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Testing aggregates

Part 3. Methods for determination of mechanical properties

British Standards Institution

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Amendments issued since publication

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2153	November 1976	Indicated by a line in the margin
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Foreword

This British Standard has been prepared, under the authority of the Road Engineering Industry Standards Committee, using metric dimensions as part of the national policy to change to the metric system. BS 8 12 was first published in 1938 and subsequently revised in 1943, 1951, 1960 and 1967.

Guidance on sampling and testing aggregates, including procedures for assessing the precision of methods of test, is given in BS 8 12 : Part 101. Other Parts of BS 8 12 published are as follows.

Part 102 Methods for sampling
Part 1 Methods for determination of particle size and shape
Part 2 Methods for determination of physical properties
Part 4 Methods for determination of chemical properties.

In this Part of the standard changes have been introduced to simplify the determination of the aggregate abrasion value and to improve the precision of the determination of the polished-stone value by comparing the test value with the polished-stone value of a stone of known stability. The change to rational metric dimensions has affected most of the apparatus detailed in this Part of the standard and the metric sizes of aggregates now regarded as standard may not give the same results as those obtained by earlier methods.

The test for the determination of crushing strength of cylinders cut from rock, included in earlier editions of this standard, has been omitted from this revision because experience has shown the repeatability and reproducibility of the results to be very poor and also because a more reliable assessment of the performance of aggregates can be obtained from tne other tests for mechanical properties.

Information on any other methods of test that are thought suitable for extensive use, or suggestions for improvement of the specified methods, are welcomed and will be considered when it becomes desirable again to revise the standard.

In particular views would be welcomed on the need to retain both the aggregate crushing value and the ten per cent fines value tests. The latter was introduced in 1960 to provide a method which is applicable to all aggregates because the aggregate crushing value may yield anomalous results for softer materials, having values of 30 or higher.

Attention is drawn to the companion standard BS 3681 'Methods for the sampling and testing of lightweight aggregates for concrete'.

The Enderby control stone and the pneumatic tyre used in the method given in clause 10 for determination of the polished stone value are no longer in production. An alternative modified method is therefore given in clause 11 which uses a new control stone and a solid rubber tyre both of which are readily available. In order to improve consistency! supplies of the new control stone are to be obtained from a stockpile held by the Transport and Road Research Laboratory, Old Wokingham Road. Crowthorne, Berks RG11 6AU. Either of the methods given in clauses 10 and 11 may be used and can be expected to give comparable results.
The alternative method is basically the same as that given in clause 10 except that some differences have been introduced to accommodate the new control stone and the solid rubber tyre. Clause 10 will be withdrawn as soon as there is evidence that the stocks held by some test laboratories of the Enderby control stone and pneumatic tyre used in that clause have been exhausted. While the addition of the alternative modified method has become urgent because the Enderby control stone and pneumatic tyre used in clause 10 are in short supply. a fuller revision is planned and comments relating to an improved test are invited.

BS 812 : Part 3 : 1975

British Standard

Testing aggregates

Part 3. Methods for determination of mechanical properties

1. Scope

This Part of the standard specifies methods for the determination of the aggregate impact value, aggregate crushing value, ten per cent fines value, aggregate abrasion value and polished-stone value of aggregates.

The tests are intended for use in obtaining assurance that material complies with specified requirements. for research, production control or assessment of variation and are done on certain size fractions

2. References

The titles of the British Standards referred to in this standard are listed on the inside back cover.

3. Reporting

3.1 General. The report shall affirm that the tests were done in accordance with this standard. Any departure from the specified test procedure shall be described with reasons for the departure and, if possible. estimates of its effect on the test results. The report shall also include details of any special processing of the sample, other than that required by the test methods. carried out in the laboratory. For example. crushing to provide larger quantities of smaller sizes or the separation of constituents from an as-dug gravel.

3.2 Certificate of sampling. The report shall affirm that a certificate of sampling was received with the sample and shall declare all the information given on the certificate. If a certificate was not received this shall be stated in the report.

4. Significanceof the results

The distribution of the results of any test on any material stems from a number ofcontributing factors. In assessing the significance of the results the repeatability and reproducibility of the test should be recognized. Estimates of these are given in appendix A and should be used in assessing test results.

5. General

All the tests in this Part of the standard are carried out on certain size fractions which normally have to be sieved out from the laboratory sample. Where such a fraction constitutes less than 15 % of the total sample the results may not be representative. The aggregate impact test, aggregate crushing test and the ten per cent fines test are likely to be affected to a greater extent than the aggregate abrasion test and polished-stone test where flaky particles are separated in preparing the test sample. Under such circumstances the following recommendations should provide a more representative test sample:

(a) where general assurance about a given source of aggregate is required a further sample of a different grade and containing more than 15 % of the required size should be obtained and tested;

(b) where a particular consignment is to be tested for impact value, crushing value or ten per cent fines value, a non-standard size should be tested.

In the event of neither of these options proving possible it may be necessary to test the original fraction. The report shall state the fact when a further sample was obtained, when a non-standard size was tested or when the test was made on a fraction containing less than 15 % of the laboratory sample.

6. Determination of aggregate impactvalue

6.1 General. The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slowly applied compressive load. With aggregate of aggregate impact value higher than 30 the result may be anomalous. Also, aggregate sizes larger than 14 mm are not appropriate to the aggregate impact test.

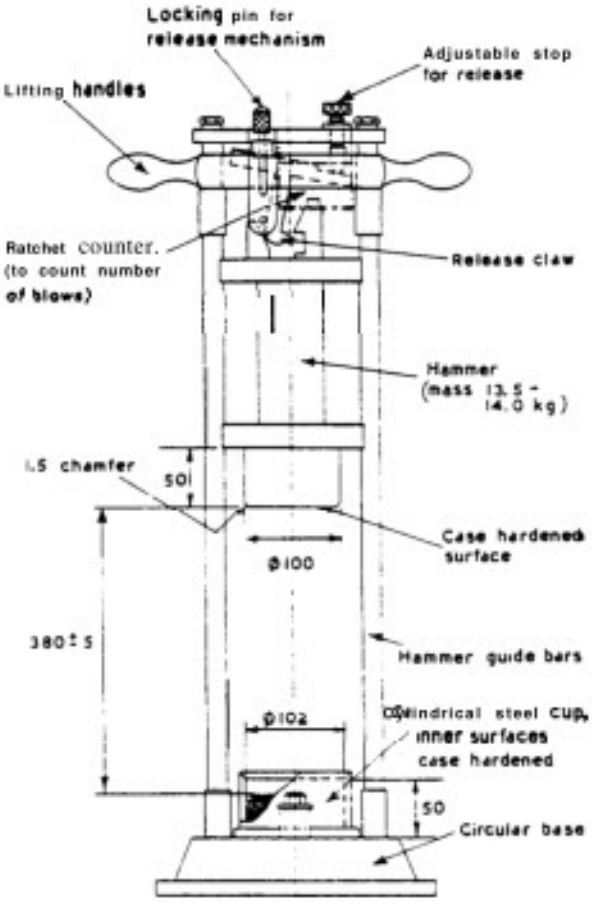
The standard aggregate impact test shall be made on aggregate passing a 14.0 mm BS test sieve and retained on a 10.0 mm BS test sieve. If required, or if the standard size is not available, smaller sizes may be tested but owing to the non-homogeneity of aggregates the results are not likely to be the same as those obtained from the standard size. In general, the smaller sizes of aggregate will give a lower impact value but the relationship between the values obtained with different sizes may vary from one aggregate to another.

6.2 Sampling. The sample for this test shall be taken in accordance with Part 103 of this standard. standard.

6.3 Apparatus. The following apparatus is required.

6.3.1 *An impact testing machine* of the general form shown in figure 1 and complying with the following.

(a) *Total mass* not more than 60 kg nor less than 45 kg.



Dimensions are in millimetres

NOTE. As a temporary measure, apparatus complying with the requirements of BS 812 : 1967 (now withdrawn) shall be deemed to comply with this requirement.

Figure 1. Aggregate impact test machine

The machine shall have a circular metal base weighing between 22 kg and 30 kg, with a plane lower surface of not less than 300 mm diameter, and shall be supported on a level and plane concrete or stone block or floor at least 450 mm thick. The machine shall be prevented from rocking either by fixing it to the block or floor or by supporting it on a level and plane metal plate cast into the surface of the block or floor.

(b) *A cylindrical steel cup* having an internal diameter of 102 mm and an internal depth of 50 mm. The walls shall be not less than 6 mm thick and the inner surfaces shall be case hardened. The cup shall be rigidly fastened at the centre of the base and be easily removed for emptying.

(c) A metal hammer weighing 13.5 kg to 14.0 kg the lower end of which shall be cylindrical in shape, 100.0 mm diameter and 50 mm long, with a 1.5 mm chamfer at the lower edge, and case hardened. The hammer shall slide freely between vertical guides so arranged that the lower (cylindrical) part of the hammer is above and concentric with the cup.

(d) *Means for raising the hammer* and allowing it to fall freely between the vertical guides from a height of 380 ± 5 mm on to the test sample in the cup, and means for adjusting the height of fall within 5 mm.

(e) Means for supporting the hammer whilst fastening or removing the cup.

NOTE. Some means for automatically recording the number of blows is desirable.

6.3.2 *BS test sieves* of aperture sizes 14.0 mm, 10.0 mm and 2.36 mm, for a standard test. For tests on aggregate sizes smaller than the standard, the appropriate aperture sizes of sieves shown in table 1 shall be used (see **7.1.3.1** of Part 1 of this standard).

6.3.3 A cylindrical metal measure of sufficient rigidity to retain its form under rough usage and with an internal diameter of 75 ± 1 mm and an internal depth of 50 ± 1 mm.

6.3.4 A straight metal tamping rod of circular cross section. 10 mm diameter, 230 mm long, rounded at one end.

6.3.5 A balance of capacity not less than 500 g, and accurate to 0.1 g.

6.4 Preparation of the test sample. The material for the standard test shall consist of aggregate passing a 14.0 mm BS test sieve and retained on a 10.0 mm BS test sieve and shall be thoroughly separated on these sieves before testing. For smaller sizes the aggregate shall be prepared in a similar manner using the appropriate sieves given in table 1. The quantity of aggregate sieved out shall be sufficient for two tests.

The aggregate shall be tested in a surface-dry condition. If dried by heating, the period of drying shall not exceed 4 h, the temperature shall not exceed 110 °C and the samples shall be cooled to room temperature before testing.

The measure shall be filled about one third full with the aggregate by means of a scoop, the aggregate being discharged from a height not exceeding 50 mm above the top of the container. The aggregate shall then be tamped with 25 blows of the rounded end of the tamping rod, each blow being given by allowing the tamping rod to fall freely from a height of about 50 mm above the surface of the aggregate and the blows being evenly distributed over the surface. A further similar quantity of aggregate shall be added in the same manner and a further tamping of 25 blows given. The measure shall finally be filled to overflowing, tamped 25 times and the surplus aggregate removed by roiling the tamping rod across, and in contact with, the top of the container, any aggregate which impedes its progress being removed by hand and aggregate being added to fill any obvious depressions. The net mass of aggregate in the measure shall be recorded (mass *A*) and the same mass used for the second test.

6.5 **Test procedure.** Rest the impact machine, without wedging or packing, upon the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.

Fix the cup firmly in position on the base of the machine and place the whole of the test sample in it and compact by a single tamping of 25 strokes of the tamping rod as above.

Adjust the height of the hammer so that its lower face is 380 ± 5 mm above the upper surface of the aggregate in the cup and then allow it to fall freely on to the aggregate. Subject the test sample to a total of 15 such blows, each being delivered at an interval of not less than 1 s. No adjustment for hammer height is required after the first blow.

Then remove the crushed aggregate by holding the cup over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. Transfer fine particles adhering to the inside of the cup and the underside of the hammer to the tray by means of a stiff bristle brush. Sieve the whole of the sample in the tray, for the standard test, on the 2.36 mm BS test sieve until no further significant amount passes in 1 min. When testing sizes smaller than the standard separate the fines on the appropriate sieve given in the 'for separating fines' column in table 1.

Weigh the fractions passing and retained on the sieve to an accuracy of 0.1 g (mass *B* and mass C respectively), and if the total mass *B* + C is less than the initial mass (mass A) by more than 1 g, discard the result and make a fresh test.

Repeat the whole procedure starting from the beginning of 6.5 using a second sample of the same mass as the first sample.

