BRITISH STANDARD

BS EN
1097-8:2000

Tests for mechanical and physical properties of aggregates —

Part 8: Determination of the polished stone value

The European Standard EN 1097-8:1999 has the status of a British Standard

ICS 91.100.15

National foreword

This British Standard is the official English language version of EN 1097-8:1999. It is included in a package of standards declared by CEN/TC154. It supersedes BS 812-113:1990 and BS 812-114:1989 which will be withdrawn on 1 December 2003.

The UK participation in its preparation was entrusted by Technical Committee B/502, Aggregates, to Subcommittee B/502/6, Test methods, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 30, an inside back cover and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

This British Standard, having been prepared under the direction of the Sector Committee for Building and Civil Engineering, was published under the authority of the Standards Committee and comes into effect on 15 March 2000

ISBN 0 580 35180 7

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1097-8

December 1999

ICS 91.100.15

English version

Tests for mechanical and physical properties of aggregates – Part 8: Determination of the polished stone value

Essais sur les propriétés mécaniques et physiques des granulats - Partie 8: Détermination du coefficient de polissage accéléré

Prüfverfahren für mechanische und physikalische Eigenschaften von Gesteinskörnungen - Teil 8: Bestimmung des Polierwertes

This European Standard was approved by CEN on 29 October 1999.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 1097-8:1999 E

Contents

Foreword

This European Standard 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 June 2000, and conflicting national standards shall be withdrawn at the latest by June 2000.

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

EN 932	Tests for general properties of aggregates
EN 933	Tests for geometrical properties of aggregates
EN 1367	Tests for thermal and weathering properties of aggregates
EN 1744	Tests for chemical properties of aggregates
prEN 13179:1998	Tests for filler aggregate used in bituminous mixtures

The other parts of EN 1097 will be:

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 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 9: Determination of the resistance to wear by abrasion from studded tyres: Nordic test
Part 10: Water suction height

In this standard annexes A, B, C and D are normative and annexes E and F are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies the method for determining the polished stone value (PSV) of a coarse aggregate used in road surfacings. An optional method for the determination of the aggregate abrasion value (AAV) which gives a measure of the resistance of aggregate to surface wear by abrasion under traffic is specified in annex A.

NOTE The AAV method should be used when particular types of skid resistant aggregates (typically those with a PSV of 60 or greater), which can be susceptible to abrasion under traffic, are required.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

EN 932-2	Tests for general properties of aggregates – Part 2: Methods for reducing laboratory samples
EN 932-3	Tests for general properties of aggregates - Part 3: Procedure and terminology for simplified petrographic description
prEN 932-5:1995	Tests for general properties of aggregates - *Part 5: Common equipment and calibration*
EN 933-3	Tests for geometrical properties of aggregates - Part 3: Determination of particle shape – Flakiness index
prEN 1097-6:1997	Tests for mechanical and physical properties of aggregates - Part 6: Determination of particle density and water absorption
ISO 48	Rubber, vulcanized or thermoplastic - Determination of hardness (hardness between 10 IRHD and 100 IRHD)
ISO 4662	Rubber - Determination of rebound resilience of vulcanizates
ISO 7619	Rubber - Determination of indentation hardness by means of pocket hardness meters

3 Definitions

For the purposes of this standard the following definitions apply.

3.1
test specimen
sample used in a single determination when a test method requires more than one determination of a property

3.2
batch
production quantity, a delivery quantity, a partial delivery quantity (railway wagon-load, lorry-load, ship's cargo) or a stockpile produced at one time under conditions that are presumed uniform

NOTE With a continuous process the quantity produced during an agreed period is treated as a batch.

3.3
laboratory sample
reduced sample derived from a bulk sample for laboratory testing

3.4
subsample
sample obtained by means of a sample reduction procedure

3.5
test portion
sample used as a whole in a single test

4 Principle

PSV is a measure of the resistance of coarse aggregate to the polishing action of vehicle tyres under conditions similar to those occurring on the surface of a road.

The test is carried out on aggregate passing a 10 mm sieve and retained on a 7,2 mm grid sieve, and is in two parts:

a) test specimens are subjected to a polishing action in an accelerated polishing machine;
b) the state of polish reached by each specimen is measured by means of a friction test. The PSV is then calculated from the friction determinations.

5 Sampling

The sample submitted to the laboratory for the test shall be obtained from a batch of normal production from the source.

Aggregate that has been freshly produced in the laboratory or has been recovered from bituminous mixtures can give misleading results and shall not be used for conformity testing.

6 Materials

6.1 General Detailed requirements for the control of materials are specified in annex B.

6.2 Natural corn emery, complying with the grading specified in table 1. This shall be used only once.

Table 1 – Grading requirements for corn emery

Nominal width of sieve aperture mm	Total passing %
0,600	98 to 100
0,500	70 to 100
0,425	30 to 90
0,355	0 to 30
0,300	0 to 5

6.3 Air-floated or water-washed natural emery flour, all of which passes a 0,050 mm test sieve. This shall be used only once.

NOTE Corundum emery flour with the following characteristics has been found to be suitable:
a) at least 50 % Al_2O_3 content;
b) particle density of at least 3,5 Mg/m^3;
c) particle size distribution (by air jet sieving) as given in table 2.

Table 2 – Particle size distribution (by air jet sieving)

Sieve size mm	% passing
0,050	99 to 100
0,032	75 to 98
0,020	60 to 80

6.4 PSV control stone, from a recognized source, with a mean PSV value in the range 50 to 60.

NOTE 1 At present the only recognized source of PSV control stone is a stock of quartz dolerite aggregate controlled by Transport Research Laboratory (TRL), Old Wokingham Road, Crowthorne, Berkshire RG11 6AU, United Kingdom.

NOTE 2 An alternative source of PSV control stone with a mean PSV value in the range 50 to 60 can be used provided the PSV value has been established in a controlled experiment carried out in at least ten laboratories, by cross testing against the TRL type control stone. In case of dispute, the TRL type control stone should be used.

6.5 Friction tester reference stone, from a recognized source, for conditioning new sliders and checking the friction tester (**11.3**), with a mean PSV value in the range 60 to 65.

NOTE 1 At present the only recognized source of friction tester reference stone is a stock of olivine basalt aggregate controlled by the Transport Research Laboratory (TRL), Old Wokingham Road, Crowthorne, Berkshire RG11 6AU, United Kingdom.

NOTE 2 An alternative source of friction tester reference stone with a mean PSV value in the range 60 to 65 can be used provided the PSV value has been established in a controlled experiment carried out in at least 10 laboratories, by cross testing against the TRL type friction tester reference stone. In case of dispute, the TRL type friction tester reference stone should be used.

7 Apparatus

7.1 General

All apparatus, unless otherwise stated, shall conform to the general requirements of prEN 932-5:1995. Additional requirements for calibration and control of the accelerated polishing machine and the rubber-tyred wheels are given in annex C.

7.2 Accelerated polishing machine

The polishing machine (see figure 1) shall be mounted on four adjustable levelling feet, placed at the corners and secured on a firm, level base of stone or concrete. It shall include the following:

7.2.1 A wheel, referred to as the "road wheel", having a flat periphery and clamping arrangements to hold the aggregate specimens shown in figure 2. It shall be of such a size and shape as to permit 14 of the specimens described in clause **8** to be clamped onto the periphery so as to form a surface of aggregate particles (406 ± 3) mm in diameter and bounded by clamping rings (44,5 ± 0,5) mm apart.

