least 1 h apart not differing by more than 0,1 %

NOTE In many cases constant mass can be achieved after a test portion has been dried for a pre-determined period in a specified oven (see 4.1.3) at (110 ± 5) °C. Test laboratories may determine the time required to achieve constant mass for specific types and sizes of sample dependent upon the drying capacity of the oven used.

4 Apparatus

Unless otherwise stated, all apparatus shall conform to the general requirements of EN 932-5.

4.1 General apparatus

4.1.1 Test sieves, conforming to EN 933-2 with aperture sizes as specified in Table 1.

Table 1 — Test sieves

Test	**Aperture size** mm
Los Angeles	1,6; 10; 11,2 (or 12,5); 14
Impact test [a]	0,2; 0,63; 2; 5; 8; 10; 11,2; 12,5

[a] For the impact test, because of the tolerances in the sieve openings, the same 8 mm test sieve used for the preparation of the test portion should again be used for the evaluation of the test.

4.1.2 Balance, capable of weighing the test portion to an accuracy of 0,1 % of the mass of the test portion.

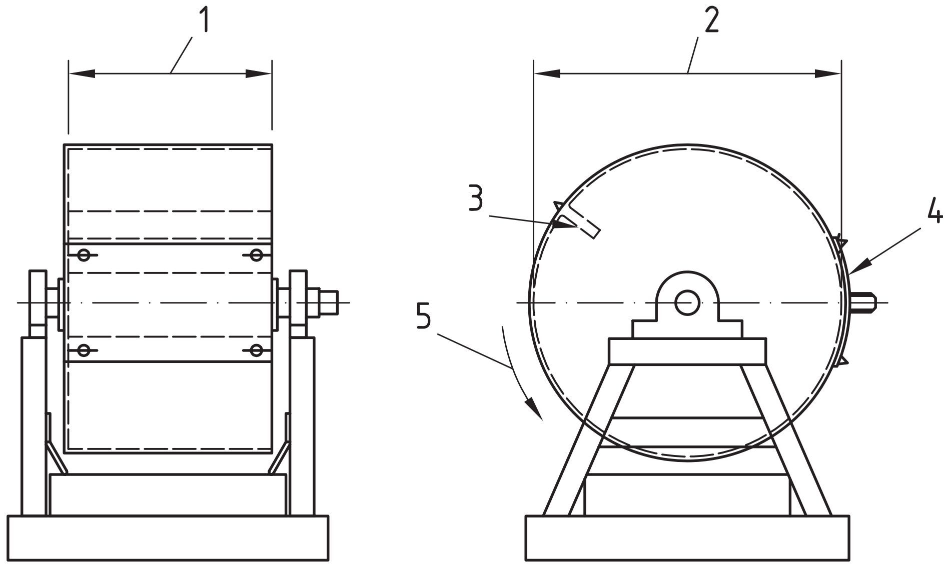
4.1.3 Ventilated oven, controlled to maintain a temperature of (110 ± 5) °C.

4.2 Additional apparatus required for the determination of resistance to fragmentation by the Los Angeles test method

4.2.1 Equipment, for reducing the laboratory sample to a test portion, as described in EN 932-2.

4.2.2 Los Angeles test machine, comprising the following essential parts.

NOTE An example of a machine that has been found to be satisfactory is shown in Figure 1.



Key

1 internal length (508 ± 5) mm
2 internal diameter (711 ± 5) mm
3 shelf
4 cover and opening
5 rotation

Figure 1 — Typical Los Angeles testing machine

4.2.2.1 Hollow drum, made of structural steel plate ($12^{+1,0}_{-0,5}$) mm thick conforming to grade S275 of EN 10025-2:2004 which has been selected to be formed without undue stress, and can be welded without significant distortion. The drum shall be closed at both ends. It shall have an internal diameter of (711 ± 5) mm and an internal length of (508 ± 5) mm. The drum shall be supported on two horizontal stub axles fixed to its two end walls but not penetrating inside the drum; the drum shall be mounted so that it rotates about a horizontal axis.

An opening (150 ± 3) mm wide shall be provided, preferably over the whole length of the drum, to facilitate insertion and removal of the sample after the test. During the test, the opening shall be sealed so that it is dustproof, by using a removable cover which enables the inside surface to remain cylindrical.

The cylindrical inner surface shall be interrupted by a projecting shelf, placed between 380 mm and 820 mm from the nearest edge of the opening. The distance shall be measured along the inside of the drum in the direction of rotation. The shelf shall have a rectangular cross section (length equal to that of the drum, width (90 ± 2) mm, thickness (25 ± 1) mm) and it shall be placed in a diametrical plane, along a generating line, and shall be rigidly fixed in place.

The shelf shall be replaced when its width at any point wears to less than 86 mm and its thickness at any point along the front edge wears to less than 23 mm.

The base of the machine shall be supported directly on a level concrete or stone block floor.

NOTE The removable cover should be made of the same steel as the drum. The projecting shelf should be made of the same steel or a harder grade.

4.2.2.2 Ball load, consisting of 11 spherical steel balls, each with a diameter of between 45 mm and 49 mm (see Annex B). Each ball shall weigh between 400 g and 445 g, and the total load shall weigh between 4 690 g and 4 860 g.

NOTE The nominal mass of the charge with new balls is 4 840 g. A positive tolerance of 20 g allows for manufacturing variation and a negative tolerance of 150 g allows for ball wear in use.

4.2.2.3 Motor, imparting a rotational speed to the drum of between 31 min^{-1} and 33 min^{-1}.

4.2.2.4 Tray, for recovering the material and the ball load after testing.

4.2.2.5 Revolution counter, which will automatically stop the motor after the required number of revolutions.

4.3 Additional apparatus required for the determination of resistance to fragmentation by the impact test method

4.3.1 Impact tester, see Annex C.

4.3.2 Equipment for testing the accuracy of the impact tester, see Annex D.

NOTE Annexes C and D are informative and do not contain any normative provisions for the application of this European Standard. However, it is strongly recommended that all the informative provisions of these annexes be observed when carrying out the test specified in Clause 6.

4.3.3 Brush and bowls.

5 Determination of resistance to fragmentation by the Los Angeles test method

5.1 Principle

A sample of aggregate is rolled with steel balls in a rotating drum. After rolling is complete, the quantity of material retained on a 1,6 mm sieve is determined.

5.2 Preparation of test portion

The mass of the sample sent to the laboratory shall have at least 15 kg of particles in the 10 mm to 14 mm size range.

The test shall be carried out on aggregate passing the 14 mm test sieve and retained on the 10 mm test sieve. In addition, the grading of the test portion shall comply with one of the following requirements:

a) between 60 % and 70 % passing a 12,5 mm test sieve; or

b) between 30 % and 40 % passing a 11,2 mm test sieve.

NOTE 1 The additional grading requirements allow the test portion to be created from product sizes other than 10/14 (see Annex B).

NOTE 2 For recycled aggregates, a test procedure for the 16/32 mm size fraction is described in Annex G.

Sieve the laboratory sample using the 10 mm, 11,2 mm (or 12,5 mm) and 14 mm test sieves to give separate fractions in the ranges 10 mm to 11,2 mm (or 12,5 mm) and 11,2 mm (or 12,5 mm) to 14 mm. Wash each fraction separately, in accordance with EN 933-1, and dry them to constant mass.