6.6 Calculations. The ratio of the mass of fines formed to the total sample mass in each test shall be expressed as a percentage, the result being recorded to the first decimal place.

$$\text{Percentage fines} = \frac{B}{A} \times 100$$

where

A is the mass of surface-dry sample (g);

B is the mass of fraction passing the sieve for separating the fines (g).

6.7 Reporting of results. The mean of the two results shall be reported to the nearest whole number as the aggregate impact value.

If a non-standard size of aggregate is tested, the size shall be reported.

Table 1. Particulars of BS test sieves for testing standard and non-standard sizes of aggregate as described in clauses 6, 7 and 8

Sample size	Nominal aperture sizes of BS test sieves complying with the requirements of BS 410 (full tolerance)		
	for sample preparation		for separating fines
	passing	retained	
	mm	mm	mm μm
Non-standard	28.0	20.0	5.00 –
	20.0	14.0	3.35 –
Standard	14.0	10.0	2.36 –
Non-standard	10.0	6.30	1.70 –
	6.30	5.00	1.18 –
	5.00	3.35	– 850
	3.35	2.36	– 600

NOTE. Aggregate sizes larger than 14.0 mm are not appropriate to the aggregate impact test.

7. Determination of aggregate crushing value

7.1 General. The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. With aggregate of an aggregate crushing value higher than 30 the result may be anomalous, and in such cases the ten per cent fines value (clause 8) should be determined instead.

The standard aggregate crushing test shall be made as described in 7.3 to 7.7 on aggregate passing a 14.0 mm BS test sieve and retained on a 10.0 mm BS test sieve. If required, or if the standard size of aggregate is not available, the test shall be made according to 7.8.

7.2 Sampling. The sample for this test shall be taken in accordance with Part 102 of this standard.

7.3 Apparatus. The following apparatus is required for the standard test.

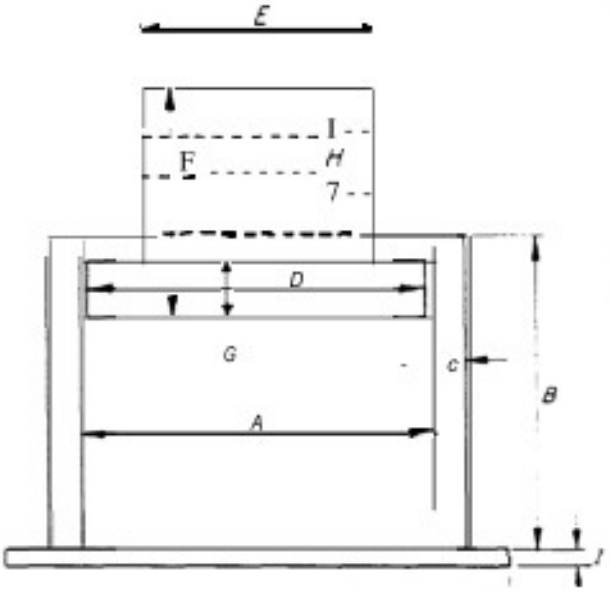
7.3.1 *An open ended steel cylinder* of nominal 150 mm internal diameter with plunger and base-plate, of the general form and dimensions shown in figure 2. The surfaces in contact with the aggregate shall be machined and case hardened, or otherwise treated, so as to have a hardness value of not less than 650 HV, in accordance with BS 427, and shall be maintained in a smooth condition.

7.3.2 A straight metal tamping rod of circular cross section, 16 mm diameter and 450 mm to 600 mm long. One end shall be rounded.

7.3.3 A balance of at least 3 kg capacity and accurate to 1 g.

7.3.4 *BS test sieves* of sizes **14.0** mm, **10.0** mm and 2.36 mm (see **7.1.3.1** of Part 1 of this standard).

7.3.5 A compression testing machine capable of applying a force of 400 kN and which can be operated to give a uniform rate of loading so that this force is reached in 10 min. The machine shall comply with the requirements of BS 1610 for a made A or a grade B machine. The machine may be used with or without a spherical seating.



7.3.6 A cylindrical metal measure (optional) for measuring the sample, of sufficient rigidity to retain its form under rough usage and having an internal diameter of 115 mm and an internal depth of 180 mm

7.4 Preparation of test sample. The material for the standard test shall consist of aggregate passing the 14.0 mm BS test sieve and retained on the 10.0 mm BS test sieve and shall be thoroughly separated on these sieves before testing. The quantity of aggregate sieved out shall be sufficient for two tests

The aggregate shall be tested in a surface-dry condition. If dried by heating the period of drying shall not exceed 4 h, the temperature shall not exceed 110°C and the aggregate shall be cooled to room temperature before testing.

The quantity of aggregate for one test shall be such that the depth of the material in the cylinder shall be 100 mm after tamping as described in 7.5.

The appropriate quantity may be found conveniently by filling the cylindrical measure in three layers of approximately equal depth, each layer being tamped 25 times from a height of approximately 50 mm above the surface of the aggregate with the rounded end of the tamping rod and finally levelled off, using the tamping rod as a straight edge.

The **mass** of **material** comprising the test sample shall be determined (mass *A*).

Key to dimensions

Letter **symbol**	Dimensions for	**Nominal 150 mm internal diameter of cylinder**	**Nominal 75*mm* internal diameter of cylinder**
	Cylinder	*mm*	**mm**
A	Internal diameter	154 ± 0.5	78.0 ± 0.5
B	Internal depth	125 to **140**	70.0 to 85.0
c	Wall thickness	≮ 16.0	≮ **8.0**
	Plunger		
D	Diameter of piston	152 ± 0.5	76.0 ± 0.5
E	Diameter of stem	95 to 155	45.0 to 80.0
F	Overall length of piston plus stem	loo to 115	60.0 to 80.0
G	Depth of piston	≮ 25.0	≮ 19.0
H	Diameter (nominal) of hole	20.0	10.0
	Baseplate		
I	Thickness (nominal)	6	6
J	Length of each side of square	200 to 230	110 to 115

NOTE. As a temporary measure, apparatus complying with the requirements of **BS812:1967** (now withdrawn) shall be deemed to comply with this requirement.

Figure 2. Outline form and principal dimensions of cylinder and plunger apparatus for aggregate crushing test

7.5 Test procedure. Put the cylinder of the test apparatus in position on the base plate, and add the test sample in thirds, each third being subjected to 25 strokes from the tamping rod distributed evenly over the surface of the layer and dropping from a height approximately 50 mm above the surface of the aggregate. Carefully level the surface of the aggregate and insert the plunger so that it rests horizontally on this surface, taking care to ensure that the plunger does not jam in the cylinder.

Place the apparatus, with the test sample and plunger in position, between the platens of the testing machine and load it at as uniform a rate as possible so that the required force is reached in 10 min. The required force shall be 400 kN.

Release the load and remove the crushed material by holding the cylinder over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. Transfer fine particles adhering to the inside of the cylinder, to the baseplate and the underside of the plunger to the tray by means of a stiff bristle brush. Sieve the whole of the sample on the tray on the 2.36 mm BS test sieve until no further significant amount passes in 1 min. Weigh the fraction passing the sieve (mass B).

Take care in all of these operations to avoid loss of the fines.

Repeat the whole procedure, starting from the beginning of 7.5. using a second sample of the same mass as the first sample.

7.6 Calculations. The ratio of the mass of fines formed to the total mass of the sample in each test shall be expressed as a percentage, the result being recorded to the first decimal place:

$$\text{Percentage fines} = \frac{B}{A} \times 100$$

where

A is the mass of surface-dry sample (g);

B is the mass of the fraction passing the 2.36 mm BS test sieve (g).

7.7 Reporting of results. The mean of the two results shall be reported to the nearest whole number as the aggregate crushing value.

7.8 Determination of aggregate crushing value for non-standard sizes of aggregate

7.8.1 *General.* If required, or if the standard size is not available. tests may be made on aggregates of other sizes larger than the standard up to a size which passes a 28.0 mm BS test sieve. using the standard apparatus. Alternatively. tests may be made on aggregates smaller than the standard down to a size which is retained on a 2.36 mm BS test sieve. using either the standard apparatus or that described in 7.8.2 which is referred to as the smaller apparatus.

Owing to the non-homopeneity of aggregates the results of tests on non-standard sizes are not likely to be the same as those obtained from standard tests. In general. the smaller sizes of aggregate will give a lower aggregate crushing value and the larger sizes a higher value, but the relationship between the values obtained will vary from one aggregate to another. However, the results obtained with the smaller apparatus have been found to be slightly higher than those with the standard apparatus and the errors for the smaller sizes of aggregate tested in the smaller apparatus are therefore compensatory.

7.8.2 *Apparatus.* The following apparatus is required.

7.8.2.1 *An open ended steel cylinder,* with plunger and baseplate, generally as described in 7.3.1. with a nominal internal diameter of 75 mm. The general form and dimensions of the cylinder and of the plunger are shown in figure 2.

7.8.2.2 A straight metal tamping rod of circular cross section 8 mm diameter and 300 mm long. One end shall be rounded.

7.8.2.3 A balance of at least 500 g capacity and accurate to 0.2 g.

7.8.2.4 *BS* 410 *test sieves* of appropriate sizes given in table 1 (see **7.1.3.1** of Part 1 of this standard).

7.8.2.5 A compression testing machine generally as described in 7.3.5 except that it shall be capable of applying a force of 100 kN, and of being operated to give a uniform rate of loading so that this force is reached in 10 min.

7.8.2.6 A cylindrical metal measure generally as described in 7.3.6 except that it shall have an internal diameter of 57 mm and an internal depth of 90 mm.

7.8.3 Preparation of test sample. The material for tests on non-standard sizes shall consist of aggregate passing and retained on corresponding BS test sieves given in table 1.

The procedure shall in other respects follow that given in 7.4 except that in tests with the smaller apparatus the quantity shall be such that the depth of material in the nominal 75.0 mm internal diameter cylinder shall be 50 mm after tamping with the smaller rod. The appropriate quantity may be found conveniently by using the smaller measure and tamping rod.

7.8.4 Test procedure. Tests on non-standard sizes shall follow the procedure given in 7.5 except that, when using the smaller apparatus, the smaller tamping rod shall be used and the total force shall be 100 kN. Take particular care with the larger sizes of aggregate to ensure that the plunger does not jam in the cylinder. Sieve the material removed from the cylinder on the appropriate sieve given in the 'for separating fines' column in table 1.

7.8.5 Calculations. Calculations for tests on non-standard sizes shall follow the method given in 7.6 substituting in the description of mass *B* the test sieve of appropriate size.

7.8.6 Reporting of results. Results of tests on non-standard sizes shall be reported as in 7.7 with, additionally, a report on the size of the aggregate tested and, if smaller than the standard size, the nominal size of the cylinder used in the test.

8. Determination of the ten per cent fines value

8.1 General. The ten per cent fines value gives a measure of the resistance of an aggregate to crushing which is applicable to both weak and strong aggregates.

The standard ten per cent fines test shall be made as described in 8.3 to 8.7 on aggregate passing a 14.0 mm BS test sieve and retained on a 10.0 mm BS test sieve. If required, or if the standard size of aggregate is not available, the test shall be made in accordance with 8.8.

8.2 Sampling. The sample for this test shall be taken in accordance with Part 102 of this standard.

8.3 Apparatus. The following apparatus is required for the standard test.

8.3.1 *An open ended steel cylinder* with plunger and baseplate, as described in 7.3.1.

8.3.2 A tamping rod as described in 7.3.2.

8.3.3 A balance as described in 7.3.3.

8.3.4 *BS* 410 *test sieves* as described in 7.3.4.

8.3.5 A compression testing machine as described in 7.3.5, except that the force which is to be applied may vary from 5 kN to 500 kN.

8.3.6 A cylindrical metal measure as described in 7.3.6.

8.3.7 (If required; *see* note in **8.5**), *a means of measuring* to the nearest 1 mm the reduction in distance between the platens of the testing machine during the test (e.g. a dial gauge).

8.4 Preparation of test sample. The preparation of the test sample shall be as described in 7.4 except that, in the case of weak materials, particular care shall be taken not to break the particles when filling the measure and the cylinder.

NOTE. Sufficient test sample for three or more tests may be necessary.

8.5 **Test procedure.** Put the cylinder of the test apparatus in position on the baseplate and add the test sample in thirds, each third being subjected to 25 strokes from the tamping rod distributed evenly over the surface of the layer and dropping from a height approximately 50 mm above the surface of the aggregate, particular care being taken in the case of weak materials not to break the particles. Carefully level the surface of the aggregate and insert the plunger so that it rests horizontally on this surface, taking care to ensure that the plunger does not jam in the cylinder.