7.2.2 A means of rotating the road wheel about its own axis at a speed of (320 ± 5) min^{-1} under test conditions.

7.2.3 Two solid rubber-tyred wheels of (200 ± 3) mm diameter and with a width of (38 ± 2) mm. These rubber-tyred wheels shall be of two different colours. A dark coloured (coarse) wheel shall be used with the corn emery and a light coloured (fine) wheel shall be used with the emery flour. The rubber tyres shall initially have a hardness of (69 ± 3) IRHD as specified in ISO 7619.

NOTE Both rubber-tyred wheels can be of the same colour provided each is clearly marked as being "coarse" or "fine" as appropriate.

7.2.4 A lever arm and weight to bring the surface of the appropriate solid rubber-tyred wheel to bear on the road wheel with a total free force of (725 ± 10) N. The solid rubber-tyred wheel shall be free to rotate about its own axis, which shall be parallel with the axis of the road wheel, and the plane of rotation of the tyre shall be in line with that of the road wheel.

The machine shall be accurately aligned so that the road wheel and either of the rubber-tyred wheels shall be free to rotate without play in the bearings:

a) the planes of rotation of the two wheels in use shall be not more than 0,33° of arc out of parallel (1 mm in 200 mm);

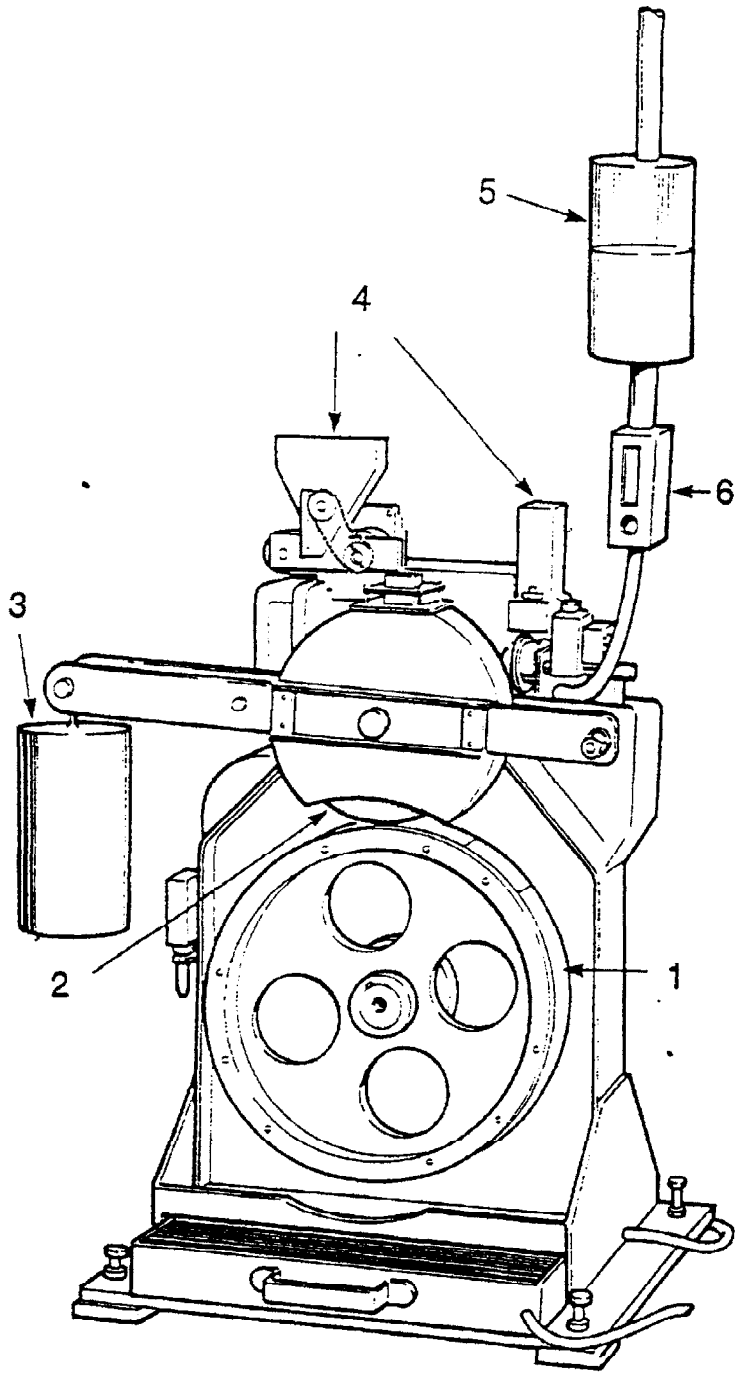
b) the planes of rotation through the centres of the two wheels in use shall be not more than 0,8 mm apart.

7.2.5 Feed mechanism, identified as being for use with the dark coloured (coarse) rubber-tyred wheel to feed the corn emery and water at the specified rates. The emery and water shall be fed directly onto the road wheel near the point of contact with the rubber-tyred wheel.

7.2.6 Feed mechanism, identified as being for use with the light-coloured (fine) rubber-tyred wheel (**7.2.3**) to feed the emery flour (**6.1.2**) and water continuously at the specified rates.

7.2.7 A means of ensuring that the rubber-tyred wheels are not left under load when not running, to prevent the risk of the tyre becoming deformed.

NOTE When not in use, the rubber-tyred wheels should be removed from the machine and stored as described in annex C.



Key :