NOTE 3 For temperature-sensitive recycled aggregates, a drying temperature of (40 ± 5) °C should be used.

Allow the fractions to cool to ambient temperature. Mix the two fractions to provide a modified 10 mm to 14 mm laboratory sample which complies with the appropriate additional grading requirement given above.

Reduce the modified laboratory sample prepared from the mixed fractions to test portion size in accordance with EN 932-2. The test portion shall have a mass of (5 000 ± 5) g.

5.3 Test procedure

Check that the drum is clean before loading the sample. Carefully place the balls in the machine, then the test portion. Replace the cover and rotate the machine for 500 revolutions at a constant speed between 31 min^{-1} and 33 min^{-1}.

Pour the aggregate into a tray placed under the apparatus, taking care that the opening is just above the tray in order to avoid losing any material. Clean out the drum, removing all fines, paying particular attention around the projecting shelf. Carefully remove the ball load from the tray, taking care not to lose any aggregate particles.

Analyze the material from the tray in accordance with EN 933-1 by washing and sieving using a 1,6 mm sieve. Dry the portion retained on the 1,6 mm sieve at a temperature of (110 ± 5) °C (or lower, see Note 3 to 5.2) until a constant mass is achieved.

5.4 Calculation and expression of results

Calculate the Los Angeles coefficient *LA* from the following equation:

$$LA = \frac{5\,000 - m}{50}$$

where

m is the mass retained on the 1,6 mm sieve, in grams.

Report the result to the nearest whole number.

NOTE A statement on the precision of the Los Angeles test is given in Annex E.

5.5 Test report

The test report shall include at least the following information:

a) confirmation that the Los Angeles test was carried out in accordance with this standard;

b) number of this standard;

c) name and origin of sample;

d) size fractions from which the test portion was obtained;

e) Los Angeles coefficient *LA*.

6 Determination of resistance to fragmentation by the impact test method

6.1 Principle

A test specimen is placed in a steel cylinder and subjected to ten impacts from a hammer of mass 50 kg, falling from a specified height. The amount of fragmentation caused by the ten impacts is measured by sieving the test specimen using five specified test sieves.

6.2 Preparation of test specimens

6.2.1 A laboratory sample shall be obtained in accordance with EN 932-1. The sample shall contain at least 5 kg of the size fraction 8 mm to 10 mm and 2,5 kg of each of the size fractions 10 mm to 11,2 mm and 11,2 mm to 12,5 mm.

6.2.2 A quantity of the size fractions 8 mm to 10 mm, 10 mm to 11,2 mm and 11,2 mm to 12,5 mm sufficient for at least three test specimens (see 6.2.3 and 6.2.4) shall be prepared from the laboratory sample using the sieves 8 mm, 10 mm, 11,2 mm and 12,5 mm specified in 4.1.1. This quantity shall be washed in accordance with EN 933-1, dried to constant mass and left to cool to between 15 °C and 35 °C.

NOTE For temperature-sensitive recycled aggregates, a drying temperature of (40 ± 5) °C should be used.

6.2.3 Material for at least three test specimens shall be recombined as follows and three test specimens shall be tested (see 6.2.4). The test specimens shall be composed of 50 % of the size fraction 8 mm to 10 mm, 25 % of the size fraction 10 mm to 11,2 mm and 25 % of the size fraction 11,2 mm to 12,5 mm and be weighed to the nearest 0,5 g. The three fractions shall be mixed thoroughly prior to weighing of the test specimen as described in 6.2.4.

6.2.4 The mass of the test specimen in kilograms shall be 0,5 times the value of the particle density in megagrams per cubic metre as determined in accordance with EN 1097-6 on a sample composed as specified in 6.2.3.

If this particle density is known from previous tests, that result can be used.

For each test specimen the quantities, in kilograms, are:

a) size fraction 8 mm to 10 mm: 0,25 times the particle density;

b) size fraction 10 mm to 11,2 mm: 0,125 times the particle density;

c) size fraction 11,2 mm to 12,5 mm: 0,125 times the particle density.

The mass of a test specimen, referred to as M, prior to the testing shall not differ by more than 1 % from the nominal mass.

6.3 Test procedure

6.3.1 The test specimen shall be poured into the mortar of the impact test machine and its surface roughly evened by hand without jigging. The pestle shall be pressed by the corresponding device onto the test specimen and the hammer lifted up to a height of 370 mm. The test specimen shall then be subjected to ten blows by the hammer.

6.3.2 After the blows, lift up the pestle and take the mortar out of the apparatus. Then pass the crushed sample carefully into a bowl. Any fine particles adhering to the mortar shall be swept into the bowl with the brush and the test specimen shall subsequently be weighed.

6.3.3 The crushed test specimen shall be sieved in accordance with EN 933-1 on the following five test sieves specified in 4.1.1, starting with the 8 mm sieve: 0,2 mm; 0,63 mm; 2 mm; 5 mm; 8 mm.

The fraction retained on the five test sieves and the pan shall be weighed to the nearest 0,5 g.

6.3.4 If the total mass of the test specimen after sieving differs from the original mass by more than 0,5 %, the impact test shall be carried out on a further test specimen.

6.4 Calculation and expression of results

Calculate the mass retained on each of the five test sieves and on the pan, for each test specimen, as a percentage of the mass, *M*, of the test specimen before testing. Calculate from this the percentage masses passing the five sieves.

Add up the percentage masses passing each of the five test sieves to give the sum of percentage masses *M.*

Calculate the impact value *SZ*, in percent, from the following formula:

$$SZ = \frac{M}{5}$$ (see Clause 3 and the worked example given in Annex F)

where

M is the sum of the percentages of the mass passing each of the five test sieves.

NOTE A statement on the precision of the impact test is given in Annex E.

6.5 Test report

The test report shall include at least the following information:

a) confirmation that the test was carried out in accordance with this Standard and number of this standard;

b) name and origin of sample;

c) size fractions from which the test portion was obtained;

d) particle density of the size fraction 8 mm to 12,5 mm rounded to 0,01 Mg/m^3 and determined in accordance with EN 1097-6;

e) test result (impact value *SZ*, together with results of single test specimens rounded to 0,01 % and mean value rounded to 0,1 %).

Annex A
(normative)

Determination of the resistance to fragmentation of aggregates for railway ballast

NOTE The following clause numbers refer to the corresponding clauses in the main document. These clauses express additions or modifications to main text clauses.

4 Apparatus

4.1 General apparatus

4.1.1 Test sieves, conforming to EN 933-2 with aperture sizes as specified in Table 1.

Table 1 — Test sieves

Test	Aperture size mm
Los Angeles	31,5; 40; 50
Impact test	31,5; 40

4.2 Additional apparatus required for the determination of resistance to fragmentation by the Los Angeles test method

4.2.2.2 Ball load, consisting of 12 spherical steel balls instead of 11. The total load shall weigh (5 210 ± 90) g.

5 Determination of the resistance to fragmentation by the Los Angeles test method

5.2 Preparation of test portion

The mass of the sample sent to the laboratory shall have at least 15 kg of particles in the 31,5 mm to 50 mm size range.