Then place the apparatus, with the test sample and plunger in position, between the platens of the testing machine. Apply force at as uniform a rate as possible so as to cause a total penetration of the plunger in 10 min of about:

(a) 15 mm for rounded or partially rounded aggregates (e.g. uncrushed gravels);
(b) 20 mm for normal crushed aggregates;
(c) 24 mm for honeycombed aggregates (e.g. some slags).

These figures may be varied according to the extent of the rounding or honeycombing.

NOTE. When an aggregate impact value (see clause 4) is available, the force required for the first ten per cent fines test can be estimated by means of the following more conveniently than by the use of the dial gauge.

$$\text{Required force (kN)} = \frac{4000}{\text{aggregate impact value}}$$

This value of force will nearly always give a percentage fines within the required range of 7.5 to 12.5.

Record the maximum force applied to produce the required penetration. Release the force and remove the crushed material by holding the cylinder over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. Transfer fine particles adhering to the inside of the cylinder and the underside of the plunger to the tray by means of a stiff bristle brush. Sieve the whole of the sample in the tray on the 2.36 mm BS test sieve until no further significant amount passes in 1 min. Weigh the fraction passing the sieve, and express this mass as a percentage of the mass of the test sample. Normally this percentage of fines will fall within the range 7.5 to 12.5, but if it does not, make a further test loading to a maximum value adjusted as seems appropriate to bring the percentage fines within the range of 7.5 to 12.5. (The formula given in 8.6 may be used for calculating the force required.)

In all of these operations take care to avoid loss of the fines. Make a repeat test at the maximum force that gives a percentage fines within the range 7.5 to 12.5.

8.6 **Calculations.** The mean percentage fines from the two tests at this maximum force shall be used in the following to calculate the force required to produce ten per cent fines.

Force required to produce ten per cent

$$\text{fines} = \frac{14x}{y + 4}$$

where

x is the maximum force (kN);
y is the mean percentage fines from two tests at x kN force.

8.7 **Reporting of results.** The force required to produce ten per cent fines shall be reported, to the nearest 10 kN for forces of 100 kN or more or to the nearest 5 kN for loads of less than 100 kN, as the ten per cent fines value.

8.8 Determination of the ten per cent fines value for non-standard sizes of aggregate

8.8.1 *General.* If required, or if the standard size is not available, tests may be made on aggregates of other sizes which pass a 28.0 mm BS test sieve and are retained on a 2.36 mm BS test sieve. Because of the lack of experience of testing sizes other than the standard it has not been possible to give any indication as to how the results obtained on non-standard sizes would compare with those obtained in the standard test as in the case of the aggregate crushing value.

8.8.2 *Apparatus.* The apparatus shall be as described in 8.3.1 to 8.3.3 and 8.3.5 to 8.3.7.

BS test sieves of appropriate sizes shall be as given in table 1.

8.8.3 Preparation of test sample. The material for test on non-standard sizes shall consist of aggregate passing and retained on corresponding BS test sieves given in table 1.

The procedure shall in other respects follow that given in 8.4.

8.8.4 Test procedure. Tests on non-standard sizes shall follow the procedure given in 8.5 using the appropriate separating sieve given in table 1; it should be noted that the penetration of the plunger may not accord with the values given in 8.5.

8.8.5 *Calculations.* Calculations for tests on non-standard sizes shall follow the method given in 8.6.

8.8.6 Reporting of results. Results of tests on non-standard sizes shall be reported as in 8.7 with, additionally, a report on the size of the aggregate tested.

9. Determination of aggregate abrasion value

9.1 General. This test gives a measure of the resistance of aggregate to surface wear by abrasion.

9.2 Sampling. The sample for this test shall be taken in accordance with Part 102 of this standard.

9.3 Apparatus. The following apparatus is required.

9.3.1 *An abrasion machine* consisting essentially of a machined flat circular cast iron or steel grinding lap not less than 600 mm in diameter, which can be rotated in a horizontal plane at a speed of 28 rev/min to 30 rev/min, fitted with a revolution counter, and which is provided with the following accessories.

(a) *At least two machined metal moulds* for preparing specimens. manufactured with removable ends and with internal dimensions of 92.0 mm × 54.0 mm × 16.0 mm, all ± 0.1 mm. (See footnote to 9.4.2.)

(b) *At least two machined metal trays or metal backing plates* for holding the prepared specimens. Trays made from 5 mm mild steel plate and of internal dimensions 92.0 mm x 54.0 mm x 8.0 mm. all ± 0.1 mm are suitable,

(c) *At least two machined flat plates* made from 5 mm mild steel plate of dimensions 115 mm x 75 mm, all ± 0.1 mm.

(d) *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. The trays shall be free to move in a vertical plane but restrained from moving in the horizontal plane.

(e) *Two weights*, each with a rounded base for pressing the test specimen against the surface of the lap and each having a means for adjusting its mass. including test specimen and tray, to 2 kg ± 10 g (see 9.7).

(f) *Means for feeding sand* continuously on the lap in front of each test specimen at a rate of 700 g/min to 900 g/min, and for removing and recovering the sand after it has passed under the test samples.

9.3.2 *BS* **410** *test sieves* 14.0 mm, 1.18 mm, 850 μm, 600 μm, 425 μm, 300 μm and 212 μm (see **7.1.3.1** of Part 1 of this standard).

9.3.3 Two fine haired brushes (about 3 mm) and a stiff brush.

9.3.4 A balance of capacity not less than 1 kg, accurate to 0.1 g.

93.5 A well ventilated oven thermostatically controlled at a temperature of 105 ± 5 °C.

9.3.6 A 20.0 mm *to* 14.0 mm *special slotted flake sorting sieve (see* 7.3.2.1 of Part 1 of this standard), having a slot width of 10.2 ± 0.15 mm.

9.4 Materials. The following materials are required.

9.4.1 *An abrasive* consisting of Leighton Buzzard silica sand, at least 75 % of which shall pass the 600 μm BS test sieve and be retained on the 425 μm BS test sieve and all of which shall pass the 850 μm BS test sieve and be retained on the 300 μm BS test sieve. The sand shall be dry and shall not have been previously used. About 3 kg shall be used for each sample.

9.4.2 Polyester resin and hardener, such as Crystic resin*, together with a release agent such as liquid car polish, a cleaning solvent or a mixture of 90 % acetone 10 % kerosine (by volume), and disposable paper cups.

9.4.3 *Fine sand* (passing the 212 μm BS test sieve), to prevent the polyester resin from squeezing up between the individual pieces of aggregate.

9.5 Sample for test. The test sample shall consist of aggregate passing the 14.0 mm BS test sieve and retained on the 20.0 mm to 14.0 mm flake sorting sieve. It shall be washed to remove surface dust. The aggregate shall be tested in a surface-dry condition. If dried by heating, the period of drying shall not exceed 4 h, the temperature shall not exceed 110 °C and the sample shall be cooled to room temperature before preparing test specimens.

* Crystic resin gives about 0.5 mm shrinkage on the length and width of the specimen: if a non-shrinking resin is used the appropriate mould dimensions should be decreased by 0.5 mm.

9.6 **Preparation of test specimen.** Two specimens shall be made for each test. As many particles as possible from the test sample, but in any case not less than 24, shall be placed in the mould in a single layer with their flattest surface lying on the bottom of the mould.

The particles may be selected from the test sample as required but care shall be taken to ensure that they are representative of the test sample.

The interstices between the pieces of aggregate shall then be filled to approximately three quarters of their depth with the fine sand which shall then be levelled with one fine haired brush. The exposed internal faces and top edges of the mould shall be lightly coated with release agent with the second fine haired brush. Sufficient resin and hardener shall then be mixed in a disposable cup and used to fill the mould to overflowing.

NOTE. Approximately equal proportions of resin and hardener have been found to be suitable when using Crystic resin.

One side of the flat plate shall then be coated with the release agent and it shall be placed firmly on the mould coated side down and held in position by a weight of not less than 2 kg. When the resin has hardened (usually after 30 min) the plate shall be removed and excess resin trimmed off with a knife or spatula. The specimen shall then be removed from the mould, the loose sand removed with the stiff brush and the specimen then weighed to the nearest 0.1 g (mass A).

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

9.7 **Test procedure.** Fit each specimen into one of the machined metal trays or metal backing plates, taking care to ensure a tight fit. Weigh each specimen in its tray with one of the weights whose mass shall then be adjusted until the total is 2 kg ± 10 g. Place the two specimens in the abrasion machine diametrically opposite to each other with their centre points 260 mm from the centre of the lap and so that the 92 mm x 54 mm face of exposed aggregate particles rests on the lap over the whole face area; then place the appropriate weights centrally on the specimens. Then turn the lap through 500 revolutions at a speed of 28 rev/min to 30 rev/min, the abrasive sand specified above being fed continuously on to it across the full width of the specimen immediately in front of each test specimen at a rate of 700 g/min to 900 g/min per specimen*. To ensure that the sand is fed beneath each specimen lift them clear of the lap for 1 revolution before the start of abrasion and at every hundredth revolution thereafter. Remove the sand with a rubber edged blade, mounted so that the rubber edge rests lightly on the lap for its full width, and collect it.

If it becomes apparent that, because of the nature of the aggregate, it has abraded away to the level of the resin backing discontinue the test. Report the number of revolutions. Conversely, some very hard aggregates may visibly score the machined surface of the grinding lap, in which case the surface shall be remachined.

Immediately screen the sand on the 1.18 mm BS test sieve and re-use it as many times as is necessary to complete the test and then discard it.

On completion of 500 revolutions remove the test specimens from the machine, remove the trays or backing plates and weigh the specimens to the nearest 0.1 g (mass B).

9.8 **Calculations.** The aggregate abrasion value of each test specimen shall be calculated as follows.

$$\frac{3\,(A - B)}{d}$$

where

A is the mass of specimen before abrasion (g);
B is the mass of specimen after abrasion (g);
d is the relative density of sample (on saturated surface-dried basis) as determined in clause 5 of Part 2 of this standard.

NOTE. The calculation is based on the percentage loss in mass of an assumed 33 ml volume of aggregate.

9.9 **Reporting of results.** The mean of the two results shall be reported to two significant figures as the aggregate abrasion value, unless the individual results differ from the mean of the two results by more than 10% of the mean value. In this case the test shall be repeated and the mean of the four tests shall be reported as the aggregate abrasion value.

10. Determination of the polished-stone value

10.1 General. The polished-stone value gives a measure of the resistance of roadstone to the polishing action of a pneumatic tyre under conditions similar to those occurring on the surface of a road. Where the surface of a road consists largely of roadstone the state of polish of the sample will be one of the major factors affecting the resistance of the surface to skidding. The actual relationship between polished-stone value and skidding resistance will vary with the traffic conditions, type of surfacing and other factors. All factors together with the reproducibility of the test should be taken into account when drawing up specifications for roadworks which include test limits for polished-stone value. The test is in two parts.

(a) *First part*. Samples of stone are subjected to an accelerated polishing action in a special machine. Two methods are given for mounting the sample for polishing.

(b) *Secondpart*. The state of polish reached by each sample is measured by means of a suitable friction test and is expressed as a laboratory determined polished-stone value.

10.2 Sampling. The sample for this test shall be taken in accordance with Part 102 of this standard.

* A slot of about 1.3 mm width is suitable.

10.3 Apparatus*. The following apparatus is required.

10.3.1 *An acceleratedpolishing machine* which shall be rigidly mounted on a firm, level base of stone or concrete and shall include the following.

(a) *A wheel (referred to below as the 'road wheel')* having a flat periphery, and of such a size and shape as to permit fourteen of the specimens described below to be clamped on the periphery so as to form a continuous surface of stone particles 45 mm wide and 406 mm in diameter.

(b) *Meansof rotating the road wheel* about its own axis at a speed of 3 15 rev/min to 325 revjmin.

(c) Means of bringing the surface of a rubber tyred wheel of 203 mm diameter and 50 mm breadth to bear on the stone surface of the road wheel with a total force of 390 ± 5 N. The tyre shall be an industrial 8 x 2 pneumatic 2-ply rating smooth hand-truck tyre, specially selected and if necessary treated to obtain a true running surface. The tyre shall have a hardness of 55 ± 5 IRHD† and shall be inflated to a pressure of310 ± 15 kN/m²; it 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.