1 Road wheel
2 Solid rubber-tyred wheel
3 Weight
4 Feed mechanisms
5 Water feed
6 Flow gauge

Figure 1 – Typical accelerated polishing machine

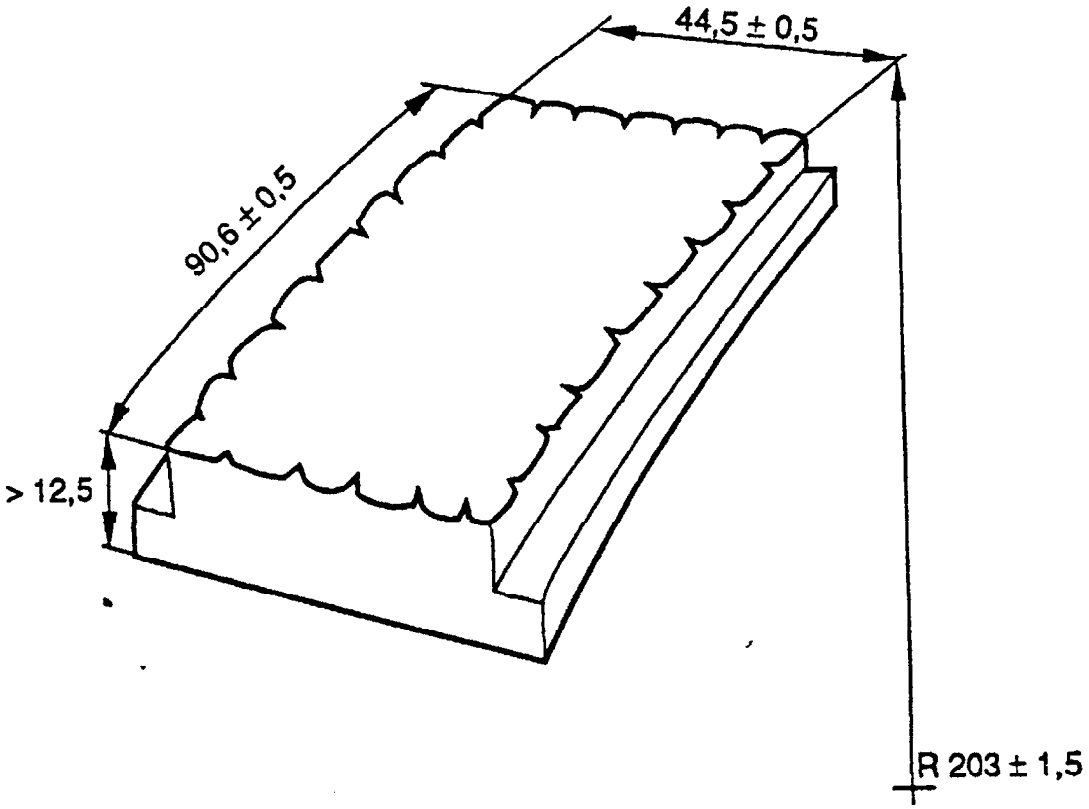


Figure 2 – Test specimen dimensions

7.3 Friction tester

7.3.1 Calibration

Additional requirements for calibration and control of the friction tester, sliders and slider rubber are given in annex D.

7.3.2 Design

The friction test shall be carried out using the equipment shown in figure 3 (see Note). All bearings and working parts shall be enclosed as far as possible, and all materials used shall be treated to prevent corrosion under wet conditions.

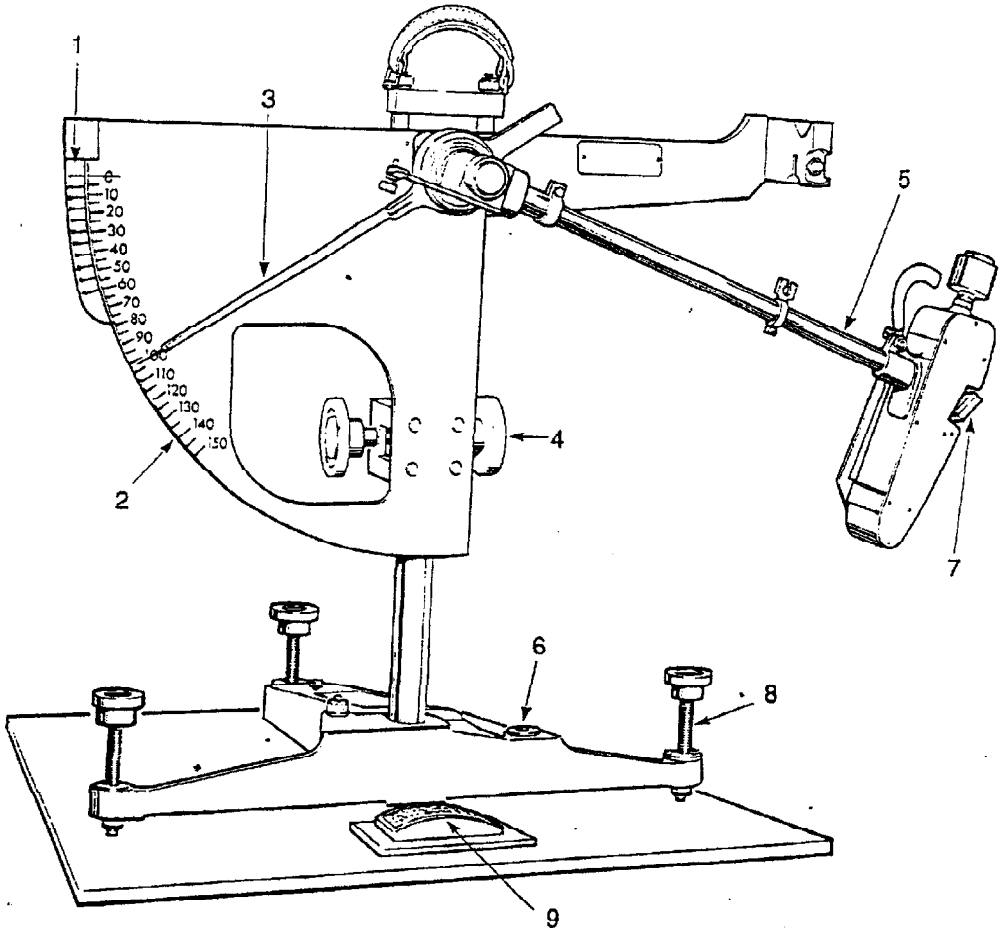
NOTE The equipment shown in figure 3 is manufactured to the design of the Transport Research Laboratory (TRL), Old Wokingham Road, Crowthorne, Berkshire RG11 6AU, United Kingdom.

The friction test equipment shall have the following features:

7.3.2.1 A spring-loaded rubber slider of the mass, size and shape as specified in **7.3.2.9**. It shall be mounted on the end of a pendulum arm so that the sliding edge is approximately 510 mm from the axis of suspension (**11.6**).

7.3.2.2 Means for setting the support column of the equipment vertical.

7.3.2.3 Means for rigidly locating one of the curved specimens from the accelerated polishing machine so that its longer dimension lies in the track of the pendulum and it is central with respect to the rubber slider and to the axis of suspension of the pendulum.



Key

1 F-scale
2 Calibration scale
3 Pointer
4 Vertical adjustment screw
5 Pendulum
6 Spirit level
7 Rubber slider
8 Levelling screw
9 Test specimen holder

Figure 3 – Friction tester

7.3.2.4 Means of raising and lowering the axis of suspension of the pendulum arm so that the slider can:

a) swing clear of the surface of the specimen; and

b) be set to traverse a curved specimen over a length of (76 ± 1) mm.

7.3.2.5 Means of holding and releasing the pendulum arm so that it falls freely from a horizontal position.

7.3.2.6 A pointer balanced about the axis of suspension, indicating the position of the pendulum arm throughout its forward swing and moving over the circular scale. The mass of the pointer shall be not more than 85 g. The friction in the pointer mechanism shall be adjustable so that, with the pendulum arm swinging freely from a horizontal position, the outward tip of a nominal 300 mm long pointer may be brought to rest on the forward swing of the arm at a point 10 mm below the horizontal.

7.3.2.7 A circular test scale (F scale) for curved specimens with a 76 mm sliding length, marked from 0 to 100 and calibrated at intervals of two units.