The test shall be carried out on aggregates passing the 50 mm test sieve and retained on the 31,5 mm test sieve.

Sieve the laboratory sample using the 31,5 mm, 40 mm and 50 mm test sieves to give separate fractions in the ranges 31,5 mm to 40 mm and 40 mm to 50 mm. Wash each fraction separately, in accordance with EN 933-1, and dry them in the oven at (110 ± 5) °C to constant mass. Allow the fractions to cool to ambient temperature.

Reduce the mass of the fractions in accordance with EN 932-2. Each fraction shall have a mass of (5 000 ± 50) g. Mix the two fractions to provide a 31,5 mm to 50 mm test portion. The test portion shall have a mass of (10 000 ± 100) g.

5.3 Test procedure

Rotate the machine for 1 000 revolutions instead of 500.

5.4 Calculation and expression of results

Calculate the Los Angeles coefficient LA_{RB} from the following equation:

$$LA_{RB} = \frac{10\,000 - m}{100}$$

5.5 Test report

The test report shall affirm that the Los Angeles test was carried out in accordance with Annex A of this standard. It shall include the following information:

c) Los Angeles coefficient LA_{RB}.

6 Determination of the resistance to fragmentation by the impact test method

6.2 Preparation of test specimens

6.2.1 The sample shall contain at least 10 kg of the size fraction 31,5 mm to 40 mm.

6.2.2 A quantity of the size fraction 31,5 mm to 40 mm sufficient for at least three test specimens (see 6.2.3) shall be prepared from the laboratory sample using the sieves 31,5 mm and 40 mm specified in 4.1.1. This quantity shall be washed in accordance with EN 933-1, dried at (110 ± 5) °C to constant mass and left to cool to between 15 °C and 35 °C.

6.2.3 Material for at least three test specimens shall be used. The mass of each 31,5 mm to 40 mm test specimen in kilograms shall be 1,05 times the value of the particle density in megagrams per cubic metre as determined in accordance with EN 1097-6:2000, Annex B.

6.3 Test procedure

6.3.1 The hammer shall be lifted up to a height of 420 mm instead of 370 mm. The test specimen shall then be subjected to twenty blows by the hammer instead of ten blows.

6.3.3 The crushed test specimen shall be sieved in accordance with EN 933-1 on the 8 mm sieve specified in 4.1.1.

The fraction passing the 8 mm sieve shall be weighed to the nearest 0,5 g and referred to as M_1.

6.4 Calculation and expression of results

Calculate the mass passing the 8 mm sieve, for each test specimen, as a percentage of the mass M of the test specimen before testing.

Calculate the impact value SZ_{RB}, in percent, from the following formula:

$$SZ_{RB} = \frac{M_1}{M}$$

where

M_1 is the mass passing the 8 mm sieve;

M is the mass of the test specimen before testing.

6.5 Test report

The test report shall include at least the following information:

d) particle density of the size fraction 31,5 mm to 40 mm rounded to 0,01 Mg/m^3 and determined in accordance with EN 1097-6;

e) test result (impact value SZ_{RB}, together with results of single test specimens rounded to 0,01 % and mean value rounded to 0,1 %).

Annex B
(informative)

Alternative narrow range classifications for the Los Angeles test

The following variations to the reference test (see 5.2) may provide additional information for certain end uses.

The narrow range classifications set out in Table B.1 can be used.

NOTE The alternative narrow range classifications for the Los Angeles test annex provides a methodology for testing size fractions other than the standard 10/14 mm size fraction in the reference test. Different numbers of balls and ball loads are given for each range classification. These have been selected in order to produce results from the non-standard fractions close to those from the standard 10/14 mm fraction. However, the relationship is not the same for all aggregates and the alternative size fractions should not be expected to give results identical to those from the 10/14 mm reference method.

Use test sieves of the appropriate size to match the range classification, instead of those defined in 4.1.1 and 5.2.

Table B.1 — Alternative narrow range classifications

Range classification mm	**Intermediate sieve size** mm	**Percentage passing intermediate sieve** %	**Number of balls**	**Mass of ball load** g
4 to 6,3	5	30 to 40	7	2 930 to 3 100
4 to 8	6,3	60 to 70	8	3 410 to 3 540
6,3 to 10	8	30 to 40	9	3 840 to 3 980
8 to 11,2	10	60 to 70	10	4 250 to 4 420
11,2 to 16	14	60 to 70	12	5 120 to 5 300

Annex C
(informative)

The impact tester: Construction, operation and safety requirements

C.1 General

All dimensions are in millimetres.

For general tolerances, accuracy grade m as specified in ISO 2768-1:1989 and ISO 2768-2:1989.

C.2 Construction

The structural elements of the impact tester involved in the impact test are shown in Figure C.1. The impact tester consists of four subassemblies:

a) lifting device, consisting of drop hammer, guides, lifting and drive motor, counters (see C.3);

b) sample holder, consisting of pestle and mortar with automatic contact pressure and adjustment device (see C.4);

c) anvil (see C.5);

d) base plate and dampers (see C.6).

C.3 to C.6 describe the mode of operation, dimensioning, material quality, surface quality and surface hardness of the subassemblies.

All movements should be along the common axis of the drop hammer, pestle, mortar and anvil. The drop hammer and the mortar contact pressure device should have a common guide (see Figure C.2) which should be adjusted into a vertical position when the impact tester is set up (see also C.4.2).

For this construction, the following characteristic values (arithmetic means of ten impacts) should be adhered to for the impact with a hammer drop height of 400 mm:

— Impact force F_{max} = (830 ± 60) kN

— Pulse P = $\int F$xdt = (240 ± 25) Nxs

— Pulse duration t = (510 ± 20) ms

For checking of the impact tester, see C.8.

C.3 Lifting device

C.3.1 General

The lifting device consists of a drop hammer, guides, lifting and drive motor and counters.

C.3.2 Drop hammer

The drop hammer shown in Figure C.3, consisting of a shaft and head, is cylindrical with a slenderness ratio of approximately 4:1. It has a replaceable head tapering towards the impact surface. The contact surface between shaft and head should be finished in such a way that it forms at least 80 % of the total area. The shaft and head should be braced by means of four bolts with waisted shank (see Figure C.3) in such a way that no load is removed from the bolts during the impact.

The drop hammer parts should be manufactured from the following materials:

a) the shaft from case hardened steel 20 MnCr 5 as specified in ISO 683-11;

NOTE 1 Hardening method; case hardened depth not less than 1 mm; required surface hardness: 54 HRC to 56 HRC (as specified in EN ISO 6508-1).

NOTE 2 Heat treatment for case hardening; as specified in ISO 683-11.

b) The head from tool steel 60 WCrV 7 as specified in EN ISO 4957; Rockwell hardness after quenching and tempering in the middle and on the edge of the impact surface: 54 HRC to 56 HRC (as specified in EN ISO 6508-1).

See also C.8 and Annex D.

C.3.3 Guides

After the structural elements have been adjusted, the drop hammer should fall in "free" fall. The replaceable side guide rails shown in Figure C.4 secure the drop hammer in its guide grooves. The arrangement of the guide grooves ensures a low degree of friction and good stability. The guide rails should be made of bright non-alloy steel St 52-3 (material number 1.0570) as specified in EN 10025-2:2004, Table A.1.