It is important that the machine shall be accurately aligned and that both wheels shall be free to rotate without play in the bearings. The following limits shall be applied:

The planes of rotation of the two wheels shall be not more than 20 minutes of arc out of parallel (1 mm in 200 mm).

The planes through the centres of the two wheels shall be not more than 0.8 mm apart.

(d) *Means to feed the corn emery* specified in 10.4.1 and water at the rates shown in 10.7 and in such a way that the emery and water are continuously and uniformly spread over the surface of the tyre and the specimens where they are in contact. The emery and water shall be fed directly on to the road wheel near the point of contact with the rubber tyred wheel.

(e) *Means to feed the emery flour* specified in 10.4.2 and water at the rates shown in 10.7 and in such a way that the emery flour and water are continuously and uniformly spread over the surface of the tyre and the specimens where they are in contact.

NOTE. A separate feed mechanism for each abrasive *is* recommended to avoid excessive readjustment.

10.3.2 A number of accurately machined metal moulds for preparing specimens of the dimensions specified in **10.5.**

10.3.3 *A friction tester* complying with the requirements set out in 10.8 and 10.9.

10.3.4 *BS 410 test sieves* of the following sizes: 10.0 mm, 600 µm, 500 µm, 425 µm, 355 µm, 300 gm, 212 µm and 53 µm (see 7.1.3.1 of Part 1 of this standard).

10.3.5 *A 14.0* mm *to 10.0* mm *special slotted flake sorting sieve (see* 7.3.2.1 of Part 1 of this standard), having a slot width of 7.2 ± 0.1 mm.

10.4 Materials. The following materials are required.

10.4.1 *A supply of fresh natural corn emery*, which shall be used only once, complying with the following grading requirements:

Nominal width of aperture	Total percentage passing
µm	
600	98 to 100
500	70 to 100
425	30 to 90
355	0 to 30
300	Oto5

10.4.2 *A supply of air-floated emery flour* the whole of which shall pass a 53 µm BS test sieve.

NOTE. Additional apparatus and materials are specified in the subclause for each mounting method (**10.5.1** and **10.5.2**).

10.5 Preparation of specimens

10.5.1 *General.* At least 3 kg of nominal 10 mm particles shall be available for each sample to be tested. The particles actually used in the preparation of the test specimens shall all pass the 10.0 mm BS test sieve and be retained on the 14 mm to 10 mm flake sorting sieve. They shall not be elongated and shall be clean and free from dust.

A representative sample shall be obtained by the method described in 5.2.2 of Part 1 of this standard from the normal run of production from the plant, since chippings that have been freshly crushed in the laboratory may give misleadingly high results. The surface texture of the particles which are to be exposed to the polishing action of the tyre shall be representative of the average surface texture of the stone; a few particles having a very smooth or very rough surface texture may occur in almost any sample, but these shall not be used in preparing the test specimen.

Each specimen shall consist of a single layer of 35 to 50 of the particles, placed as closely as possible and covering an area of 90.6 mm x 44.5 mm, set in a sand-cement mortar or a resin as described in **10.5.2** or 10.5.3 respectively with their exposed surfaces proud of the backing. The surface of the specimen shall be flat across the shorter dimension but shall be curved in the arc of a circle of 406 mm diameter along the longer dimension.

The finished specimen shall present the natural surface of the stone chippings with no sharp projecting edges to the polishing tyre and shall be not less than 12.5 mm thick; the under surface shall be the arc of a circle of exactly the same diameter as the periphery of the road wheel of the polishing machine. Four specimens shall be made from each material to be tested.

* Where necessary, information on the current sources of supply of any of the apparatus or materials required for this test can be obtained from the Transport and Road Research Laboratory, Old Wokingham Road, Crowthorne, Berks. RG11 6AU.

† BS 2719 gives methods of testing hardness by means of pocket type rubber hardness meters. The revision of the standard, which is in course of preparation, specifies hardness in terms of international rubber hardness degrees (IRHD) which have the same values as the obsolete British Standard rubber hardness degrees.

10.5.2 *Sand-cement mortar specimens. The* following apparatus and materials are required.

(a) *Fine sand* all passing a 212 µm test sieve.

(b) *Iron wire* (approximately 1.2 mm diameter). Three approximately 75 mm lengths are required for each specimen. Straightened large paper-clips are satisfactory.

(c) High alumina cement (see BS 915).

(d) *A water spray.*

(e) A spatula.

(f) *A stiff bristle brush.*

(g) *A tray.*

The specimen shall be prepared by carefully placing 35 to 50 selected particles in a single layer with their flattest surfaces lying on the bottom of the mould. The interstices between the particles shall then be filled to one quarter to a half of their depth with fine sand (all passing a 212 µm BS test sieve), the sand wetted thoroughly with a fine spray of water, three pieces of 1.2 mm iron wire laid along the longer dimension to act as reinforcement* and the mould filled to overflowing with a mortar made from equal portions by mass of sand passing a 212 µm BS test sieve and high alumina cement; the consistency of the mortar shall be such as to permit it to flow freely between the particles. The mould shall then be left until the mortar has stiffened sufficiently to be struck off accurately level with the curved sides of the mould (usually between 3 h and 6 h). The specimen shall then be left in the mould, covered by a water-saturated cloth, for a further 24 h, after which it shall be removed from the mould and the loose sand brushed free with the stiff bristle brush. The specimen shall be stored under water with the stone surface downwards for 7 days to 14 days.

10.5.3 *Resin specimens.* The following apparatus and materials are required.

(a) *Release agent* or liquid car polish.

(b) *Cleansing solvent* or a mixture of 90 % acetone and 10 % kerosine (by volume).

(c) Polyester resin and hardener, such as Crystic resin.

(d) *Disposable paper cups.*

(e) Clear flexible plastics sheet such as acetate or polyethylene sheet.

(f) *A metalplate* shaped to the radius (189 mm) of the polishing test mould and a little larger than the mould.

(g) *A 2 kg weight or a clamp.*

(h) *Two fine haired brushes* (about 3 mm).

(i) *A stiffbristle brush.*

(j) A spatula.

The specimen shall be prepared by carefully placing 35 to 50 selected particles in a single layer with their flattest surfaces lying on the bottom of the mould. The interstices between the particles shall then be filled to approximately three quarters of their depth with fine sand (all passing a 212 µm BS test sieve) which shall then be levelled with one fine haired brush. The exposed internal faces and top edges of the mould shall be lightly coated with release agent using the second fine haired brush. The hardener shall be mixed with the resin in a disposable cup; the exact proportion is not critical and depends upon the resin used.

NOTE. Approximately equal proportions of the two components have been found to be suitable when using Crystic resin.

The mould shall be filled to overflowing with the mixed resin and when it has reached a suitable consistency the surplus shall be floated off with the spatula without disturbing the main body of the resin.

NOTE. Alternatively the surplus may be squeezed out by covering the mould with the plastics sheet and pressing the metal plate on to the sheet.

When the resin commences to harden (after 5 min to 10 min) any excess resin shall be trimmed from the edges with a knife and the metal plate shall be pressed to the back of the specimen by means of the weight (2 kg minimum) or the clamp, to prevent distortion during setting. After the resin has completely set and cooled (about 30 min from mixing) the specimen shall be removed from the mould and the loose sand removed with the stiff bristle brush, and after a further 30 min may be subjected to the polishing procedure. The solvent should be used to clean moulds, tools, etc., as required.

10.6 **Calibration of the** polishing **machine.** Before a new tyre is used on a test it shall be given a preliminary run of 3 h with corn emery, and 3 h with emery flour, as in an actual test but using spare† specimens, two of which shall be unpolished Enderby specimens, (see also **10.5**). Following polishing, the Enderby specimens shall be tested in the standard manner and the mean result recorded. If this result is greater than 54 the above procedure shall be repeated using further pairs of unpolished Enderby specimens until the mean result obtained falls in the range of 48 to 54. If, in the first instance, the mean figure obtained with the Enderby specimens falls below 48 the tyre shall be discarded. Following the above conditioning, the tyre shall be used for test runs until either it is apparent that its use for a further run will give a mean figure of less than 48 with the Enderby specimens or it shows signs of irregular or excessive wear. The tyre shall not be used for more than 20 runs.

As a check on results, two freshly prepared specimens of stone from Enderby Quarry, Leicestershire, shall be included in each test run. The mean value for these two specimens shall lie in the range 48 to 54. If this is not the case then the complete test shall be rejected and the whole test procedure shall be examined and any necessary modifications made so as to ensure that the mean value given by two specimens of stone from Enderby Quarry lies within the range 48 to 54.

* The reinforcement may be inserted after the mortar has been placed, but if this is done great care will be necessary to avoid disturbance of the chippings.

† Specimens that have been used in earlier tests are suitable.

10.7 Accelerated polishing of specimens. The temperature of the room in which the accelerated polishing is carried out shall be 20 ± 5 °C.

Fourteen specimens shall be numbered as follows :

four specimens of 1st sample shall be numbered 1 to 4,

four specimens of 2nd sample shall be numbered 5 to 8*,

four specimens of 3rd sample shall be numbered 9 to 12*,

two specimens of Enderby control shall be numbered 13 and 14,,

and then arranged in the following order:

13, 4, 5, 8, 7, 1, 10, 14, 3, 11, 12, 2, 6, 9.

The fourteen specimens shall be clamped in the specified order round the periphery of the road wheel of the polishing machine, strips of polyethylene 0.25 mm thick being inserted between adjacent specimens and between the underside of the specimens and the periphery of the wheel where necessary. The outer surface of the specimens shall form a continuous strip of particles with a periphery of 406 mm diameter, upon which the pneumatic tyred wheel shall ride freely without bumping or slipping. Any gaps shall be filled with a suitable packing piece level with the remainder of the specimen.

The road wheel shall then be brought to a speed of 315 rev/min to 325 rev/min and the pneumatic tyred wheel shall be brought to bear on the surface of the specimens with a total force of 390 ± 5 N. Water and the corn emery specified in **10.4.1** shall be fed continuously on to the road wheel at rates within the following limits for a period of 3 h ± 1 min.

	Rate of feed
Corn emery	20 g/min to 35 g/min
Water	The water shall be fed at a rate just sufficient to carry the corn emery to the wheel; this is approximately the same rate as for the corn emery.

The run shall be interrupted after 2 h and the used corn emery removed from the base.

On completion, i.e. after 3 h, the machine and specimens shall be thoroughly cleaned by washing so that all trace of the corn emery is removed. The machine shall subsequently be operated continuously for a further 3 h ± 1 min as described in the preceding paragraphs, except that in place of the corn emery the flour specified in 10.4.2 shall be fed continuously with water at rates within the following limits:

	Rate of feed
Emery flour	2 g/min to 4 g/min.
Water	The rate of feed of the water shall be twice that of the emery flour.

The specimens shall then be removed from the machine and shall be thoroughly washed in running water to remove all trace of the emery flour. Emery flour which almost invariably packs in the interstices between the stone particles shall be removed by scrubbing with a stiff bristle brush. The slightest trace of emery flour on or between the stone particles will cause a lowering of the result of the friction test.

After washing, the specimens shall be stored face downwards under water at a temperature of 18 °C to 22 °C for a period of between ½ h and 2 h and immediately on removal from the water shall be tested on the friction tester as described below. At no time prior to this testing shall the specimens be allowed to dry out.

10.8 Friction tester. The friction test shall be made with a tester constructed in accordance with drawings supplied by the TRRL†. All bearings and working parts of the instrument shall be enclosed as far as possible, and all materials used shall be suitably treated to prevent corrosion under wet conditions.

The tester shall provide the following.

(a) *A spring loaded rubber slider* of the mass, size and shape specified below mounted on the end of a pendulum arm so that the sliding edge is approximately 510 mm from the axis of suspension.

(b) *Means for setting the* column of the instrument vertical.

(c) Means for rigidly locating one of the curved specimens from the accelerated polishing machine with its longer dimension in the track of the pendulum and centrally with respect to the rubber slider and to the axis of suspension of the pendulum.

(d) *Means for raising and lowering the axis of suspension* of the pendulum so that the slider can

(1) swing clear of the surface of the specimen, and

(2) be set to slide over a fixed length of surface of 76.0 mm as near as is visually possible but in any case within ± 0.5 mm.

(e) Means for holding and releasing the pendulum arm so that it falls freely from a horizontal position.

(f) *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 drawn up as specified in 10.9. The mass of the pointer shall be not more than 85 g and 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 300 mm long pointer may be brought to rest on the forward swing of the arm at a point 10 mm below the horizontal.