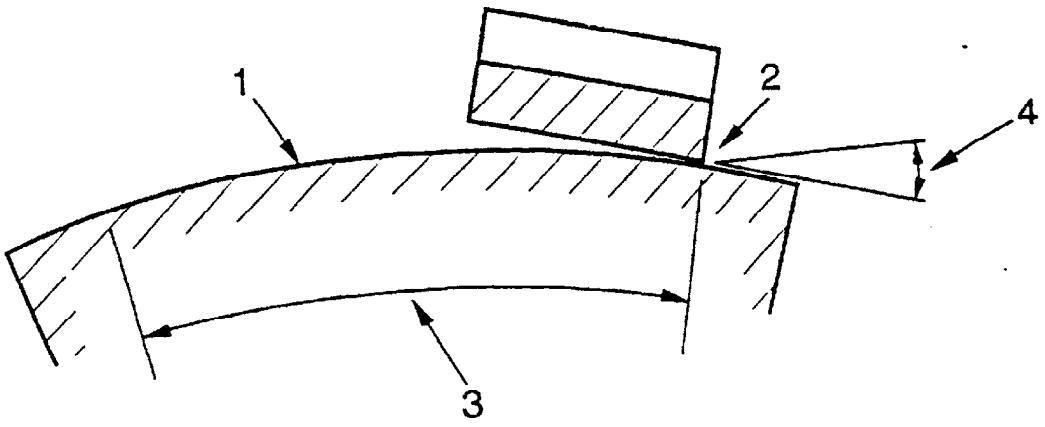
NOTE A circular calibration scale for a sliding length of 126 mm on a flat surface may also be incorporated into the friction tester, as shown in figure 3. It is not needed for this test method.

7.3.2.8 The mass of the pendulum arm, including the slider, shall be (1,50 ± 0,03) kg. The centre of gravity shall lie on the axis of the arm at a distance of (410 ± 5) mm from the axis of suspension.

7.3.2.9 The slider shall consist of a rubber pad (31,75 ± 0,50) mm wide by (25,4 ± 1,0) mm long (in the direction of swing) and (6,35 ± 0,5) mm thick. This shall be held on a rigid base with a central pivoting axis and the combined mass of the slider and base shall be (20 ± 5) g. The slider assembly shall be mounted on the end of the pendulum arm in such a way that when the arm is at the lowest point of its swing, with the trailing edge of the slider in contact with the test specimen, the plane of the slider is angled at (26 ± 3) ° to the horizontal.

NOTE 1 In this configuration the slider can turn about its axis without obstruction to follow unevenness of the surface of the specimen as the pendulum swings.

NOTE 2 The relative positions of the pendulum at the lowest point of its swing, the slider and the test specimen are illustrated in figure 4.



Key :

1 Pendulum
2 Slider
3 Test specimen
4 Angle, (26 ± 3)°

Figure 4 – Position of the pendulum, the slider and the test specimen

7.3.2.10 The slider shall be spring-loaded against the test surface. The nominal static force on the slider as set by the equipment calibration procedure defined in annex D shall be (22,2 ± 0,5) N in its median position. The change in the static force on the slider shall be not greater than 0,2 N/mm deflection of the slider.

7.3.2.11 The initial resilience and hardness of the slider shall conform to table 3. The working edges of the slider shall be square and clean-cut, and the rubber free from contamination by, for example, abrasive or oil.

Table 3 – Properties of the slider

Property	Temperature				
	0 °C	10 °C	20 °C	30 °C	40 °C
Resilience (%)[a]	43 to 49	58 to 65	66 to 73	71 to 77	74 to 79
Hardness (IRHD)[b]	50 to 65	50 to 65	50 to 65	50 to 65	50 to 65

[a] Lüpke rebound test in accordance with ISO 4662.
[b] International rubber hardness in accordance with ISO 48.

7.4 Test sieves

Sieves with square apertures and sizes 10 mm; 0,600 mm; 0,500 mm; 0,425 mm; 0,355 mm; 0,300 mm and 0,050 mm.

7.5 Grid sieve

Sieve with a bar spacing of (7,2 ± 0,1) mm and conforming to the general requirements of EN 933-3.

NOTE A flake sorting sieve with a slot width of (7,2 ± 0,1) mm and a slot length of (40 ± 1) mm can be used.

7.6 Length gauge or callipers

Length gauge or callipers having a gap between the pins or faces of (14,7 ± 0,2) mm.

7.7 Equipment for preparing test specimens

Equipment for preparing test specimens shall consisting of the following:

a) release agent such as liquid car polish;
b) liquid cleaner, for cleaning the equipment after use;
c) synthetic resin and hardener;
d) container for mixing resin and hardener;
e) flexible plastics sheet of a material such as polyvinylacetate;
f) accurately machined moulds for preparing specimens of the dimensions shown in figure 2;
g) rigid covers having one plane face, and the other shaped to the radius of curvature (189,0 ± 0,5 mm) of the polishing test mould and slightly larger than the mould;
h) a means of holding the cover onto the resin backing such as G-clamps or weights;
i) two fine-haired brushes of about 3 mm diameter;
j) a stiff bristle brush;
k) a spatula;
l) dry fine aggregate (sand), all passing the 0,300 mm sieve.

NOTE Filler can be added to the resin to make it less fluid. The resin can also be added to the mould in two layers.

8 Preparation of test specimens

8.1 Reduce the laboratory sample using the procedures specified in EN 932-2 to produce a subsample such that when it is sieved in accordance with **8.2**, a minimum of 2 kg is available for preparing the specimens.

NOTE Six different aggregates can be tested at the same time.

8.2 Sieve the subsample so that all of the aggregate particles pass the 10 mm test sieve and are retained on the grid sieve. Wash and dry the retained sample and remove any elongated particles identified using the length gauge or callipers.

8.3 Obtain a minimum mass of 1 kg of the PSV control stone by the methods specified in **8.1** and **8.2**.

8.4 Using the methods specified in **8.5** to **8.8**, prepare four specimens of each aggregate and four specimens of the control stone. Each specimen shall consist of between 36 and 46 aggregate particles, obtained as specified in **8.2** and **8.3**.

NOTE The surface texture of the particles which are to be exposed to the polishing action of the rubber-tyred wheel should be representative of the average surface texture of the aggregate. Particles of differing appearance should be distributed randomly between the four specimens. Poorly selected specimens will give unrepresentative results.

8.5 Lightly coat the exposed internal faces and top edges of the metal moulds with release agent using one of the fine-haired brushes. Prepare each specimen by carefully placing the selected particles randomly in a single layer, with their flattest surfaces lying on the bottom of the mould.

Place them as closely as possible to each other and cover as much of the bottom of the mould as is possible.

Then fill the interstices between the particles to approximately three-quarters of their depth with fine aggregate (sand). Level off with a fine-haired brush or by gentle blowing. Care shall be taken not to disturb the aggregate particles.

8.6 Mix the hardener with the resin in the container in accordance with the manufacturer's instructions. Fill the mould to overflowing with the mixed resin and float off the surplus with the spatula without disturbing the main body of the resin.

NOTE As an alternative to floating-off, the surplus may be squeezed out by covering the mould with a plastic sheet and pressing the metal cover onto the sheet.

8.7 When the resin begins to harden (normally after 5 min to 10 min), trim any excess resin from the edges of the mould with a knife. Press the metal cover to the back of the specimen by means of a clamp or weights to prevent distortion during setting. Remove the specimen from the mould after the resin has set and cooled (normally about 30 min after mixing). Remove the loose fine aggregate (sand) with the stiff bristle brush.

After the resin has completely set and cooled, wait a further 30 min before polishing the specimen in accordance with clause **10**. Clean the moulds and tools as required.

8.8 Check that each finished specimen presents the natural surface of the aggregate particles to the rubber-tyred wheel, with no sharp projecting edges, and is not less than 12,5 mm thick. Reject any specimen with resin exposed at the surface or with disturbed particles.

NOTE The exposed surfaces of the specimens should stand proud of the backing resin.