C.3.4 Lifting and drive motor, counters

The lifting motor raises the drop hammer to the required position. The drop height, calculated from the bottom edge of the drop hammer to the dome of the pestle should be capable of being set from 200 mm to 500 mm at intervals of 1 mm.

The drop height should be corrected automatically by the drive motor by the amount the specimen is compressed by the impact so that the drop height is constant to within 2,0 mm over the duration of the whole test.

Two electric counters should record the number of impacts. One of the counters should disconnect the lifting motor after the desired number of impacts and the second counter should record the total number of impacts.

C.4 Sample holder

C.4.1 General

The holder, consisting of pestle and mortar, should be positioned between the drop hammer and the anvil during the impact test. Whereas the mortar forms an interference fit with the anvil, the pestle should be pressed against the specimen in the mortar by the contact pressure device via springs.

C.4.2 Mortar

The mortar as shown in Figure C.5 should be made of the same case hardening steel as the shaft of the drop hammer (see C.3.2). It should have a flat, non-recessed ground support with a Rockwell hardness of 54 HRC to 56 HRC (as specified in EN ISO 6508-1). The smaller surface for holding the specimen inside the mortar thus experiences uniform contact pressure with the anvil face.

C.4.3 Pestle

The pestle as shown in Figure C.6 should be made of the same steel as the drop hammer head (see C.3.2) and should be quenched and tempered in the same way because of the high impact forces occurring during the impact test. The Rockwell hardness of the impact surface should be 54 HRC to 56 HRC (as specified in EN ISO 6508-1).

The force should be applied to the pestle at one point. For this, the contact point of the pestle should be spherical. The cylindrical part of the pestle provides the necessary guidance in the mortar.

Two turnbuckles connect the contact pressure device and the pestle. The turnbuckles should be made of quenched and tempered steel 1C 45 (material number 1.0503) as specified in EN 10083-2.

It is possible to control the alignment between drop hammer, pestle and mortar by the vertical movement of the pestle as it is driven automatically into and out of the mortar. The correct position is reached when the pestle is driven centrically into the mortar, taking into account the play between pestle and mortar. When the pestle has reached its end position, no change in the play around the sides should be visible to the naked eye.

C.4.4 Contact pressure and adjustable device

The (1 000 ± 100) N friction fit of the pestle and specimen in the mortar should be maintained throughout the test procedure. As the specimen is increasingly compressed, the contact pressure is corrected by the drive motor so that the original contact pressure is maintained after each impact. The elastic contact pressure may be applied to the pestle, e.g. by means of six springs with a constant force of approximately 5 N/mm via a polyamide 66 centring ring, as specified in ISO 1874-1, enclosed by a steel ring.

For adjustment purposes, it is necessary that the pestle is held against the contact pressure flange initially with a force of 250 N. In the loading condition, a further 750 N should be applied, giving 8 mm more spring excursion during the impact procedure.

C.5 Anvil

The anvil (see Figure C.7) should be cylindrical in shape. Its end face should be tapered to form a truncated cone. Its total mass is concentrated concentrically and uniformly in the impact direction. The end face should be flat and form the seat for the mortar. There should be bracing elements to brace the mortar on the anvil. The bracing elements should be adjustable to allow adjustment of the mortar on the anvil. Holes should be provided in the anvil to take the dampers. The anvil should be made of grade 250 grey cast iron as specified in ISO 185.

C.6 Base plate and dampers

The base plate in Figure C.7 should be made of steel St 37-2 (material number 1.0037) as specified in EN 10025-2:2004, Table A.1. The frame and anvil should stand vertically, separate from each other, on the same base (see Figure C.2). The frame should form a friction fit with the base. The base should be fastened by means of anchor bolts to a solid, flat and horizontal supporting surface. The static loading of the supporting surface resulting from the mass of the impact tester via the base is approximately 14 000 N. With a drop height of 400 mm, the short-time additional loading of the supporting surface is approximately 27 000 N. The "sinusoidal" loading lasts approximately 1 ms. Four dampers, as shown in Figure C.8, should be fitted between the base and the anvil.

Each damper should be capable of being loaded with at least 10 000 N.

NOTE Guideline value of range of:

— spring at maximum loading: 2,5 mm to 4,5 mm;

— oscillation frequency at maximum loading: 500 min^{-1} to 600 min^{-1};

— rubber quality: Natural rubber mixture of 60 IRHD to 80 IRHD hardness as specified in ISO 48;

— dimensional tolerances: Class M4 as specified in ISO 3302-1.

Anvil, dampers and base should be connected by means of screw bolts. The dampers enable the anvil to be adjusted, form a specific base and act as silencers against the supporting surface.

C.7 Safety requirements and testing

C.7.1 The drop hammer should be secured by means of a suspension device against unintentional release when the mortar is being inserted or removed from the impact tester.

C.7.2 Protection should be provided against reaching into the danger area of the drop hammer during operation. This can be provided, for example, by a moveable screen which is locked in position during operation.

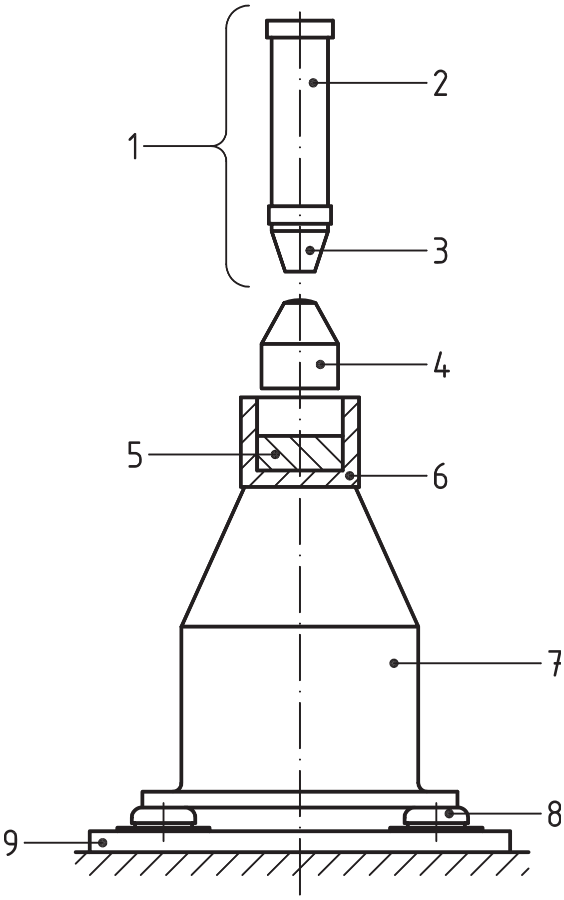
The safety requirements given in C.7.1 and C.7.2 should be fully tested by visual examination.

C.7.3 The necessary silencing measures should be taken during the operation of the impact test, e.g. soundproofed room, soundproofing jacket.

NOTE See also Noise at Work Directive 2003/10/EC.