*These may be replaced by spare specimens if less than three samples are to be polished.

† Drawings and instructions, finalized in March 1960, may be obtained from the Transport and Road Research Laboratory, Old Wokingham Road, Crowthorne, Berks. RG11 6AU.

The mass of the swinging arm including the slider shall be 1.50 ± 0.03 kg the centre of gravity lying on the axis of the arm at a distance of 410 ± 5 mm from the centre of suspension.

The slider shall consist of a rubber pad 31.75 mm wide, 25.4 mm deep and 6.35 mm thick held on a rigid base with a total mass of 20 ± 5 g which is mounted on an axis set at an angle of approximately 26° with the horizontal when the pendulum is at the lowest point of its swing, so that only the rear edge of the slider contacts the test surface, and the slider can turn about its axis without obstruction to follow unevenness of the surface perpendicular to the plane of the pendulum swing.

The slider shall be spring loaded against the test surface and the nominal static force on the slider as set by the procedure defined in the instructions supplied with the drawings 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 per millimetre deflection of the slider.

The slider shall comply with the requirements given in table 2.

The working edges of the slider shall be square and clean cut, and the rubber free from contamination (abrasive or oil, etc.). No slider shall be used which is more than a year old.

The rubber in the sheet or slider form shall be stored in the dark at a temperature between 10 °C and 20 °C.

10.9 Calibration of the tester. The calibration of the tester shall be checked at least once a year*. The scale† of the instrument when used for this test shall be the unit F drawn up by means of the following equation :

$$F = \frac{W \times X}{P D p} \times 100$$

where

F is a measure of the coefficient of friction (times 100);

W is the force exerted by the swinging arm (N);

X is the distance of the effective centre of gravity of the arm from the centre of oscillation (mm);

Z is the vertical distance of the edge of the scale below the zero of the scale, which shall be 10 mm below the horizontal when the arm is released to swing freely from the horizontal, (mm);

P is the nominal static force on the slider (N), as defined in 10.8;

D is the sliding distance (mm);

p is the length of the pointer (mm).

The instrument shall be cross-checked using the sliding length of 126 mm with the BSI standard friction tester on the following wetted surfaces:

(a) a glass plate;

(b) five smooth-looking surfaces having a texture depth less than 0.25 mm and covering a range of at least 25 to 75 units;

(c) five rough-looking surfaces having a texture depth greater than 0.50 mm and covering a range of at least 35 to 70 units.

On these tests no pairs of results obtained with the two instruments on any surface shall differ by more than 3 units and the mean results for the 11 samples shall not differ by more than 1.5 units.

10.10 Friction test procedure. Make the test at a temperature of 20 ± 2 °C and place the apparatus (including slider) in the room for at least 2 h before the tests commence, so that it may attain this temperature.

Rest the tester upon a firm level surface and adjust the levelling screws so that the 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 the zero position on the scale.

Each rubber slider edge may be used for a period of up to one year (when it should be discarded) provided the following procedure is adopted.

(a) Maintain a stock of Criggion specimens for control purposes. These shall be made from stone from Criggion Quarry and shall be made and polished as in an actual determination. When tested they shall yield a value in the range 59 to 66. Record the values and air-dry the specimens and store them in a sealed container for future use.

Table 2. Properties of slider

Property	At temperature (°C) of				
	0	10	20	30	40
Resilience %‡	43 to 49	58 to 65	66 to 73	71 to 77	74 to 79
Hardness IRHD§	55 ± 5	55 ± 5	55 ± 5	55 ± 5	55 ± 5

* The selection and testing of the rubber for the slider, and the calibration of the tester, are carried out at the BSI Test House, Hemel Hempstead Centre, Maylands Avenue, Hemel Hempstead, Herts.

† An auxiliary scale is required for this test, because of the shorter sliding distance (76 mm) as compared with the longer distance (126 mm) used for checking and road testing.

‡ Lüpke rebound test in accordance with BS 903:Part A8.

§ International rubber hardness degrees in accordance with BS 903:Part A26.

(b) Before being brought into use 'condition' a new slider by swinging it five times over the dry surface of a polished Criggion specimen following with a further 20 swings on its wetted surface. Keep the Criggion specimen used for this purpose apart from the Criggion control specimens described in (a); it may be used repeatedly provided its value (when wet) does not fall below 55.

(c) Before each set of measurements, check the slider by testing a Criggion control specimen and record the resulting value. Additional polishing through repeated testing yields progressively lower values and the control shall be discarded when its value falls below 59 and a new control drawn from the stock. If a check value is more than 2 units lower (or one unit higher) than the last recorded value for the control, discontinue testing until the reason has been traced and any fault rectified. A fault could lie in the instrument or its operation or because of changes in the slider. It is recommended that more than one slider be kept in use to facilitate differentiation between a faulty slider and a defective instrument.

(d) A slider that develops excessive burring and scoring through prolonged use can lead to unsatisfactory results. which are usually high, and shall be rejected.

Then rigidly locate the first test specimen with its longer dimension lying in the track of the pendulum, and centrally with respect to the rubber slider and to the axis of suspension of the pendulum, and in such a way that the slider of the pendulum will traverse it in the same direction as it has been trafficked in the polishing machine.

NOTE. For this purpose it is advisable to mark one longitudinal edge of each specimen. If this mark is on the side of the specimen furthest from the operator during polishing, it should be nearest to him during testing and vice versa.

Then adjust the height of the axis of suspension of the pendulum so that in traversing the specimen the rubber slider is in contact with it over the whole width of the slider and over a length of 76.0 mm as near as visually possible but in any case within $\pm$ 0.5 mm. Then wet the surfaces of the specimen and the rubber slider with a copious supply of clean water, care being taken not to disturb the slider from its set position. Then release the pendulum and pointer from the horizontal position and note the reading of the pointer. Carry out this operation five times, re-wetting the specimen each time, and record the mean of the last three readings to the nearest whole number.

Test the specimens in the following order:

13, 1, 3, 5, 7, 9, 11, 12, 10, 8, 6, 4, 2, 14.

10.11 Calculations. The mean and range of the recorded values of the four specimens shall be calculated and recorded to the nearest whole number.

The mean of the recorded values of the two Enderby control specimens shall be calculated and recorded to the nearest 0.5 unit.

If the range of the values of the four specimens is greater than 5 units or if the mean value of the control specimens, without further rounding, does not lie within the range 48 to 54, the test results shall be rejected and the whole test procedure shall be examined and any necessary modifications made to ensure that these requirements for range and mean are satisfied.

If the range of the values of the four specimens is 5 units or less and the mean value of the control specimens, without further rounding, lies within the range 48 to 54, the polished-stone value shall then be obtained from the mean value of the four specimens and the mean value of the control specimens by reference to table 3.

10.12 Reporting of results. The polished-stone value* obtained from table 3 shall be reported.

* This is not, and should not be confused with, the sideway force coefficient nor with the 'skid-resistance' value determined on a road.

Table 3. Calculation of PSV

Enderby control value	48	48.5	49	49.5	50	50.5	51	51.5	52	52.5	53	53.5	54
Mean measured **value**	**Value** to be reported												
25	27	26	26	26	6	25	25	5	25	24	24	24	24
26	28	27	27	27	7	26	26	6	26	25	25	25	25
27	29	28	28	28	8	27	27	7	26	26	26	26	25
28	30	29	29	29	9	28	28	8	27	27	27	27	26
29	31	30	30	30	0	29	29	9	28	28	28	28	27
30	32	32	31	31	31	30	30	0	29	29	29	29	28
31	33	33	32	32	32	31	31	1	30	30	30	30	29
32	34	34	33	33	33	32	32	2	31	31	31	31	30
33	35	35	34	34	34	33	33	3	32	32	32	31	31
34	36	36	35	35	35	34	34	4	33	33	33	32	32
35	37	37	36	36	36	35	35	5	34	34	34	33	33
36	38	38	37	37	37	36	36	6	35	35	35	34	34
37	39	39	39	38	38	37	37	7	36	36	36	35	35
38	40	40	40	39	39	38	38	8	37	37	37	36	36
39	41	41	41	40	40	39	39	9	38	38	38	37	37
40	43	42	42	41	1	40	40	0	39	39	38	38	38
41	44	43	43	42	2	41	41	1	40	40	39	39	39
42	45	44	44	43	3	42	42	2	41	41	40	40	40
43	46	45	45	44	4	43	43	3	42	42	41	41	41
44	47	46	46	45	5	44	44	4	43	43	42	42	42
45	48	47	47	46	6	45	45	5	44	44	43	43	42
46	49	48	48	47	7	46	46	6	45	45	44	44	43
47	50	49	49	48	8	47	47	7	46	46	45	45	44
48	51	50	50	49	9	48	48	8	47	47	46	46	45
49	52	52	51	50	0	49	49	9	48	48	47	47	46
50	53	53	52	52	51	50	50	50	49	49	48	48	47
51	54	54	53	53	52	52	51	51	50	50	49	49	48
52	55	55	54	54	53	53	52	51	51	51	50	50	49
53	56	56	55	55	54	54	53	52	52	51	51	51	50
54	57	57	56	56	55	55	54	53	53	52	52	51	51
55	58	58	57	57	56	56	55	54	54	53	53	52	52
56	60	59	58	58	57	57	56	55	55	54	54	53	53
57	61	60	59	59	58	58	57	56	56	55	55	54	54
58	62	61	60	60	59	59	58	57	57	56	56	55	55
59	63	62	61	61	60	60	59	58	58	57	57	56	56
60	64	63	62	62	61	61	60	59	59	58	58	57	57
61	65	64	63	63	62	62	61	60	60	59	59	58	58
62	66	65	65	64	63	63	62	61	61	60	60	59	59
63	67	66	66	65	64	64	63	62	62	61	61	60	59
64	68	67	67	66	65	65	64	63	63	62	62	61	60
65	69	68	68	67	66	66	65	64	64	63	63	62	61
66	70	69	69	68	67	67	66	65	65	64	64	63	62
67	71	70	70	69	68	68	67	66	66	65	64	64	63
68	72	72	71	70	69	69	68	67	67	66	65	65	64
69	73	73	72	71	70	70	69	68	68	67	66	66	65
70	74	74	73	72	71	71	70	69	69	68	67	67	66
71	75	75	74	73	72	72	71	70	70	69	68	68	67
72	77	76	75	74	73	73	72	71	71	70	69	69	68
73	78	77	76	75	74	74	73	72	72	71	70	70	69
74	79	78	77	76	75	75	74	73	73	72	71	71	70
75	80	79	78	77	77	76	75	74	74	73	72	71	71
76	81	80	79	78	78	77	76	75	75	74	73	72	72
77	82	81	80	79	79	78	77	76	76	75	74	73	73
78	83	82	81	80	80	79	78	77	77	76	75	74	74
79	84	83	82	81	81	80	79	78	77	77	76	75	75
80	85	84	83	82	82	81	80	79	78	78	77	76	76
81	86	85	84	83	83	82	81	80	79	79	78	77	76
82	87	86	85	84	84	83	82	81	80	80	79	78	77
83	88	87	86	86	85	84	83	82	81	81	80	79	78
84	89	88	87	87	86	85	84	83	82	82	81	80	79

11. Alternative method for determination of the polished-stone value

11.1 General. The polished-stone value gives a measure of the resistance of roadstone to the polishing action of vehicle tyres under conditions similar to those occurring on the surface of a road. Where the surface of a road consists largely of roadstone the state of polish of the sample will be one of the major factors affecting the resistance of the surface to skidding. The actual relationship between polished-stone value and skidding resistance will vary with the traffic conditions, type of surfacing and other factors. All factors together with the reproducibility of the test should be taken into account when drawing up specifications for roadworks which include test limits for polished-stone value. The test is in two parts.

(a) *First part*. Samples of stone are subjected to an accelerated polishing action in a special machine. Two methods are given for mounting the sample for polishing.

(b) Second *part*. The state of polish reached by each sample is measured by means of a suitable friction test and is expressed as a laboratory determined polished-stone value.

11.2 Sampling. The sample for this test shall be taken in accordance with Part 102 of this standard. this standard.

11.3 Apparatus*. The following apparatus is required.

11.3.1 *An accelerated polishing machine* which shall be rigidly mounted on a firm, level base of stone or concrete and shall include the following.