9 Conditioning of the rubber-tyred wheel

9.1 Before using any new rubber-tyred wheel on a test, give it a preliminary run with its appropriate abrasive. Use the new rubber-tyred wheel as in an actual test (clause **10**), but with 12 spare specimens and two previously unpolished control stone specimens on the road wheel.

NOTE Specimens from earlier tests are suitable as spare specimens in this preliminary run.

9.2 Following accelerated polishing of the specimens, friction test the control stone specimens in accordance with clause **11** and record the mean result. This value shall lie in the range specified for the recognized PSV control stone used.

If the mean result is greater than the higher limit of the specified range, make further preliminary runs using fresh specimens of the control stone. If the result is less than the lower limit of the specified range, or if the difference between the two results is greater than five, the new rubber-tyred wheel is unsuitable for the test.

10 Accelerated polishing of specimens

10.1 Carry out the accelerated polishing at a room temperature of (20 ± 5) °C.

10.2 14 specimens are polished during each run, numbered as follows:

a) two specimens of first aggregate, numbered 1 and 2;
b) two specimens of second aggregate, numbered 3 and 4;
c) two specimens of third aggregate, numbered 5 and 6;
d) two specimens of fourth aggregate, numbered 7 and 8;
e) two specimens of fifth aggregate, numbered 9 and 10;
f) two specimens of sixth aggregate, numbered 11 and 12;
g) two specimens of PSV control stone, numbered 13 and 14.

Arrange the specimens in the following order: 13, 9, 3, 7, 5, 1, 11, 14, 10, 4, 8, 6, 2, 12

NOTE Spare specimens can be used to fill up the wheel if six aggregates are not available.

10.3 Clamp the 14 specimens in the order specified in **10.2** around the periphery of the road wheel. Mark the specimens so that the direction of rotation can be determined at a later stage (**11.6**). The test surface of the specimens shall form a continuous strip of particles lying on the circumference of a circle with a diameter of (406 ± 3) mm, upon which the rubber-tyred wheel can ride freely without bumping or slipping. Fill any gaps with suitable packing pieces, flush with the surface of the adjacent specimens.

10.4 Bring the road wheel to a speed of (320 ± 5) min^{-1} and bring the dark-coloured (coarse) rubber-tyred wheel to bear on the surface of the specimens. Use the appropriate feed mechanism to feed the corn emery at a rate of (27 ± 7) g/min continuously with water onto the road wheel for a period of (180 ± 1) min. The rate of flow of water should be just enough to carry the corn emery to the wheel.

NOTE 1 The water flow rate is normally approximately the same rate as for the corn emery.

Interrupt the test run at (60 ± 5) min and (120 ± 5) min to clean out any excess corn emery which has accumulated in the base. After (180 ± 1) min, remove the road wheel from the machine.

Thoroughly clean the machine and specimens by washing so that all trace of the corn emery is removed.

NOTE 2 It is important that the used corn emery is not allowed to make contact with the light-coloured (fine) rubber-tyred wheel.

10.5 Fit the light-coloured (fine) rubber-tyred wheel and feed mechanism for emery flour. Refit the road wheel and operate the machine for a further (180 ± 1) min as in **10.4** but without interruption.

Feed the emery flour (**6.1.2**) at a rate of (3,0 ± 1,0) g/min continuously with water at a rate of flow of twice the measured rate of flow of emery flour ± 1,0 g/min.

NOTE The rubber-tyred wheels should not be left under load at any time other than when the wheel is running; otherwise the tyre can become deformed.

10.6 Replace the rubber-tyred wheels periodically, when indicated by uneven wear or other damage or when the control stone value falls outside the range specified for the recognized PSV control stone used (**12.2**). Condition replacement rubber-tyred wheels in accordance with clause **9**.

NOTE Current experience indicates that replacement can be needed after 25 runs, particularly for the dark-coloured (coarse) rubber-tyred wheel used with corn emery.

10.7 On completion, remove the road wheel and clean the machine. Remove the specimens from the wheel and thoroughly wash them with a jet of water to remove all trace of emery flour. Clean the interstices between the stone particles by scrubbing with a bristle brush.

NOTE Any trace of emery flour on or between the stone particles will affect the result of the friction test.

10.8 After washing, store the specimens face downwards under water at a temperature of (20 ± 2) °C for a recorded time of between 30 min and 120 min. On removal from the water, immediately perform the friction test in accordance with clause **11**. Do not allow the specimen to dry out before testing.

10.9 Repeat the complete test procedure (**10.1** to **10.8**) with the two remaining specimens of each aggregate and control stone.

11 Friction test procedure

11.1 Keep the friction test apparatus and sliders in a room where the temperature is controlled at (20 ± 2) °C for at least 120 min before the test begins and for the duration of the test.

11.2 Place the friction tester on a firm level surface and adjust the levelling screws so that the pendulum support column is vertical. Then raise the axis of suspension of the pendulum, so that the arm swings freely, and adjust the friction in the pointer mechanism so that when the pendulum arm and pointer are released from the right hand horizontal position, the pointer comes to rest at zero on the test scale (F-scale). Ensure that the track of the slider is parallel to the long axis of the specimen across the sliding distance.

11.3 Maintain a stock of test specimens made using friction tester reference stone (**6.1.4**) to condition sliders and for checking. Make and polish the specimens as in an actual determination.

When first tested in accordance with **11.6** and **11.7** the polished specimens shall produce a value within the range specified for the friction tester reference stone used. Record the values and air-dry the specimens before storing them in a sealed container for future use.

NOTE The specified range for the TRL type friction tester reference stone is 58 to 66.

11.4 Before using a new slider, ensure that each working edge of the rubber slider is correctly conditioned by swinging it five times over the dry surface of a polished friction tester reference stone specimen, followed by a further 20 swings on its wetted surface.

Keep the friction tester reference stone specimen used for this purpose apart from any other specimens. The specimen used for conditioning new sliders may be used repeatedly, providing the recorded value

when tested wet is no more than three units less than the lower value of the specified range (not less than 55 for the TRL type friction tester reference stone).

11.5 Before measuring the set of specimens polished on each test run, check the performance of both working edges of the slider by testing a friction tester reference stone specimen (**11.3**) from the sealed container, after soaking in accordance with **10.8**. Record the resulting values.

Additional polishing through repeated friction testing can yield progressively lower values. The friction tester reference stone specimen shall be discarded when the value falls more than one unit below the specified range (below 57 for the TRL type friction tester reference stone).

When a new friction tester reference stone specimen is drawn from the sealed container, its checked value shall not be more than two units lower or one unit higher than the value when first tested (**11.3**). If the value is outside this range, discontinue testing and check the friction tester and its operation.

NOTE More than one slider should be kept in use, to help differentiate between a faulty slider and a faulty friction tester.

Discard any slider with working edges which have become scored or rounded.

11.6 Place the first test specimen firmly so that its longer dimension lies in the track of the pendulum and it is central with respect to the rubber slider and to the axis of suspension of the pendulum. Place it in such a way that the slider of the pendulum will traverse it in the opposite direction to its direction of travel on the road wheel.

NOTE For example if the mark (**10.3**) is on the side of the specimen furthest from the operator during polishing, it should be nearest to the operator during friction testing.

11.7 Adjust the height of the pendulum arm before testing each specimen so that when it is traversing the specimen, the slider is in contact with the specimen over a length of (76 ± 1) mm and over its whole width. Maintain the setting for all friction measurements on the specimen.