C.8 Checking of impact tester

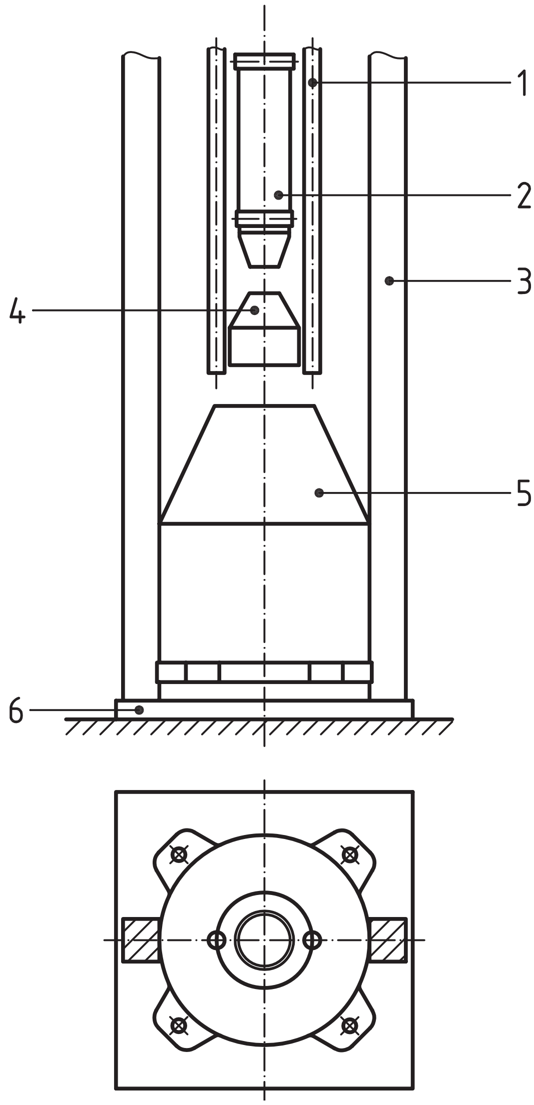
After setting up the impact tester, it should be subjected to an acceptance test as specified in Annex D by an independent institution. This test should be repeated every two years.



Key

1 drop hammer
2 shaft
3 head
4 pestle
5 specimen
6 mortar
7 anvil
8 damper
9 base

Figure C.1 — Diagrammatic representation of impact tester

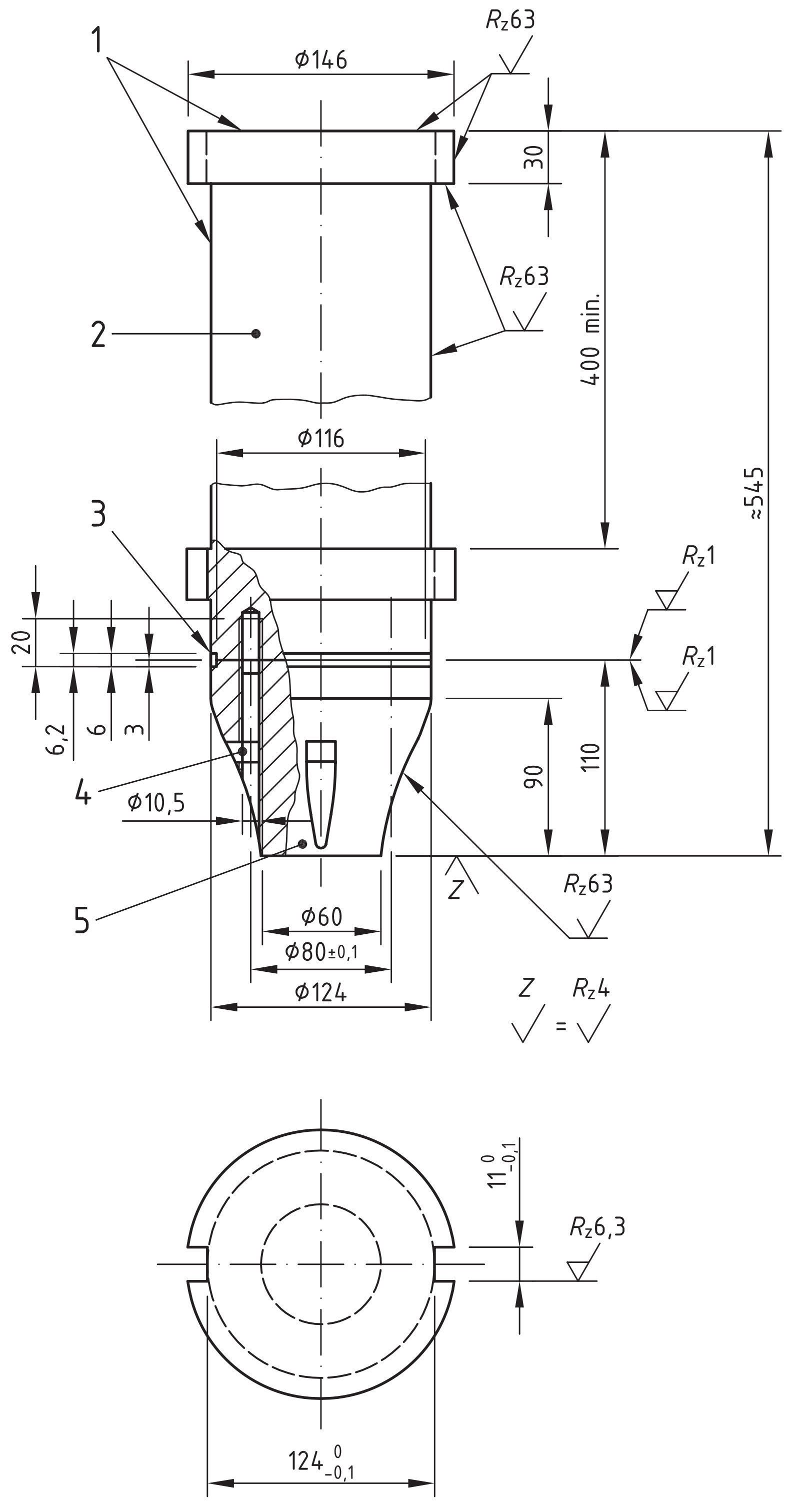


Key

1 guide for contact pressure and adjustment device and drop hammer
2 drop hammer
3 frame
4 pestle with contact pressure and adjust device
5 anvil
6 base