(a) *A wheel (referred to below as the 'road wheel')* having a flat periphery, and of such a size and shape as to permit fourteen of the specimens described below to be clamped on the periphery so as to form a continuous surface of stone particles 45 mm wide and 406 mm in diameter.

(b) *Means of rotating the road wheel* about its own axis at a speed of 315 rev/min to 325 rev/min.

(c) Two solid rubber tyred wheels of 200 mm diameter and with a width of 38 mm. These wheels shah be of two colours. A dark-coloured wheel shah be used for the corn emery and a light-coloured wheel for the emery flour. The rubber tyres† shall be made to the Avon Tyre Ltd. compound code 4454 and shall have a hardness of 69 ± 3IRHD (see BS 2719).

(d) *Means of bringing the surface of the appropriate solid rubber tyred wheel to bear on the road wheel* with a total force of 725 ± 10 N. It shah 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 and both wheels shall be free to rotate without play in the bearings. The following limits shall be applied:

The planes of rotation of the two wheels shall be not more than 20 minutes of arc out of parallel (1 mm in 200 mm).

The planes through the centres of the two wheels shall be not more than 0.8 mm apart.

(e) Mechanism‡, dark-coloured for use with the dark-coloured wheel (see (c)), to feed the corn emery specified in 11.4.1 and water at the rates shown in 11.7 and in such a way that the emery and water are continuously and uniformly spread over the surface of the tyre and the specimens over the surface of the tyre and the specimens where they are in contact. The emery and water shall be fed direct on to the road wheel near the point of contact with the rubber tyred wheel.

(f) *Mechanism*‡, light-coloured for use with the light-coloured wheel (see (c)), to feed the emery flour specified in 11.4.2 and water at the rates shown in 11.7 and in such a way that the emery flour and water are continuously and uniformly spread over the surface of the tyre and the specimens where they are in contact.

(g) Means of ensuring that the solid rubber-tyred wheel is not left under load when not running, otherwise there is a risk of the tyre becoming deformed.

11.3.2 *A number of accurately machined metal moulds* for preparing specimens of the dimensions specified in 11.5.

11.3.3 *A friction tester* complying with the requirements set out in 11.8 and 11.9.

11.3.4 *BS* 410 *test sieves* of the following sizes:– 10.0 mm, 600 pm, 500 pm, 425 pm, 355 pm, 300 pm, 212 pm and 53 pm (see 7.1.3.1 of Part 1 : 1975 of this standard).

11.3.5 *A* 14.0 *mm to* 10.0 *mm special slotted flake sorting sieve* (see 7.3.2.1 of Part 1 : 1975 of this standard), having a slot width of 7.2 ± 0.1 mm.

11.4 Materials*. The following materials are required.

11.4.1 *A supply of fresh natural corn emery,* which shall be used only once, complying with the following grading requirements:

Nominal width of aperture	Total percentage passing
µm	
600	*98* to 100
500	70 to 100
425	*30* to *90*
355	*0* to *30*
300	*0* to *5*

*Where necessary. information on the current sources of supply of any of the apparatus or materials required for this test can be obtained from the Transport and Road Research Laboratory, Old Wokingham Road, Crowthorne, Berks. RG11 6AU.

†Obtainable from the suppliers of the accelerated polishing machine.

‡A separate feed mechanism is necessary for each abrasive.

11.43 A supply of air-floated or water-washed emery flour the whole of which shah pass a 53 µm BS test sieve when tested according to the decantation test (see 7.2.4 of Part 1 : 1975 of this standard), but using a 53 pm test sieve instead of the 75 pm sieve used in the procedure specified in Part 1.

11.43 *A supply of PSV control stone (see the* foreword).

11.4.4 *A supply of* Criggion *stone (see* 11.10).

NOTE. Additional apparatus and materials are specified in the subclause for each mounting method (11.5.2 and 11.53).

11.5 Preparations of specimens

11.5.1 *General.* A representative sample shah be obtained by the method described in 5.2.2 of Part 1 : 1975 of this standard from the normal run of production from the plant, since chippings that have been freshly crushed in the laboratory may give misleadingly high results.

The particles actually used in the preparation of the test specimens shah all pass the 10.0 mm BS test sieve and be retained on the 14 mm to 10 mm flake sorting sieve. They shah not be elongated and shah be clean and free from dust. The sample shah provide a minimum of 2 kg of material meeting these requirements.

The surface texture of the particles which are to be exposed to the polishing action of the tyre shah be representative of the average surface texture of the stone; a few particles having a very smooth or very rough surface texture may occur in almost any sample but these shah not be used in preparing the test specimen.

Each specimen shah consist of a single layer of 35 to 50 of the particles, placed as closely as possible and covering an area of 90.6 mm x 44.5 mm, set in a sand-cement mortar or a resin as described in 11.5.2 or 11 .5.3 respectively with their exposed surfaces proud of the backing. The surface of the specimen shah be flat across the shorter dimension but shall be curved in the arc of a circle of 406 mm diameter along the longer dimension.

The finished specimen shah present the natural surface of the stone chippings with no sharp projecting edges to the polishing tyre and shah be not less than 12.5 mm thick; the under surface shah be the arc of a circle of exactly the same diameter as the periphery of the road wheel of the polishing machine. Any specimen with mortar or resin exposed at the surface shall be rejected. Four specimens shah be made from each material to be tested.

11 .5.2 *Sand-cement mortar specimens.* The following apparatus and materials are required.

(a) Fine sand ail passing a 312 µm test sieve.

(b) *Iron wire* (approximately 1.2 mm diameter). Three approximately 75 mm lengths are required for each specimen. Straightened large paperclips are satisfactory.

(c) High alumina cement (see BS 9 15).

(d) *A water spmy.*

(e) A spatula.

(f) *A stiff bristle brush.*

(g) *A tray.*

The specimen shah be prepared by carefully placing 35 to 50 selected particles in a single layer with their flattest surfaces lying on the bottom of the mould. The interstices between the particles shah then be filled to between one-quarter and one-half of their depth with fine sand (all passing a 212 µm BS test sieve), the sand wetted thoroughly with a fine spray of water, three pieces of 1.2 mm iron wire laid along the longer dimension to act as reinforcement* and the mould filled to overflowing with a mortar made from equal portions by mass of sand passing a 212 µm BS test sieve and high alumina cement; the consistency of the mortar shah be such as to permit it to flow freely between the particles. The mould shah then be left until the mortar has stiffened sufficiently to be struck off accurately level with the curved sides of the mould (usually between 3 h and 6 h).

The specimen shah then be left in the mould, covered by a water-saturated cloth, for a further 24 h, after which it shah be removed from the mould and the loose sand brushed free with the stiff bristle brush. The specimen shah be stored under water with the stone surface downwards for 7 days to 14 days.

11 .5.3 *Resin specimens.* The following apparatus and materials are required.

(a) *Release agent* or liquid car polish.

(b) *Cleansing solvent* or a mixture of 90 % acetone and 10 % kerosine (by volume).

(c)Polyester resin and hardener, such as Crystic resin.

(d) *Disposable paper cups.*

(e) Clear flexible plastics sheet such as acetate or polyethylene sheet.

(f) *A pair of rigid metal* covers having one face plane, the other shaped to the radius (189 mm) of the polishing test mould and a little larger than the mould.

(g) *A clamp,* such as a 200 mm G-clamp.

(h) *Two fine haired brushes* (about 3 mm).

(i) *A stiff bristle brush.*

(j) *A spatula.*

The specimen shah be prepared by carefully placing 35 to 50 selected particles in a single layer with their flattest surfaces lying on the bottom of the mould. The interstices between the particles shah then be filled to approximately three-quarters of their depth with fine sand (ah passing a 212 µm BS test sieve) which shall then be levelled with one fine haired brush. The exposed internal faces and top edges of the mould shah be lightly coated with release agent using the second fine haired brush. The hardener shall be mixed with the resin in a disposable cup; the exact proportion is not critical and depends upon the resin used.

*The reinforcement may be. inserted after the mortar has been placed, but if this is done great care will be necessary to avoid disturbance of the chippings.

NOTE. Approximately equal proportions of the two components have been found to be suitable when using Crystic resin.

The mould shall be filled to overflowing with the mixed resin and when it has reached a suitable consistency the surplus shall be floated off with the spatula without disturbing the main body of the resin.

NOTE. Alternatively the surplus may be squeezed out by covering the mould with the plastic sheet and pressing the metal cover on to the sheet.

When the resin commences to harden (after 5 min to 10 min) any excess resin shall be trimmed from the edges with a knife and the metal cover shall be pressed to the back of the specimen by means of the clamp, to prevent distortion during setting. After the resin has completely set and cooled (about 30 min from mixing) the specimen shall be removed from the mould and the loose sand removed with the stiff bristle brush, and after a further 30 min may be subjected to the polishing procedure. The solvent should be used to clean moulds. tools, etc, as required.

11.5.4 *Quality of specimens.* All test specimens shall be critically examined and any with matrix at the surface or with disturbed chipping shall be rejected.

11.6 Calibration of the polishing machine. Before a new tyre is used on a test, a preliminary run with the appropriate abrasive shall be made using the new tyre* as in an actual test† but using spare specimens‡. (see also **11.5**). Following polishing, the control specimens shall be tested in the standard manner and the mean result recorded. If this result is greater than 57 or less than 51 this test shall be rejected. and any necessary modification made so as to ensure that the mean value given by the two fresh specimens of the control stone lies within the range 51 to 57.

NOTE. More than one preliminary run may be required to lower the control values to the permitted range.

The use of a solid rubber tyre shall be limited to 40 runs. and be rejected earlier if showing excessive wear or damage.

11.7 Accelerated polishing of specimens. The temperature of the room in which the accelerated polishing is carried out shall be 20 ± 5 °C.

Fourteen specimens shall be numbered as follows:

four specimens of 1st sample shall be numbered 1 to 4,

four specimens of 2nd sample shall be numbered 5 to 8§,

four specimens of 3rd sample shall be numbered 9 to 12§,

two specimens of the PSV control stone shall be numbered 13 and 14,

and then arranged in the following order:

13, 4, 5, 8, 7, 1, 10, 14, 3, 11, 12, 2, 6, 9.

The fourteen specimens shall be clamped in the specified order round the periphery of the road wheel of the polishing machine, strips of polyethylene 0.25 mm thick being inserted between adjacent specimens and between the underside of the specimens and the periphery of the wheel where necessary.

The outer surface of the specimens shall form a continuous strip of particles with a periphery of 406 mm diameter, upon which the rubber-tyred wheel shall ride freely without bumping or slipping. Any gaps shall be filled with a suitable packing piece level with the remainder of the specimen.

The road wheel shall then be brought to a speed of 315 rev/min to 325 rev/min and the dark-coloured wheel shall be brought to bear on the surface of the specimens with a total force of 725 ± 10 N. Water and the corn emery specified in **11.4.1 shall** be fed continuously on to the road wheel using the dark-coloured feed mechanism at rates within the following limits for a period of 3 h ± 1 min.

	Rate of feed
Corn emery	20 g/min to 35 g/min
Water	The water shall be fed at a rate just sufficient to carry the corn emery to the wheel; this is approximately the same rate as for the corn emery.

The run shall be interrupted after 2 h and the used corn emery removed from the base. On completion, i.e. after 3 h, the machine and specimens shall be thoroughly cleaned by washing so that all trace of the corn emery is removed.

The lightcoloured wheel and emery flour feed mechanism shall next be fitted. The machine shall subsequently be operated continuously for a further 3 h ± 1 min as described in the preceding paragraphs, except that in place of the corn emery the flour specified in **11.4.2** shall be fed continuously with water at rates within the following limits.

	Rate of feed
Emery flour	2 g/min to 4 g/min
Water	The rate of feed of the water shall be twice that of the emery flour.

It is important that the solid rubber tyred wheel is not left under load at any time other than when the wheel is running, otherwise there is a risk of the tyre becoming deformed.

The specimens shall then be removed from the machine and shall be thoroughly washed in running water to remove all trace of the emery flour. Emery flour which almost invariably packs in the interstices between the stone particles shall be removed by scrubbing with a stiff bristle brush. The slightest trace of emery flour on or between the stone particles will cause a lowering of the result of the friction test.

After washing, the specimens shall be stored face downwards under water at a temperature of 18 °C to 32 °C for a period of between ½ h and 2 h and immediately on removal from the water shall be tested on the friction tester as described below. At no time prior to this testing shall the specimens be allowed to dry out.

11.8 Friction tester. The friction test shall be made with a tester manufactured under licence to the

*It is essential to use the correct wheel appropriate to each abrasive.