NOTE A pointer fixed to the foot of the slider can help to achieve this.

Wet the surfaces of the specimen and the rubber slider with a copious supply of clean water. Do not disturb the slider from its set position. Release the pendulum arm and pointer from the horizontal position and record the position where the pointer comes to rest on the F-scale to the nearest whole number. Return the pointer to the horizontal release position.

Perform this operation five times, rewetting the specimen each time. Record the mean of the last three readings to the nearest 0,1 unit.

11.8 Test seven specimens in the following order:

13, 1, 10, 3, 5, 12, 8.

Reverse the slider and use the second working edge to test the other seven specimens in the following order:

7, 11, 6, 4, 9, 2 and 14.

11.9 Repeat the complete test procedure (**11.1** to **11.8**) with the two remaining specimens.

12 Calculation and expression of results

12.1 Calculate the mean of the recorded values of the two PSV control stone specimens from each test run to the nearest 0,1 unit, giving two results.

12.2 The results of the whole test shall be rejected if the difference between the two test results obtained from **12.1** is more than 5,0 units, or if at least one of the two test results lies outside the specified range for the PSV control stone used. If the results are rejected, the whole test shall be repeated.

The specified range for the TRL type PSV control stone is (49,5 to 55,5).

12.3 For satisfactory test runs (**12.2**), the PSV for each aggregate tested shall be calculated as specified in **12.3.1** to **12.3.3**.

12.3.1 Calculate the mean value *S* of the recorded values of the four aggregate test specimens (two from each run) by summing the mean of each run and dividing by two. Record the result to the nearest 0,1 unit.

12.3.2 Calculate the mean value *C* of the recorded values of the four PSV control stone specimens (two from each run) by summing the mean of each run and dividing by two. Record the result to the nearest 0,1 unit.

12.3.3 Calculate the PSV to the nearest whole number, from the following equation:

$$PSV = S + (52,5) - C$$

where:

S is the mean value for the four aggregate test specimens;
C is the mean value for the four PSV control stone specimens.

NOTE An indication of the precision of the PSV test is given in annex E.

13 Test report

The test report shall state that the PSV value was determined in accordance with this European Standard and whether or not a certificate of sampling is available. If available, a copy of the certificate of sampling shall be provided with the test report.

The test report shall also contain at least the following additional information:

a) reference to this European Standard;
b) sampling report (if available);
c) sampling identification and description (in accordance with EN 933-3).
d) the PSV value for the aggregate;
e) the overall mean value recorded for the PSV control stone (**12.3**);
f) the individual values and the mean values for each test run for the four aggregate test specimens and the four PSV control stone specimens, clearly indicating which values relate to which test run.

Annex A (normative)

Determination of aggregate abrasion value (AAV)

A.1 General

This annex specifies a method for the determination of the aggregate abrasion value (AAV) which gives a measure of the resistance of aggregate to surface wear by abrasion under traffic.

A.2 Principle

Two specimens are selected from a test portion. The selected particles are orientated and then embedded in resin, and are fixed in contact with a horizontally rotating lap wheel. The specimens are loaded and an abrasive fine aggregate (sand) fed continuously through the contacting surfaces of the specimen and lap wheel for a specified number of revolutions.

The AAV is determined from the differences in mass of the specimens before and after abrasion. The test is carried out on aggregate passing a 14 mm sieve and retained on a 10,2 mm grid sieve

The particle density (on a saturated and surface dried basis) of the laboratory sample shall also be determined, in accordance with clause **7** of prEN 1097-6:1997.

A.3 Sampling

Sampling shall be carried out in accordance with clause **5**.

A.4 Materials

A.4.1 Abrasive, consisting of round grained silica fine aggregate (sand) containing at least 96 % quartz. All of the fine aggregate (sand) shall pass the 0,850 mm sieve and be retained on the 0,300 mm sieve. Additionally, at least 75 % of the fine aggregate (sand) shall pass the 0,600 mm test sieve and be retained on the 0,425 mm sieve. The fine aggregate (sand) shall be dry and shall not have been used previously.

NOTE: About 30 kg is required for each test.

A.4.2 Synthetic resin and hardener, together with a release agent such as liquid car polish, a suitable liquid cleaner liquid and a container for mixing the resin.

NOTE 1 The cleaner should be used to clean moulds, tools, etc., as required.

NOTE 2 Filler can be added to the resin to make it less fluid. The resin can also be added to the mould in two layers.

A.4.3 Fine aggregate (sand), to prevent the resin from squeezing up between the individual pieces of aggregate.

NOTE Fine aggregate (sand) passing the 0,300 mm test sieve is suitable.

A.5 Apparatus

A.5.1 General

All apparatus, unless otherwise stated, shall conform to the general requirements of prEN 932-5:1995.

A.5.2 Abrasion machine, consisting of a machined flat circular cast iron or steel grinding lap wheel not less than 600 mm in diameter, which can be rotated in a horizontal plane at a speed of 28 min^{-1} to 31 min^{-1}.The abrasion machine shall be fitted with a revolution counter and the accessories detailed in **A.5.2.1** to **A.5.2.6**.

A.5.2.1 At least two machined metal moulds for preparing specimens, manufactured with removable ends and with internal dimensions of (92,0 ± 0,1) mm long by (54,0 ± 0,1) mm wide by (16,0 ± 0,1) mm deep.

NOTE Some suitable resins give about 0,5 mm shrinkage on the length and width of the specimen. If a non-shrinking resin is used, these dimensions are reduced by 0,5 mm.

A.5.2.2 At least two machined metal trays or metal backing plates for holding the prepared specimens.

NOTE Trays made from 5 mm mild steel plate and with internal dimensions of (92,0 ± 0,1) mm long by (54,0 ± 0,1) mm wide by (8,0 ± 0,1) mm deep are suitable.

A.5.2.3 At least two machined flat plates made from 5 mm mild steel plate with dimensions of (115,0 ± 0,1) mm long by (75,0 ± 0,1) mm wide.

A.5.2.4 A means for locating two of the trays (or specimens with backing plates) with their centre points 260 mm from the centre of the lap diametrically opposite to each other and with their long sides lying in the direction of rotation of the lap wheel. The trays shall be free to move in a vertical plane but restrained from moving in the horizontal plane.

A.5.2.5 Two weights, each with a rounded base for pressing the test specimen against the surface of the lap wheel and each having a means for adjusting their mass, including test specimen and tray, to (2000 ± 10) g.

A.5.2.6 A means for feeding fine aggregate (sand) continuously on the lap wheel in front of each test specimen at a rate of (800 ± 100) g/min and for removing the fine aggregate (sand) after it has passed under the test samples.

NOTE Regular testing of very hard aggregates can visibly score the machined surface of the lap wheel. The surface should be inspected between test runs and any grooves greater than 0,2 mm deep should be rectified by machining.

A.5.3 Test sieves, with square apertures and sizes 14,0 mm; 0,850 mm; 0,600 mm; 0,425 mm and 0,300 mm.

NOTE The woven wire sieves are only required if the grading of the abrasive fine aggregate (sand) needs to be verified.

A.5.4 Grid sieve, with a bar spacing of (10,2 ± 0,15) mm and conforming to the general requirements of EN 933-3.