Figure C.2 — Set-up of the moving parts

Dimensions in millimetres

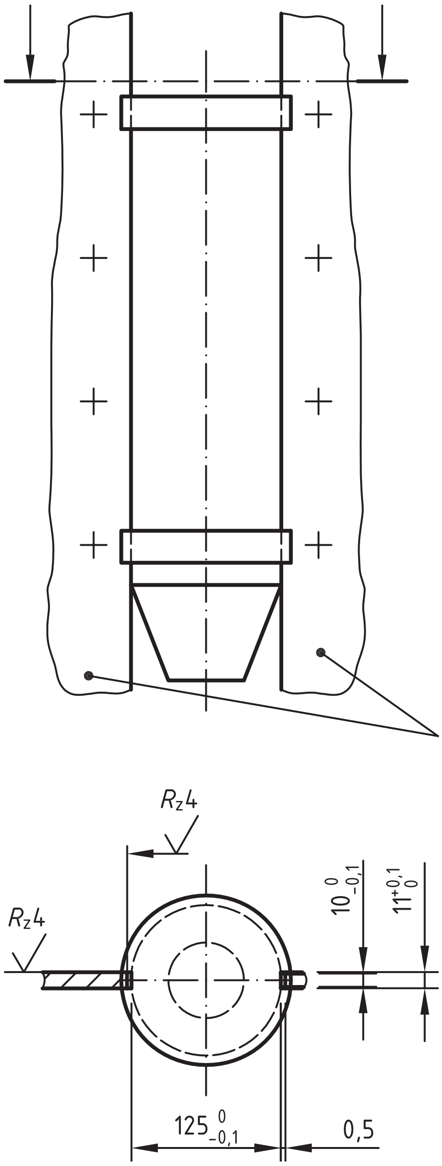


Key

1 length and total diameter matched to a total mass (including suspension device of (50 ± 0,1) kg)
2 shaft
3 centring ring
4 hexagon socket head cap screws conforming to product grade A of ISO 4762:2004
5 head

Figure C.3 — Hammer

Dimensions in millimetres

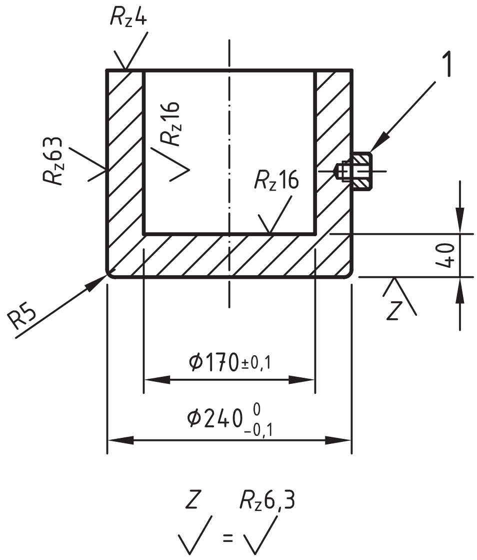


Key

1 replaceable guide rail

Figure C.4 — Guide rails

Dimensions in millimetres

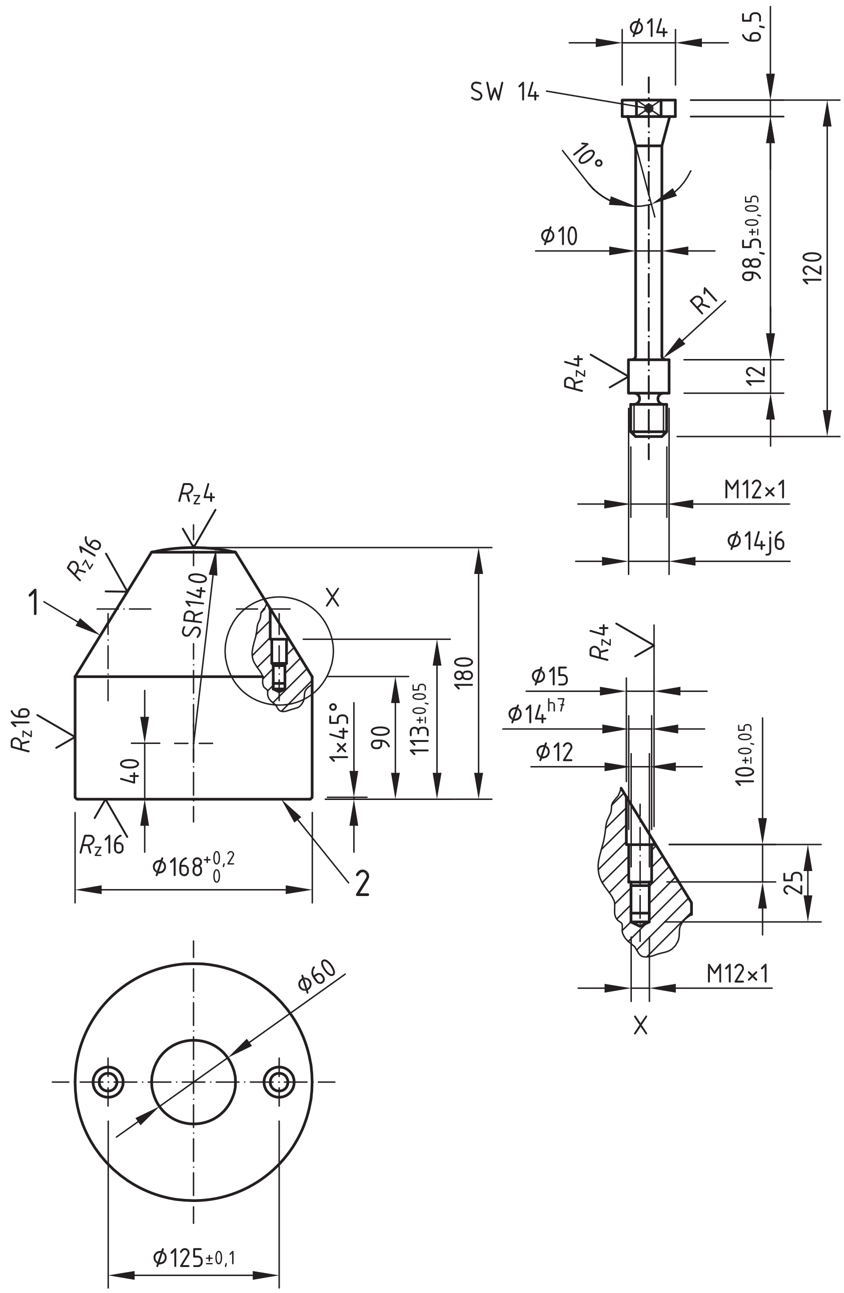


Key

1 the mass of the mortar fixing element and guide rail should exceed 4 kg

Figure C.5 — Mortar

Dimensions in millimetres



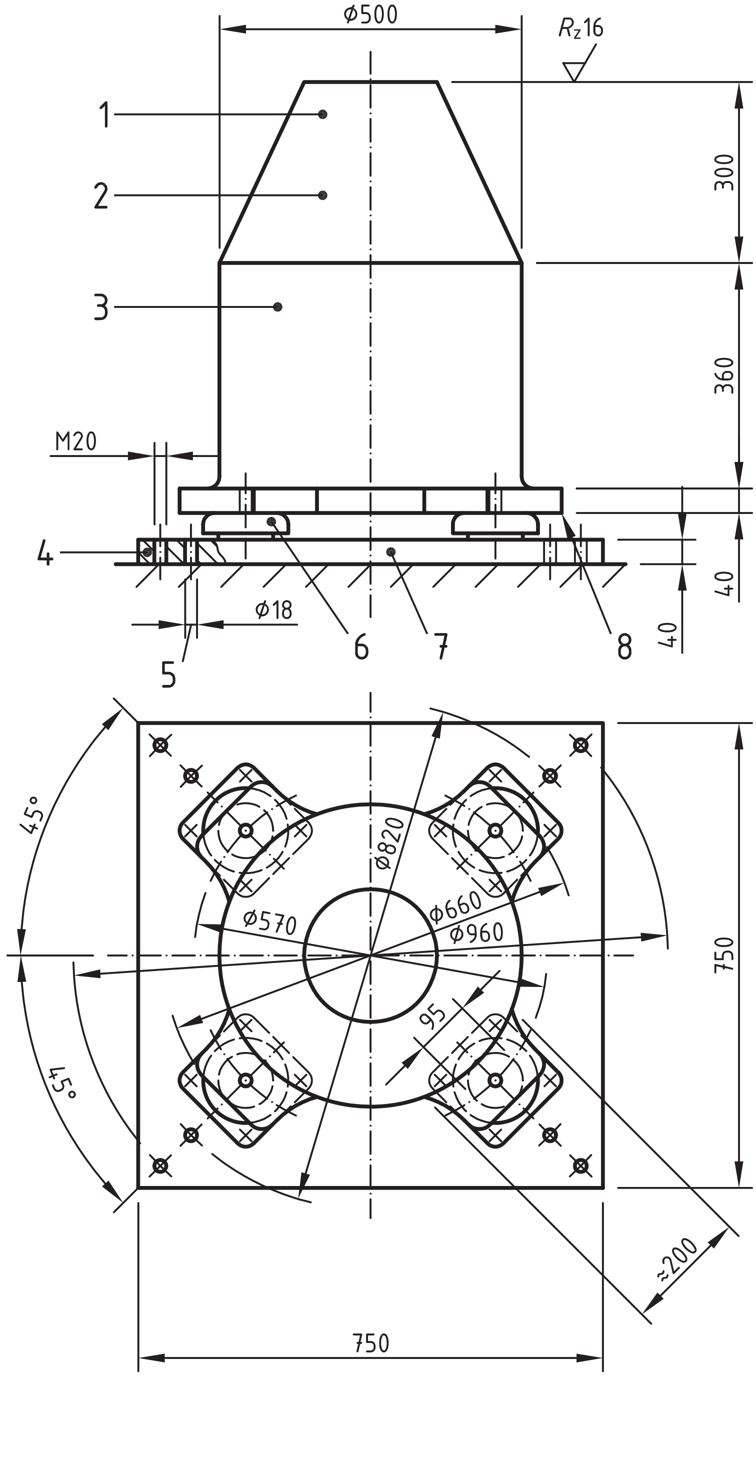
Key

1 contact pressure and adjustment device

2 matching to a mass of (23 ± 0,1) kg

Figure C.6 — Pestle with turnbuckle

Dimensions in millimetres



Key

1 anvil
2 mass approximately 800 kg
3 ISO 8062 – CT 11 tolerance
4 thread for adjusting screw
5 through hole for anchor bolt
6 damper
7 base plate
8 support

Figure C.7 — Anvil with base plate and dampers

Dimensions in millimetres

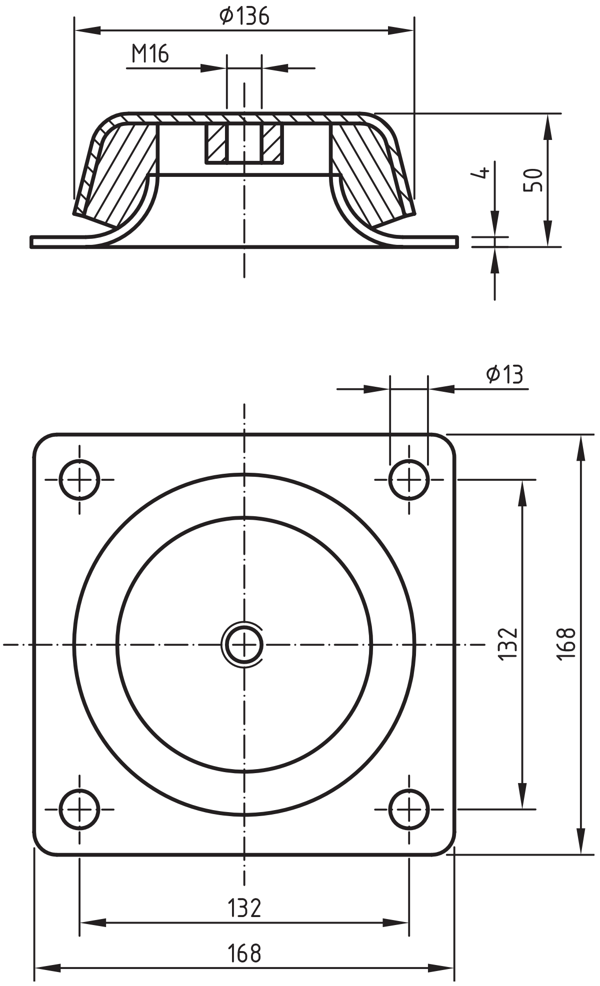


Figure C.8 — Construction of the dampers

Annex D
(informative)

Checking of the impact tester

D.1 General

Testing of the impact tester as described in C.8 is necessary to obtain reproducible impact conditions for all impact testers.

This test establishes whether impact testers as specified in Annex C meet the requirements of and are applicable for the impact test described in this standard.

D.2 Checklist

Checking covers the following items:

a) ensuring the vertical set-up and guide play between pestle and mortar;

b) determining the hardness of the hammer head, pestle, mortar and anvil;

c) surface condition;

d) condition of the bolts with waisted shank;

e) pestle pressure device;

f) drop height constancy;

g) determination of impact effect.

D.3 Apparatus and test agents

D.3.1 Spirit level, accurate to within 0,2 mm/m.

D.3.2 Test device for determining impact effect consisting of:

a) sensor;

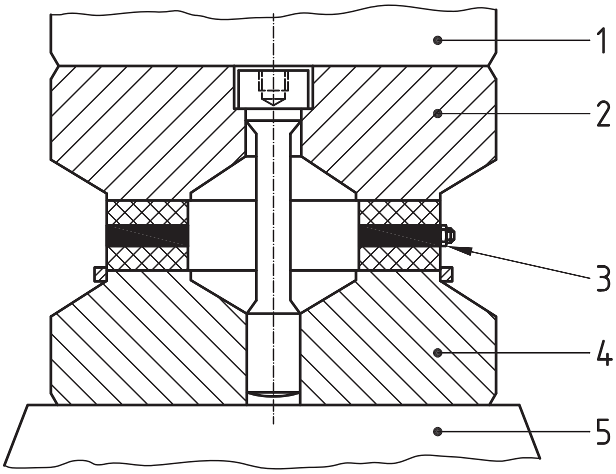
b) transducer; and

c) indicator.

The sensor consists of a quartz-crystal transducer with a maximum capacity of 1 100 kN. Figure D.1 shows an example of the sensor set-up.

In order to transform the measured values, the measured signals are amplified and inputted into a pulse analyser. This consists of a digital counter for recording the pulse duration, a peak voltage recorder for determining the maximum amplitude and an integrating amplifier for determining the pulse magnitude (for example of test set-up, see Figure D.2). The apparatus error should not exceed ± 1 %.

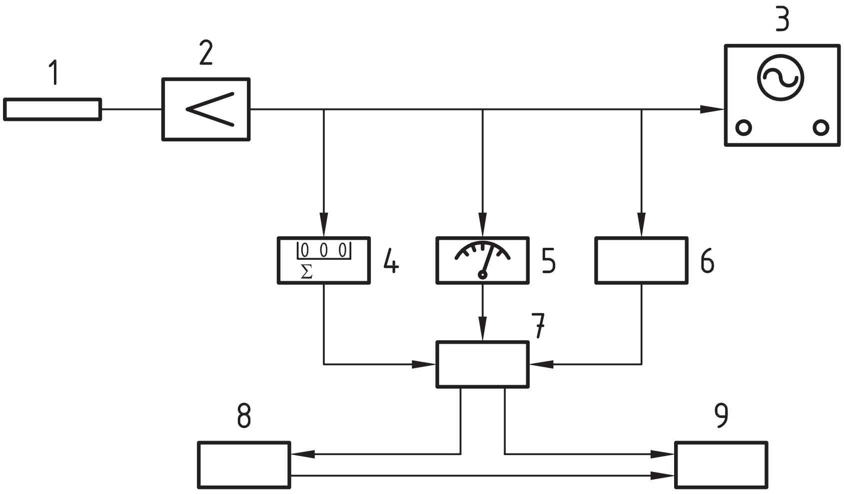
To show the measured values, the three individual signals are, for example, printed out via an analogue/digital transformer. The force/time relation is shown as a voltage/time curve on a storage oscillograph and may be kept in photographic form.



Key

1 pestle
2 top half of clamp
3 transducer (quartz disk)
4 bottom half of clamp
5 anvil

Figure D.1 — Sensor fitted between pestle and anvil for determining the force/time relationship during impact



Key

1 transducer
2 charge amplifier
3 storage oscillograph
4 digital computer
5 peak voltage recorder
6 integrating amplifier
7 control unit
8 analogue digital converter
9 printer

Figure D.2 — Example of test set-up for determining the impact effect

D.3.3 Apparatus for non-destructive determination of Rockwell hardness.

D.3.4 Steel straight-edge, at least 200 mm long.

D.3.5 Standard surface, for producing a reference print.

D.3.6 Torque wrench.

D.3.7 Measuring rods, 398 mm and 402 mm long.

D.4 Procedure

D.4.1 Verification of vertical set-up and guide play between pestle and mortar

The vertical set-up is verified by means of the spirit level and the centric, friction-free entry of the pestle into the mortar.

D.4.2 Determination of hardness of hammer head, pestle, mortar and anvil

During the acceptance test of the impact tester, it should be checked whether:

a) the impact surface of the head in the middle and towards the margin;

b) the impact surface of the pestle; and

c) the basal surface of the mortar

have a Rockwell hardness of 54 HRC to 56 HRC (as specified in EN ISO 6508-1). In the re-test, the Rockwell hardness should still be at least 54 HRC.

When the tester has been set up for the first time, the Rockwell hardness of the inner surface of the mortar and the end face of the anvil should also be measured.

D.4.3 Testing the surface

D.4.3.1 A straight-edge covering the whole surface to be tested should be used to check whether the basal surface of the mortar and the end face of the anvil are flat.

To test for the required surface quality, a light source should be used to establish that no, or very little, light appears between the straight-edge and workpiece and, if the latter is the case, that it is distributed over the whole measuring area.

D.4.3.2 The contact areas between hammer head and shaft determined by means of an ink mark after bracing and impact stressing should be compared with a reference mark to see whether the contact is over more than 80 % of the area.

D.4.3.3 A visual comparison with standard surfaces should be made to check whether the hammer head and shaft contact surface, the basal surface of the mortar and the anvil end face meet the requirements contained in Figures C.3, C.5 and C.7.

D.4.4 Testing of bolts with waisted shanks

A torque wrench should be used to check that the prebracing of the bolts with waisted shanks for connecting hammer head and shaft is 67 Nm.

D.4.5 Testing of contact pressure device

It should be checked that the spring force of the contact pressure device is (1 000 ± 100) N. The test device for determining the impact effect (see D.3.2) should be used for this purpose.

D.4.6 Testing of drop height constancy

Measuring rods should be used to check that the drop height of 400 mm is maintained to within 2,0 mm.

D.4.7 Determination of impact effect

Ten impacts from a drop height of 400 mm should be carried out and the impact force, pulse and pulse duration should be measured. It should be checked whether the arithmetic means of these variables lie within the ranges given in C.2.

Similarly, the arithmetic means of the impact force, pulse and pulse duration from ten impacts from drop heights of 200 mm and 300 mm should be determined and recorded.

Annex E
(informative)

Precision

E.1 General

The results given in E.2 and E.3 were interpreted in accordance with ISO 5725-2:1994.

E.2 Los Angeles test

Repeatability r_1 and reproducibility R_1 have been determined by a European cross testing program carried out on three levels of Los Angeles coefficients *LA,* ranging from 8 to 37, by 28 laboratories as follows:

$$r_1 = 0,06 \times X$$

$$R_1 = 0,17 \times X$$

where

X represents the *LA* coefficient.

No precision data is given for aggregates for railway ballast.

E.3 Impact test

The repeatability r_1 and reproducibility R_1 have been determined by a European cross testing program carried out by 16 laboratories on the same three levels as the Los Angeles test. Their impact values *SZ* ranged from 11,0 to 27,7 resulting in the following precision:

$$r_1 = 0,350 + 0,012\,9 \times X$$

$$R_1 = 0,106 \times X$$

where

X represents the *SZ* value.

The repeatability r_1 and reproducibility R_1 of the impact test for aggregates for railway ballast have been determined by a German cross testing. The impact values SZ_{RB} ranged from 11,0 to 27,7 resulting in the following precision:

$$r_1 = 0,57 + 0,07 \times X$$

$$R_1 = 1,84 + 0,07 \times X$$

where

X represents the SZ_{RB} value.

Annex F
(informative)

Worked example of calculation of impact value *SZ*

Table F.1 — Example data

Test sieve	**Original mass: 1 350,0 g**		
Punched holes / Wire cloth	**Mass retained**		**Mass passing**
Openings in mm	g	%	%
8	721,5	53,5	46,5
5	304,5	22,6	23,9
2	181,0	13,4	10,5
0,63	86,0	6,4	4,1
0,2	30,0	2,2	1,9
pan	26,0	1,9	–
Sum:	1 349,0	100,0	86,9

Impact value $SZ = \frac{M}{5} = \frac{\text{Sum of passing}}{5}$

$$SZ = \frac{M}{5} = \frac{86{,}9\,\%}{5} = 17{,}38\,\%$$

Annex G
(informative)

Alternative narrow range classification for the Los Angeles test of 16/32 mm recycled aggregates

For coarse recycled aggregates the following variation to the reference test (see 5.2) may be suitable.

The range classification set out in Table G.1 can be used.

Use test sieves of the appropriate size to match the range classification, instead of those defined in 4.1.1 and 5.2.

Table G.1 — Alternative narrow range classification

Range classification mm	**Intermediate sieve size** mm	**Percentage passing intermediate sieve** %	**Number of balls**	**Mass of ball load** g
16 to 31,5	22,4	45 to 55	14	5 810 to 6 010

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