†It is essential that the test includes the use of the other wheel and abrasive as is appropriate to comply with the complete test procedure.

‡Specimens that have been used in earlier tests are suitable.

§These may be replaced by spare specimens if less than three samples are to be polished.

Transport and Road Research Laboratory (TRRL) design. All bearings and working parts of the instrument shall be enclosed as far as possible, and all materials used shall be suitably treated to prevent corrosion under wet conditions.

The tester shall provide the following.

(a) *A spring loaded rubber slider* of the mass, size and shape specified below mounted on the end of a pendulum arm so that the sliding edge is approximately 5 10 mm from the axis of suspension.

(b) *Means for setting the column* of the instrument vertical.

(c) *Means for rigidly locating one of the curved specimens* from the accelerated polishing machine with its longer dimension in the track of the pendulum and centrally with respect to the rubber slider and to the axis of suspension of the pendulum.

(d) *Means for raising and lowering the axis of suspension* of the pendulum so that the slider can

(1) swing clear of the surface of the specimen, and

(2) be set to slide over a fixed length of surface of 126.0 mm as near as is visually possible but in any case within ± 0.5 mm.

(e) *Means for holding and releasing the pendulum arm* so that it falls freely from a horizontal position.

(f) *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 drawn up as specified in 11.9.

The mass of the pointer shall be not more than 85 g and 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 300 mm long pointer may be brought to rest on the forward swing of the arm at a point 10 mm below the horizontal.

The mass of the swinging arm including the slider shall be 1.50 ± 0.03 kg, the centre of gravity lying on the axis of the arm at a distance of 410 ± 5 mm from the centre of suspension.

The slider shall consist of a rubber pad 3 1.75 mm wide. 35.4 mm deep and 6.35 mm thick held on a rigid base with a total mass of 20 ± 5 g which is mounted on an axis set at an angle of approximately 26" with the horizontal when the pendulum is at the lowest point of its swing, so that only the rear edge of the slider contacts the test surface, and the slider can turn about its axis without obstruction to follow unevenness of the surface perpendicular to the plane of the pendulum swing.

The slider shall be spring loaded against the test surface and the nominal static force on the slider as set by the procedure defined in the instructions supplied with the drawings 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 per millimetre deflection of the slider.

The slider shall comply with the requirements given in table 2.

The working edges of the slider shall be square and clean cut, and the rubber free from contamination (abrasive or oil, etc).

The rubber in the sheet or slider form shall be stored in the dark at a temperature between 10 °C and 20 "C.

11.9 **Calibration of the tester.** The calibration of the tester shall be checked at least once a year*. The scale† of the instrument when used for this test shall be the unit F drawn up by means of the following equation:

$$F = \frac{WXZ}{PDp} 100$$

where

F is a measure of the coefficient of friction (times 100);

W is the force exerted by the swinging arm (N);

X is the distance of the effective centre of gravity of the arm from the centre of oscillation (mm);

Z is the vertical distance of the edge of the scale below the zero of the scale, which shall be 10 mm below the horizontal when the arm is released to swing freely from the horizontal (mm);

P is the nominal static force on the slider (N). as defined in 11.8;

D is the sliding distance (mm);

p is the length of the pointer (mm).

The instrument shall be crosschecked using the sliding length of 126 mm with the BSI standard friction tester on the following wetted surfaces:

(a) a glass plate;

(b) five smooth-looking surfaces having a texture depth less than 0.25 mm and covering a range of at least 25 to 75 units;

Table 2. Properties of slider

Property	At temperature (°C) of				
	0	10	20	30	40
Resilience %‡	43 to 49	58 to 65	66 to 73	71 to 77	74 to 79
Hardness IRHD§	55 ± 5	55 ± 5	55 ± 5	55 ± 5	55 ± 5

*The calibration of the tester is carried out at the BSI Test House, Hemel Hempstead Centre, Maylands Avenue, Hemel Hempstead, Herts. Herts.

† An auxiliary scale is required for this test, because of the shorter sliding distance (76 mm) as compared with the longer distance (126 mm) used for checking and road testing.

‡ Lüpke rebound test in accordance with BS 903 : Part A8.

§ International rubber hardness degrees in accordance with BS 903 : part ,426.

(c) five rough-looking surfaces having a texture depth greater than 0.50 mm and covering a range of at least 35 to 70 units.

On these tests no pairs of results obtained with the two instruments on any surface shall differ by more than 3 units and the mean results for the 11 samples shall not differ by more than 1.5 units.

11.10 Friction test procedure. Make the test at a temperature of 20 ± 2 °C and place the apparatus (including slider) in the room for at least 2 h before the tests commence, so that it may attain this temperature.

Rest the tester upon a firm level surface and adjust the levelling screws so that the 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 the zero position on the scale.

Each rubber slider edge may be used provided the following procedure is adopted.

(a) Maintain a stock of Criggion specimens for control purposes. These shall be made from stone from Criggion Quarry and shall be made and polished as in an actual determination. When tested they shall yield a value in the range 59 to 66. Record the values and air-dry the specimens and store them in a sealed container for future use.

(b) Before being brought into use 'condition' a new slider by swinging it five times over the dry surface of a polished Criggion specimen following with a further 20 swings on its wetted surface. Keep the Criggion specimen used for this purpose apart from the Criggion control specimens described in (a): it may be used repeatedly provided its value (when wet) does not fall below 55.

(c) Before each set of measurements, check the slider by testing a Criggion control specimen and record the resulting value. Additional polishing through repeated testing yields progressively lower values and the control shall be discarded when its value falls below 59 and a new control drawn from the stock. If a check value is more than 2 units lower (or one unit higher) than the last recorded value for the control. discontinue testing until the reason has been traced and any fault rectified. A fault could lie in the instrument or its operation or because of changes in the slider. It is recommended that more than one slider be kept in use to facilitate differentiation between a faulty slider and a defective instrument.

(d) A slider that develops excessive burring and scoring through prolonged use can lead to unsatisfactory results. which are usually high, and shall be rejected.

Then rigidly locate the first test specimen with its longer dimension lying in the track of the pendulum. and centrally with respect to the rubber slider and to the axis of suspension of the pendulum, and in such a way that the slider of the pendulum will traverse it in the same direction as it has been trafficked in the polishing machine.

NOTE. For this purpose it is advisable to mark one longitudinal edge of each specimen. If this mark is on the side of the specimen furthest from the operator during polishing, it should be nearest to him during friction testing and vice versa.

Then adjust the height of the axis of suspension of the pendulum so that in traversing the specimen the rubber slider is in contact with it over the whole width of the slider and over a length of 76.0 mm as near as visually possible but in any case within ± 0.5 mm. Then wet the surfaces of the specimen and the rubber slider with a copious supply of clean water, care being taken not to disturb the slider from its set position. Then release the pendulum and pointer from the horizontal position and note the reading of the pointer. Carry out this operation five times, re-wetting the specimen each time, and record the mean of the last three readings to the nearest whole number.

Test the specimens in the following order:

13, 1, 3, 5, 7, 9, 11, 12, 10, 8, 6, 4, 2, 14.

11.11 Calculations. The mean and range of the recorded values of the four specimens shah be calculated and recorded to the nearest whole number.

The mean of the recorded values of the two PSV control stone specimens shah be calculated and recorded to the nearest 0.5 unit.

If the range of the values of the four specimens of any sample is greater than 5 units the results for that sample shall be rejected. If the mean value of the PSV control specimens, without further rounding, does not lie within the range 5 1 to 57. the test results shall be rejected and the whole test procedure shah be examined and any necessary modifications made to ensure that these requirements for range and mean are satisfied.

If the range of the values of the four specimens is 5 units or less and the mean value of the control specimens, without further rounding, lies within the range 5 1 to 57. the polished-stone value shall then be obtained from the mean value of the four specimens and the mean value of the control specimens by reference to table 3a.

11.12 Repeatability and reproducibility. Replicate tests at three levels and for eight laboratories yielded average estimates of repeatability (r) of 4 3 and reproducibility (R) of 6.0 when analysed in accordance with BS 5497 : Part 1.

11.13 Reporting of results. Report the polished stone value* obtained from table 3a.

*This is not. and should not be confused with, the sideway force coefficient nor with the 'skid-resistance' value determined on a road.

Table 3a. Calculation of PSV (alternative method)

PSV control **value**	51	51.5	52	52.5	53	53.5	54	54.5	55	55.5	56	56.5	57
Mean **measured value**	Value to be reported												
25	25	25	25	25	25	24	24	24	24	23	23	23	23
26	27	26	26	26	26	25	25	25	25	24	24	24	24
27	28	27	27	27	26	26	26	26	26	25	25	25	25
28	29	28	28	28	27	27	27	27	26	26	26	26	26
29	30	29	29	29	28	28	28	28	27	27	27	27	26
30	31	30	30	30	29	29	29	29	28	28	28	28	27
31	32	31	31	31	30	30	30	30	29	29	29	29	28
32	33	32	32	32	31	31	31	31	30	30	30	29	29
33	34	33	33	33	32	32	32	31	31	31	31	30	30
34	35	34	34	34	33	33	33	32	32	32	32	31	31
35	36	35	35	35	34	34	34	33	33	33	33	32	32
36	37	36	36	36	35	35	35	34	34	34	33	33	33
37	38	37	37	37	36	36	36	35	35	35	34	34	34
38	39	38	38	38	37	37	37	36	36	36	35	35	35
39	40	39	39	39	38	38	38	37	37	37	36	36	36
40	41	40	40	40	39	39	39	38	38	37	37	37	36
41	42	41	41	41	40	40	39	39	39	38	38	38	37
42	43	42	42	42	41	41	40	40	40	39	39	39	38
43	44	43	43	43	42	42	41	41	41	40	40	40	39
44	45	44	44	44	43	43	42	42	42	41	41	40	40
45	46	45	45	45	44	44	43	43	43	42	42	41	41
46	47	46	46	46	45	45	44	44	43	43	43	42	42
47	48	47	47	47	46	46	45	45	44	44	44	43	43
48	49	48	48	48	47	47	46	46	45	45	45	44	44
49	50	49	49	49	48	48	47	47	46	46	46	45	45
50	51	50	50	50	49	49	48	48	47	47	46	46	46
51	52	51	51	51	50	50	49	49	48	48	47	47	47
52	53	53	52	52	51	51	50	50	49	49	48	48	47
53	54	54	53	52	52	52	51	51	50	50	49	49	48
54	55	55	54	53	53	52	52	52	51	51	50	50	49
55	56	56	55	54	54	53	53	52	52	52	51	51	50
56	57	57	56	55	55	54	54	53	53	52	52	51	51
57	58	58	57	56	56	55	55	54	54	53	53	52	52
58	59	59	58	57	57	56	56	55	55	54	54	53	53
59	60	60	59	58	58	57	57	56	56	55	55	54	54
60	61	61	60	59	59	58	58	57	57	56	56	55	55
61	62	62	61	60	60	59	59	58	58	57	57	56	56
62	63	63	62	61	61	60	60	59	59	58	58	57	57
63	64	64	63	62	62	61	61	60	60	59	59	58	57
64	65	65	64	63	63	62	62	61	61	60	59	59	58
65	66	66	65	64	64	63	63	62	61	61	60	60	59
66	67	67	66	65	65	64	64	63	62	62	61	61	60
67	68	68	67	66	66	65	64	64	63	63	62	62	61
68	69	69	68	67	67	66	65	65	64	64	63	63	62
69	70	70	69	68	68	67	66	66	65	65	64	64	63
70	71	71	70	69	69	68	67	67	66	66	65	64	64
71	72	72	71	70	70	69	68	68	67	67	66	65	65
72	73	73	72	71	71	70	69	69	68	67	67	66	66
73	74	74	73	72	72	71	70	70	69	68	68	67	67
74	75	75	74	73	73	72	71	71	70	69	69	68	68
75	76	76	75	74	74	73	72	72	71	70	70	69	68
76	77	77	76	75	75	74	73	72	72	71	71	70	69
77	79	78	77	76	76	75	74	73	73	72	72	71	70
78	80	79	78	77	77	76	75	74	74	73	72	72	71
79	81	80	79	78	78	77	76	75	75	74	73	73	72
80	82	81	80	79	78	78	77	76	76	75	74	74	73
81	83	82	81	80	79	79	78	77	77	76	75	75	74
82	84	83	82	81	80	80	79	78	78	77	76	75	75
83	85	84	83	82	81	81	80	79	78	78	77	76	76
84	86	85	84	83	82	82	81	80	79	79	78	77	77

Appendix A

Repeatability and reproducibility of test results

A.1 General. The distribution of results of any test on any material stems from a number of contributing factors and to allow for these factors in comparing results by the same test operator or results by test operators working in different laboratories estimates of the distribution are required. Such estimates are given in this appendix together with the definition of the terms 'repeatability' and 'reproducibility' which are used in assessing the distribution of test results. An example of the application of the estimate is also given. The values may also be useful in setting limits in specifications for materials and in assessing the difference between different materials.