NOTE A flake sorting sieve with a slot width of (10,2 ± 0,15) mm and a slot length of (40 ± 1) mm can be used.

A.5.5 Balance, of at least 2,5 kg capacity, accurate to 0,1 g.

A.5.6 Two small fine-haired brushes.

A.5.7 Brush, with stiff bristles.

A.5.8 Clamp, such as a 200 mm G-clamp.

A.6 Preparation of test specimens

A.6.1 Test portion

Reduce the laboratory sample using the procedures specified in EN 932-2 and sieve to produce a test portion consisting of aggregate passing the 14,0 mm sieve and retained on the grid sieve. The mass of the test portion shall be sufficient to allow two test specimens to be prepared as specified in **A.6.2**.

After sieving the aggregate, wash to remove surface dust and allow surface to dry in air. The aggregate shall be tested in surface-dry condition and shall be at room temperature before the preparation of the test portion as specified in **A.6.2**.

A.6.2 Specimens

Prepare two specimens for each test.

Lightly coat the internal faces and top edges of the mould with release agent using one fine-haired brush.

From the prepared test portion, select as many particles as possible, but never less than 24, and place them in the mould in a single layer with their flattest surface lying at the bottom of the mould.

> NOTE The surface texture of the particles which are to be exposed to the abrasive action should be representative of the average surface texture of the aggregate. Particles of differing appearance should be distributed randomly between the two specimens. Poorly selected specimens will give unrepresentative results.

Fill the interstices between the pieces of aggregate to approximately three-quarters of their depth with the fine aggregate (sand) and level the fine aggregate (sand) with the other fine-haired brush. Mix sufficient resin and hardener and fill the mould to overflowing.

Coat one side of the flat plate with the release agent and place it firmly on the mould, coated side down. Hold the plate in position with the clamp. When the resin has hardened (usually after 30 min) remove the plate and trim off the excess resin with a knife or spatula.

Remove the specimen from the mould, remove the loose fine aggregate (sand) with the stiff brush and weigh the specimen to the nearest 0,1 g (mass *A*). Reject any specimen with resin exposed at the surface or with disturbed particles.

A.7 Procedure

Fit each specimen into one of the machined metal trays or metal backing plates, taking care to ensure a tight fit. Weigh a specimen in its tray with one of the weights and adjust the mass until the total is (2000 ± 10) g. Repeat for the second specimen, tray or backing plate and weight.

> NOTE 1 The abrasion of the aggregate during the procedures described in this clause can generate particles that could be injurious to health. It is essential that appropriate precautions are taken, such as by the use of dust masks or dust-containing and/or extracting facilities.

Locate the two specimens in the abrasion machine with the aggregate particles resting on the lap wheel over the whole face area. Then place the appropriate weights centrally on the specimens.

Turn the lap wheel through 500 revolutions at a speed of 28 min^{-1} to 31 min^{-1}. Feed the abrasive fine aggregate (sand) continuously onto the lap wheel immediately in front of, and across the full width of, each test specimen at a rate of (800 ± 100) g/min for each specimen.

NOTE 2 A feeder slot width of about 1,3 mm may be suitable.

To ensure that the abrasive fine aggregate (sand) is fed beneath each specimen, lift each of them clear of the lap wheel for one revolution before the start of abrasion and at every 100th revolution thereafter. Remove the abrasive fine aggregate (sand) with a rubber-edged blade, mounted so that the rubber edge rests lightly on the lap wheel for its full width, and discard the abrasive fine aggregate (sand).

If it becomes apparent that abrasion has reached the level of the resin backing (because of the nature of the aggregate) discontinue the test and report the number of revolutions.

On completion of 500 revolutions, remove the test specimen from the machine and remove the trays or backing plates and weights. Weigh the specimens to the nearest 0,1 g (mass *B*).

A.8 Calculation and expression of results

Calculate the AAV of each test specimen, to three significant figures, in accordance with the following equation:

$$\mathrm{AAV} = \frac{3(A-B)}{\rho_{ssd}}$$

where:

A	is the mass of specimen before abrasion, in grams;
B	is the mass of specimen after abrasion, in grams;
ρ_{ssd}	is the particle density of the aggregate (on saturated surface-dried basis) as determined in accordance with prEN 1097-6:1997, in megagrams per cubic metre.

NOTE 1 The calculation is based on the percentage loss in mass of an assumed 33 ml volume of the aggregate. Because of this assumption, AAV is reported as a dimensionless unit.

Calculate the mean of the two results to two significant figures.

Report the mean as the AAV, unless the individual results differ by more than 0,2 times the mean value. In this case repeat the test on two further specimens, calculate the median of the four results to two significant figures, and report the median as the AAV.

The median of four results is calculated by excluding the highest and the lowest result and calculating the mean of the two middle results.

NOTE 2 An indication of precision for the AAV test is given in annex E.

A.9 Test report

The test report shall state that the AAV value was determined in accordance with this standard and whether or not a certificate of sampling is available. If available, a copy of the certificate of sampling shall be provided with the test report.

The test report shall also contain at least the following additional information:

a) reference to this European Standard;
b) the aggregate abrasion value (AAV);
c) the values recorded for the two (or four) individual test specimens.

Annex B (normative)

Control of materials

Corn emery and emery flour

Check the particle size distribution of each delivered batch of corn emery (**6.1.1**) and emery flour (**6.1.2**) before use.

Verification is not necessary if the criteria are confirmed by a manufacturer's or supplier's certificate.

Annex C (normative)

Calibration of the accelerated polishing machine

C.1 Control of rubber-tyred wheels

C.1.1 The hardness and dimensions of the rubber-tyred wheels shall be verified (**7.2.3**). The certificate of conformity shall also state the date of manufacture of the rubber tyre.

NOTE Verification is not necessary if the criteria are confirmed by a manufacturer's or supplier's certificate.

C.1.2 Store the rubber-tyred wheels in the dark at a temperature of (20 ± 5) °C. If the storage conditions cannot be conformed to, either annually verify that the hardness continues to comply with the criteria for initial hardness (**C.1.1**) or withdraw the tyre from use two years after the date of manufacture.

C.1.3 If a rubber tyre has been stored at below 15 °C before delivery to the laboratory, condition the rubber by raising its temperature to (30 ± 2) °C for at least 24 h before use.

C.1.4 Annually, check the dimensions of each rubber-tyred wheel (**7.2.3**).

C.2 Accelerated polishing machine

C.2.1 Every six months check the water flow gauge (**10.4** and **10.5**).

C.2.2 Annually, verify the rotational speed of the road wheel (**7.2.2**) under test conditions.

C.2.3 Annually, verify the total free force applied to the road wheel by each rubber-tyred wheel (**7.2.4**).