A.2 Definitions. For the purposes of this appendix the following definitions apply:

value. Where results are reported as a mean of two or more determinations the figures for repeatability and reproducibility are based on the mean value.

repeatability (r). Quantitative expression of the random error associated with a single test operator in a given laboratory obtaining successive results with the same apparatus under constant operating conditions on identical test material. It is defined as that difference between two such single results as would be exceeded in the long run in only one case in twenty in the normal and correct operation of the test method.

For the purposes of this standard the identical test material for repeatability tests shall be obtained by dividing a sample of twice* the amount required to obtain a single test result by the sample reduction procedure described in 5.2.4 of Part 1 of this standard.

reproducibility (R). Quantitative expression of the random error associated with test operators working in different laboratories, each obtaining single results on identical test material when applying the same method. It is defined as that difference between two such single and independent results as would be exceeded in the long run in only one case in twenty in the normal and correct operation of the test method.

For the purposes of this standard the identical test material shall be obtained by first dividing a sample of twice* the amount required to obtain a single test result into two equal portions, one for each laboratory and then, where appropriate, each laboratory shall reduce each portion to the amount required for single determinations by the sample reduction procedure described in 5.2.4 of Part 1 of this standard.

Mathematically, the precision statements are of the form :

repeatability: $r = 1.96\sqrt{2}\sigma_1$

reproducibility: $R = 1.96\sqrt{2}\sqrt{\sigma_1^2 + \sigma_2^2}$

where

σ_1 is the best estimate of single-operator standard deviation? within a laboratory, and

σ_2 is the standard deviation t applicable to all causes of variability other than repeatability of testing when results of different operators in different laboratories are compared.

A.3 Estimates of repeatability and reproducibility. Table 4 gives estimates of repeatability and reproducibility for the tests in this standard for which figures are at present available. These values represent the greatest differences that can be expected between test results on duplicate samples in the normal run of testing within and between laboratories respectively.

* These quantities are given for the purpose of defining 'identical material'. Estimates of r and R should be based on a larger number of tests and laboratories.

† Standard deviation is defined in BS 2846.

Table4. Estimates of the repeatability and reproducibility of a number of tests for aggregates

Test	BS 812 Part number	Repeatability r	Reproducibility R
Relative density (wire basket method saturated surface-dried basis)	2		
Most aggregates		0.02	0.04
Some porous aggregates of low density (< 2.60)		up to 0.04	up to 0.08
Water absorption	2	5% of value recorded	10% of value recorded
Bulk density	2	10kg/m³	20 kg/m3
Aggregate impact value	3	1.0	2.0
Aggregate crushing value	3	0.8	1.5
Ten per cent fines value	3	7kN	14kN
Aggregate abrasion value	3	1.5*	3.0*
Polished-stone value	3	4.9	6.0*

A.4 An example of the application of estimates. A laboratory purchases secondhand equipment for the polished-stone value determination and wishes to reassure itself that its technique and equipment are satisfactory. It prepares a number of identical subsamples from a large sample of aggregate and tests two of them obtaining results of 61 and 64 respectively. Because difference between these results (3 units) is less than the repeatability of the test (4.9), the laboratory has no reason to doubt the consistency of its testing. However, this gives no guarantee that its equipment is satisfactory or that its technique has no bias. Therefore two more of the identical samples are sent to another laboratory experienced in the test which obtains values of 59 and 57. The means for the two laboratories are thus 62.5 and 58.0 respectively.

Were these the results of single determinations the difference (4.5) would be less than the reproducibility of the test and there would be no cause for concern, but the difference should be compared with $\frac{6.0}{\sqrt{2}} = 4.2$ because the values of reproducibility (and repeatability) for the means of results are inversely proportional to the square root of the number of tests used to derive the mean. It can be seen that the difference slightly exceeds the reproducibility figure calculated above and hence further investigation is necessary to establish the cause of the discrepancy. This could be the 1 in 20 case, the sample subdivision may not have produced identical subsamples or the results produced by the second laboratory may not be correct. Where a check of the apparatus and procedure does not reveal anything incorrect it is recommended that further co-operative tests be arranged with additional laboratories.

* Based on the 1967 revision of the test; modifications in the present revision should lower these figures.

BSI publications referred to in this standard

This standard makes reference to the following British Standards:

BS 413 Test sieves
BS 427 Method for Vickers hardness test
BS 812 Testing aggregates
Part 101 Guide to sampling and testing aggregates*
Part 102 Methods for sampling
Part 1 Methods for determination of particle size and shape*
Part 2 Methods for determination of physical properties*
Part 4 Methods for determination of chemical properties*
BS 903 Methods of testing vulcanized rubber
Part A8 Determination of rebound resilience
Part A26 Determination of hardness
BS 915 High alumina cement
BS 1610 Methods for the load verification of testing machines
BS 2719 Methods of use and calibration of pocket type rubber hardness meters
BS 2846 The reduction and presentation of experimental results
BS 5497 Precision of test method
Part 1 Guide for the determination of repeatability and reproducibility for a standard test method

* Referred to in the foreword only.

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1. Scope

This Part of this standard covers the determination of the amount of water soluble chloride salts in the aggregate. Tests for other chemical properties of aggregates may be covered in due course.

2. References

The titles of the standards publications referred to in this standard are listed on page 3.

3. Chloride content

3.1 Principle. This test is a method of measuring the amount of water soluble chloride salts present in an aggregate. The chlorides are expressed in terms of equivalent sodium chloride and reported as the chloride salt content. The method is based on that of V/where an excess of silver nitrate solution is added to the chloride solution and the unreacted portion is back titrated with standard potassium thiocyanate, using ferric ammonium sulphate as an indicator,

3.2 Sampling. The sample for this test shall be taken and submitted in accordance with clause 5 of Part 1 : 1975 of this standard. Where the aggregate to be tested carries surface water the salts will normally be dissolved in both this and the absorbed water and hence the salt content will be affected by migration of water through the bulk materials. Great care shall be taken to ensure that the sample is representative of the moisture content. as well as the solids, by preventing loss of moisture, except through evaporation, through the sampling procedure and at any subsequent stage up to the point of test.

NOTE. It is recommended thet when this determination is applied in practice further consideration should be given to the place and time of sampling the aggregate in question, so that the results will be meaningful for the particular purpose.

3.3 Apparatus. The following apparatus is required.

3.3.1 A *balance* capable of weighing to 1 kg, accurate to 0.1 g.

3.2 A *balance* capable of weighing 100 g, accurate to 0.1 g.

3.3 *Two 1000 ml volumetric flasks.*

3.3.4 *A 10 ml graduated measuring cylinder.*

3.3.5 A 500 ml graduated measuring cylinder.

3.3.6 A 100 ml pipette.

3.3.7 *A 25 ml pipette.*

3.3.6 Two 50 ml burettes.

3.3.9 Conical flasks, 250 ml capacity. At least four are recommended.

3.3.10 A wash *bottle* containing distilled water.

3.3.11 An *amber-coloured glass reagen t bottle.*

3.3.12 *Three plastics bottles.* wide mouth, with screw tops, 1 litre to 1.25 litre capacity.

3.3.13 A *well-ventilated oven,* capable of being controlled to maintain a temperature of 105 ± 5 °C.

3.3.14 A *funnel and a good quality filter paper* which yields a clear filtrate may be required in a few cases.

3.4 **Reagents.** Use only reagents of recognized analytical reagent grade, and only distilled water or water of equivalent quality.

3.4.1 *Silver nitrate* solution (0.1N). Dry about 20 g of silver nitrate at not more than 110 °C for 1 h to 2 h and allow to cool. Weigh 16.967 g of the dried silver nitrate, dissolve in distilled water and dilute to 1000 ml in a volumetric flask. Store the solution in the amber-coloured glass reegent bottle end protect from prolonged exposure to sunlight.

3.4.2 *Potassium thiocyanate solution (approximately* 0.1N). Dissolve 10.5 g of potassium thiocyanate in distilled water and dilute to 1000 ml in a volumetric flask. Standardize the solution according to 3.6; it will be a little stronger than 0.1 N,

3.4.3 Nitric acid (approximately 6N). Dilute 100 ml of nitric acid (70 % HNO_3 1.42 g/ml) with distilled water to 250 ml. Boil the diluted acid until it is colourless.

3.4.4 3,5,5 Trimethylhexan-1-ol.

3.4.5 *ferric alum indicator solution.* A cold saturated solution of ferric ammonium sulphate in water (about 40 %I to which a few drops of 6N nitric acid have been added.

3.6 Standardiution of the potassium thiocyrnate solution. Pipette 25 ml of 0.1N silver nitrate solution into a 260 ml conical flask and add 5 ml of 6N nitric acid and 1 ml of ferric alum indicator solution. Then add potassium thiocyanate solution from a burette until the first permanent colour change occurs, that is from colourless to pale brown. Note the volume of potassium thiocyanate solution added and calculate the normality of the solution from the following equation.

$$T = \frac{2.5}{V_1}$$

where

T is the normality of potassium thiocyanate solution

V_1 is the volume of potassium thiocyanate added (ml)

3.6 **Subsamples** for **test.** Three representative subsamples shall be obtained from the sample received et the laboratory by preparing the sample for reduction by quartering in accordance with 5.2.4(b) of Part 1 : 1975 of this standard and dividing the flattened heap along three radii to produce three equal parts. Each part shall then, separately, be reduced either by using a sample divider or by quartering, all in accordance with 5.24 of Part 1 : 1976 of this standard, taking care to avoid loss of moisture, except through evaporation. The mass of each of these three subsamples shall be about 0.5 kg for fine aggregate and 1 kg for coarse aggregate and all-in aggregate. Each subsample shall be dried by heating at atemperature not exceeding 110 °C.

3.7 Procedure

3.7.1 Genera/. The chloride salt content shall be determined on each of the three subsamples using the procedures given in 3.7.2 and 3.7.3 as appropriate.

3.7.2 *fine aggregate.* Place a known mass *(ml* of about 500 g of the dry subsample in the wide mouth, screw topped plastics bottle. Add 500 ml of distilled water and allow to stand for 24 h, with occasional shaking. Take one 100 ml portion *of* the supernatent liquid by means of the pipette and transfor to the 250 ml conical flask.

NOTE. If the supernatant liquid is discoloured by suspended silt or clay it should be filtered before the portion is taken.

Add 6 ml of 6N nitric acid to the flask followed by 0.1N silver nitrate solution from a burette until all the chloride has been precipitated and then add 10 ml in excess. Note the total volume (V_1) of silver nitrate solution added.

Add 2 ml of 3,5,5 trimethylhexan-1-ol and agitate the solution vigorously to coagulate the precipitate. Add 6 ml of the ferric alum indicator solution followed by the standardized potassium thiocyanate solution from a burette until the first permanent colour change occurs, that is from colourless to pale brown. Note the volume (V_2) of potassium thiocyanrte solution added.

3.7.3 *Coarse aggregate and all-in aggregate.* The procedure shall be the same as that for fine aggregate except that the mass of the dry subsample shall be about 1 kg.

3.8 Calculation. The chloride salts shall be expressed as the equivalent sodium chloride content and shall be calculated from the following equation.

$$C = (V_1 - 10\,V_2 T)\,\frac{2.925}{m}$$

where

C is the chloride salts as a percentage by mass of the dry aggregate

V_1 is the volume of 0.1N silver nitrate solution added (ml)

V_2 is the volume of strndardized potassium thiocyanate solution added (ml)

T is the normality of the standardized potassium thiocyanate solution

m is the mass of the subsample(g)

3.0 **Reporting of results.** The average of the three determinations shall be reported as the chloride salt content to the nearest 0.01 % together with the individual results obtained.

Normality = 0.1011

Standards publications referred-to

BS 812 Methods for sampling and tasting of mineral aggregates, sands and fillers
Part 1 Sampling, size, shape and dessificrtion
Part 2 Physical properties
Part 3 Mechanical properties