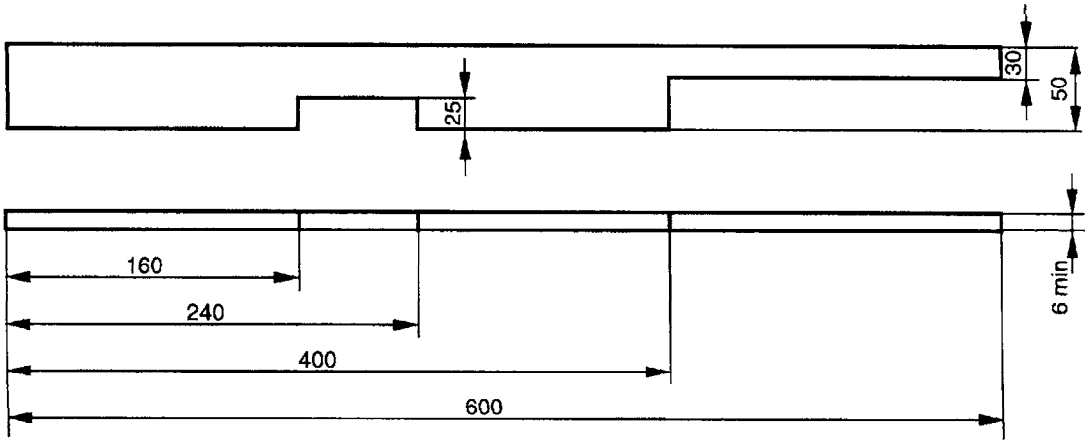
C.2.4 Annually, verify the alignment of the road wheel relative to each rubber-tyred wheel (**7.2.4**).

NOTE The requirements can be checked by using a notched steel straight edge (figure C.1) with dimensions to suit the wheel configuration of the accelerated polishing machine. The rim of the road wheel is used as a measurement datum.

C.3 Rate of flow of corn emery and emery flour

At the start of each polishing run, verify the rate of flow of corn emery (**10.4**) and emery flour (**10.5**).

Dimensions in millimetres



NOTE Dimensions are for guidance only. Actual dimensions will vary with the type of apparatus used.

Figure C.1 – Typical notched straight edge

Annex D (normative)

Calibration of the friction tester and sliders

D.1 Friction tester

D.1.1 General

The friction tester shall be calibrated annually by a recognized calibration laboratory, in accordance with the procedure specified in **D.1.2** to **D.1.5**.

D.1.2 Mass of pendulum arm and pointer

D.1.2.1 *Remove the pendulum arm and pointer.*

D.1.2.2 Weigh the pointer to the nearest 1 g. Measure its length to the nearest 1 mm and ensure that it is straight.

D.1.2.3 *Weigh the complete pendulum arm assembly to the nearest 5 g.*

D.1.3 Balancing of the pendulum arm assembly

D.1.3.1 Balance the pendulum arm on a knife edge with the adaptor nut in its extreme position.

D.1.3.2 With the slider assembly in a horizontal position, adjust the counterweight in the trailing edge of the assembly until it is balanced about the pendulum arm.

D.1.3.3 Measure the distance from the centre of oscillation to the centre of gravity of the pendulum arm *assembly to the nearest 1 mm.*

D.1.4 Setting the effective spring tension

D.1.4.1 Remove the small retaining plate covering the slider lifting handle.

D.1.4.2 With the slider assembly foot inverted, suspend a load equivalent to 22,2 N from the spindle.

D.1.4.3 Adjust the spring tension until the lifting handle is brought to its median position. The complete movement of the slider (parallel to the pendulum arm) when using the lifting handle shall be at least 6,5 mm.

D.1.4.4 Check the change in static force on the slider by the addition and subtraction of weights to the applied load and by measuring the deflection of the slider for each increment of load.

NOTE Suitable increments are about 20 g.

D.1.4.5 The complete movement of the slider (deflection) shall be at least 11 mm.

D.1.5 Setting the pointer stop

Adjust the pointer stop until the centre line of the pointer is parallel with the pendulum arm in a vertical position, with the friction tester assembled and levelled.

D.2 Control of sliders and slider rubber

D.2.1 The resilience and hardness of the slider rubber shall be verified using the criteria specified in table 3. The certificate of conformity shall also state the date of manufacture.

Verification is not necessary if the criteria are confirmed by a manufacturer's or supplier's certificate.

NOTE If it is necessary to verify the resilience of the rubber, it should be noted that the Lüpke rebound test is not suitable for testing rubber sheet. The test specified in ISO 4662 is a suitable alternative.

D.2.2 Store the sliders and any sheet rubber in the dark at a temperature of (20 ± 5) °C. Record the date of first use of each slider.

D.2.3 Before each use of the friction tester, check the angle of the plane of the slider (figure 4).

NOTE An angular metal template is a suitable means of checking.

D.2.4 If a slider is in use one year after the date of first use, either withdraw it from use or confirm that it continues to conform to the criteria specified in table 3.

Withdraw a slider from use when the working edges become excessively scored or rounded.

Annex E (informative)

Precision

E.1 General

Definitions of repeatability r and r_1 and reproducibility R and R_1 are given in EN 932-6 and results of cross-border tests have been interpreted in accordance with ISO 5725.

NOTE For the aggregate abrasion value (AAV) test, reproducibility $R2$ is also used in the United Kingdom.

E.2 PSV value - National Standard

The repeatability r and reproducibility R have been determined on the basis of duplicate tests in 11 laboratories in the United Kingdom at three levels of PSV (averaging 69, 53 and 40) as part of a precision experiment controlled by the British Standards Institution.

Estimates of the repeatability (r) and reproducibility (R_1) of the test for determining the PSV value are:

$$r = 3 \quad \text{and} \quad R_1 = 5$$

NOTE Estimates of the variance are given by $\sqrt{V_r} = 1,2$ $\sqrt{V_L} = 1,1$ and $\sqrt{V_s} = 1,2$.

E.3 PSV value - European cross-border testing

The results of a European cross-border testing experiment carried out by 18 laboratories in 1996, as part of a project funded by the European Community under the Measurements and Testing Programme, are given in table E.1 and table E.2.

Table E.1 – Repeatability and reproducibility (PSV units)

		Level 1	Level 2	Level 3
Average	X	46,3	55,4	66,7
Repeatability standard deviation	S_{r1}	0,721	0,754	1,057
Reproducibility standard deviation	S_{R2}	1,786	1,716	2,032
Repeatability limit	r_1	2,0	2,1	3,0
Reproducibility limit	R_1	5,0	4,8	5,7

Table E.2 – Functional relationships (PSV units)

	Functional relation
Repeatability standard deviation	$S_{r1} = 0,015X$
Reproducibility standard deviation	$S_{R2} = 1,18 + 0,0119X$
Repeatability limit	$r_1 = 0,042X$
Reproducibility limit	$R_1 = 3,30 + 0,0333X$

E.4 Aggregate abrasion value (AAV)

The values given in table E.3 apply when a test result is obtained as the average of the determinations of the aggregate abrasion value on two specimens made using the same test portion and run at the same time.

NOTE The precision data given in table E.3 is from a precision experiment carried out in the United Kingdom involving 13 laboratories, under the control of the British Standards Institution.

Table E.3 – Precision values for the determination of aggregate abrasion value

		Level 1	Level 2
Average	X	4	16
Repeatabilility limit	r_1	0,6	2,5
Reproducibility limit	R_2	1,5	3,5

Annex F (informative)

Bibliography

EN 932-6	Tests for general properties of aggregates - Part 6: Definitions of repeatability and reproducibility
ISO 5725	Precision of test methods - Determination of repeatability and reproducibility for a standard test method by inter-laboratory tests

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: 020 8996 9000. Fax: 020 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: 020 8996 9001. Fax: 020 8996 7001.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: 020 8996 7111. Fax: 020 8996 7048.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: 020 8996 7002. Fax: 020 8996 7001.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL