British Standard

BRITISH STANDARD

BS 598-107: 1990

Incorporating Amendments Nos. 1, 2 and 3

Sampling and examination of bituminous mixtures for roads and other paved areas —

Part 107: Method of test for the determination of the composition of design wearing course rolled asphalt

ICS: 93.080.20

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Road Engineering Standards Policy Committee (RDB/-) to Technical Committee RDB/36 upon which the following bodies were represented:

British Aggregate Construction Materials Industries
British Civil Engineering Test Equipment Manufacturers' Association
British Tar Industry Association
County Surveyor's Society
Department of the Environment (Property Services Agency)
Department of Transport (Highways)
Department of Transport (Transport and Road Research Laboratory)
Institute of Asphalt Technology
Institute of Petroleum
Institution of Civil Engineers
Institution of Highways and Transportation
Mastic Asphalt Council and Employers' Federation
Mastic Asphalt Producers' Association
Refined Bitumen Association Ltd.
Sand and Gravel Association Ltd.
Society of Chemical Industry
Coopted members

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Contents

Foreword

This part of BS 598 has been prepared under the direction of Technical Committee B/510.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriate qualified and experienced people.

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

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 18, an inside back cover and a back cover.

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Sidelining in this document indicates the most recent changes by amendment.

1 Scope

This part of BS 598 describes a method for the determination of the composition of design wearing course rolled asphalt.

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

2 Definitions

For the purposes of this part of BS 598 the definitions given in BS 6100 apply together with the following.

NOTE These definitions apply specifically to the design method.

2.1
stability

the maximum resistance to deformation in newtons of a moulded asphalt specimen

2.2
flow

the deformation of the moulded specimen in millimetres at the point of maximum resistance

2.3
mix density

the mass of asphalt mixture per unit volume of the compacted specimen

2.4
design binder content

the binder content of an asphalt mixture

3 General

Aggregate compositions suitable for wearing course rolled asphalt that is to be specified by the design method are given in Table 3 and Table 4 of BS 594-1:1985. This part of BS 598 describes the procedure to be followed when deciding a suitable binder content for a chosen aggregate composition. The appropriate binder content will differ, for any particular grading of aggregate, according to the nature and source of the aggregate, hence the need for a design procedure, particularly if an unfamiliar aggregate source is to be used.

It has to be emphasized that the design procedure is not simple and takes time. At least three consecutive working days are needed to carry out the procedure properly, and great care and attention to detail are essential if a reliable result is to be obtained. Precise conformity to all the requirements for apparatus and procedure will give a binder content that can be used with confidence in specification; other equipment and the use of short cuts and variation in procedure will almost certainly give misleading results.

The procedure gives a binder content, called the design binder content, which is a compromise between the conflicting needs of stability, durability and workability.

The method involves the determination of a binder content of the complete mix using Marshall test equipment. Specimens for test are made with the aggregate required for use in the plant mix and with a range of binder contents using the grade of binder proposed for the actual job. Marshall stability, flow and densities are determined by defined procedures which also permit the calculation of other properties.

Appendix B of BS 594-1:1985 gives advice on the application of test data obtained from the design procedure for deciding the best composition of wearing course asphalt for a given site. Suggestions are also given in the same appendix on the verification procedure to be adopted.

4 Apparatus

NOTE All dimensions are nominal unless tolerances are given.

4.1 *Balance,* of not less than 2 kg capacity, accurate to 0.1 g.

NOTE A second balance, accurate to 0.5 g, is convenient for proportioning aggregates, filler and binder.

4.2 *Oven,* complying with appendix A with fan assisted air circulation, fitted with thermostatic control to maintain temperature in the range 80 °C to 200 °C.

NOTE Two ovens may be found to be convenient. Aggregates, moulds and steel blocks may be heated in one oven and binder in a smaller oven with a time switch controller.

4.3 *Mechanical mixing unit,* of not more than 8 L capacity, capable of combining 1 500 g of aggregate, filler and binder speedily and thoroughly without loss.

NOTE A mechanical mixer with detachable mixing bowl and accurately controlled heating element capable of maintaining the bowl at the required temperature is suitable. A wire whisk of adequate strength is normally found most suitable and the design illustrated has been found to be satisfactory for planetary mixers.

4.4 *Whisk,* of a suitable design such as that shown in Figure 1.

NOTE 1 Alternative designs of the whisk head to that shown in Figure 1 are suitable providing the wire scrapes the bowl sides.

NOTE 2 Since the wire blades wear out quickly, an economical method of obtaining a whisk is to purchase a boss and bayonet fitting as shown and to produce and fit the wires separately.

4.5 *Steel mould cylinders,* with a 101.6 ± 0.1 mm internal diameter, complete with mould bases and extension collars as shown in Figure 2, sufficient in number to enable the work to continue as required.

4.6 *Steel compaction hammer,* of total mass 7 850 ± 50 g including a sliding weight of 4 535 ± 25 g with a free fall of 457 ± 5 mm that acts upon the foot assembly as shown in Figure 3. The apparatus shown in Figure 2 is suitable for hand compaction. The foot assembly shall comprise a spring housing and a helical compression spring of hardened and tempered steel with a load rate of 10 N/mm to 18 N/mm and designed to exert a preload of 80 N to 150 N when confined within the foot assembly leaving a minimum movement of 20 mm. The foot of the hammer shall be machined flat and smooth and be securely fixed to the foot assembly.

4.7 *Automatic compactor*, the mass, free fall and design of the complete hammer foot assembly being as specified in **4.6**. The operating mechanism shall not be supported by the laminated hardwood block of the compaction pedestal. The free fall height shall be measured when the machine is in operation and be capable of being maintained within the specified tolerances throughout the compaction procedure. The automatic mechanism shall be capable of applying 50 blows at the rate of 60 ± 5 blows per minute.

NOTE The use of an automatic compactor is recommended particularly in cases of dispute.

4.8 *Steel block*, of 100 mm diameter by not less than 50 mm high. This is used for the initial heating of the compaction hammer.

NOTE The use of more than one block may be advantageous.

4.9 *Compaction pedestal*, as shown in Figure 4 and consisting of the following.

a) *Vibrated concrete base*, of minimum density 2 200 kg/m^3 and minimum dimensions 450 mm × 450 mm × 200 mm with a shoulder to receive a laminated hardwood block.

b) *Laminated hardwood block*, 200 ± 4 mm × 200 ± 4 mm in cross-section and 450 ± 4 mm in height, made from straight-grained, seasoned timber (such as sapele) free from shakes, splits and knots with a density of 560 kg/m^3 to 720 kg/m^3 at a moisture content of 8 % to 10 %. The block shall be built up of between six and ten approximately equal laminations of quarter sawn board bonded with waterproof resin glue. The ends shall be smooth and normal to the vertical axis and the block shall be treated with a water-resistant impregnant and varnished to minimize changes of moisture content.

c) *Mild steel plate*, 300 ± 5 mm × 300 ± 5 mm × 25 ± 1 mm fitted with a positive location to receive the hardwood block and with a mould assembly holder to secure the mould assembly centrally on the pedestal during compaction and a guide to ensure that the hammer is maintained in a truly vertical position throughout compaction. The mild steel plate with assembly holder and guide shall be secured to the base with four tie rods each tensioned to the equivalent of a torque of 10 ± 1 N·m on an M10 thread.

NOTE The compaction pedestal plays an important part in the compaction of specimens and it is essential that it conforms with the detailed description.

4.10 *Extractor*, of suitable design to eject the specimens from the moulds without distortion or shock to the specimens.

4.11 *Water bath*, fitted with thermostatic control to maintain the temperature at 60 ± 0.5 °C, with a tray or trays and deep enough to allow at least 25 mm depth of water above and below the specimens. It shall be made so that the specimens can be placed flat face down and not in contact with one another. The bath shall be fitted with one or more pumps, impellers or stirring devices to ensure a continuous circulation of water around the specimens.

NOTE It is recommended that the water bath be large enough to hold a minimum of 15 specimens.

4.12 *Steel or cast iron testing head*, as shown in Figure 5, having segments machined to an inner radius of 50.8 ± 0.05 mm.

4.13 *Compression testing machine*, having a minimum capacity of 22 kN and capable of applying a constant rate of strain to the specimens of 50 ± 3 mm/min under all loading conditions. The load measurement device shall be calibrated in accordance with BS 1377-1 or BS 1610-1.

Means of measuring flows of up to 10 mm with an accuracy of ± 0.1 mm and of indicating the maximum load and flow achieved during the test shall be provided.

NOTE Methods by which the test data can be retained as a printed or graphical display are preferred. Any such device should be capable of recording load to an accuracy of grade B of BS 1610 and flow to an accuracy of ± 0.1 mm.

4.14 *Riffle box*, of sufficient size to blend samples of aggregates prior to weighing out to ensure representative sampling (see clause **6**).

4.15 *Cans, containers and trays,* comprising binder cans fitted with lids, aggregate containers and trays of adequate capacity.

4.16 *Silicone grease.* A grease to Ministry of Defence Standard 50-10[1)] is suitable.

4.17 *Spatulas*, as follow:

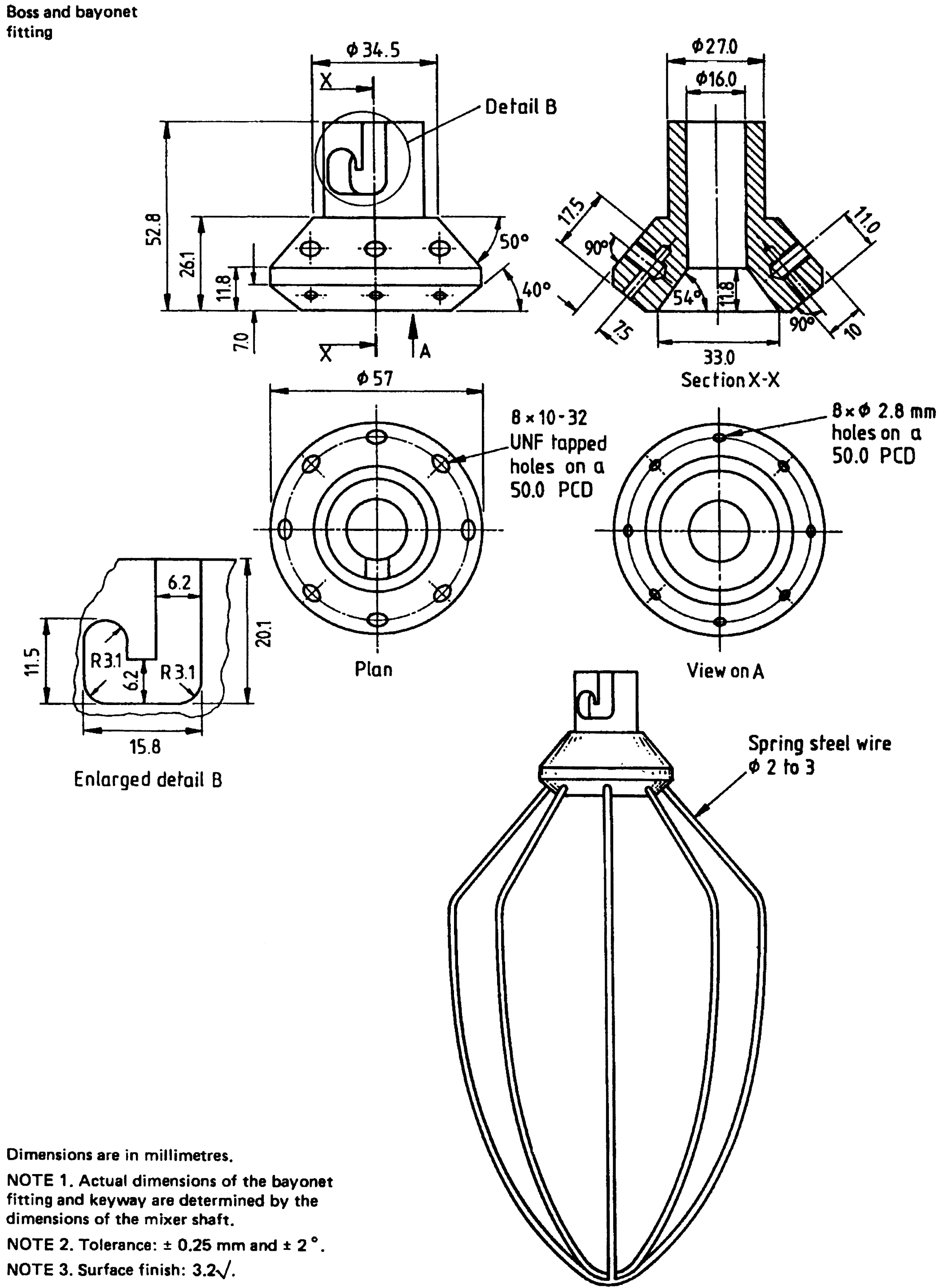
size 1: with blade approximately 150 mm long × 25 mm wide

size 2: with blade approximately 200 mm long × 32 mm wide.

4.18 *Sieves*, having apertures of 2.36 mm and 75 µm and complying with BS 410.

4.19 *Heat-resistant gloves.*

[1)] MOD standard 59-10 "Insulating and filling compounds (insulating compound, electric/silicon grease type)" published by Directorate of Standardization, Ministry of Defence, London.



Dimensions are in millimetres.

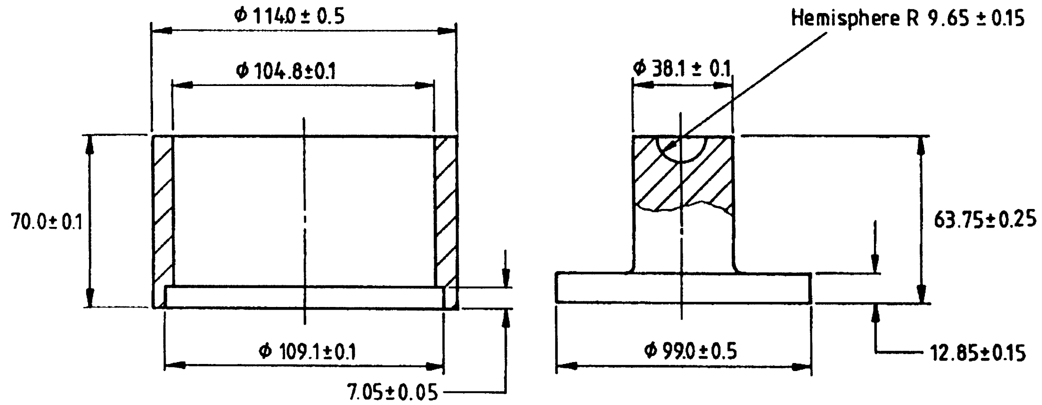
NOTE 1. Actual dimensions of the bayonet fitting and keyway are determined by the dimensions of the mixer shaft.

NOTE 2. Tolerance: ± 0.25 mm and ± 2 °.

NOTE 3. Surface finish: $3.2\surd$.

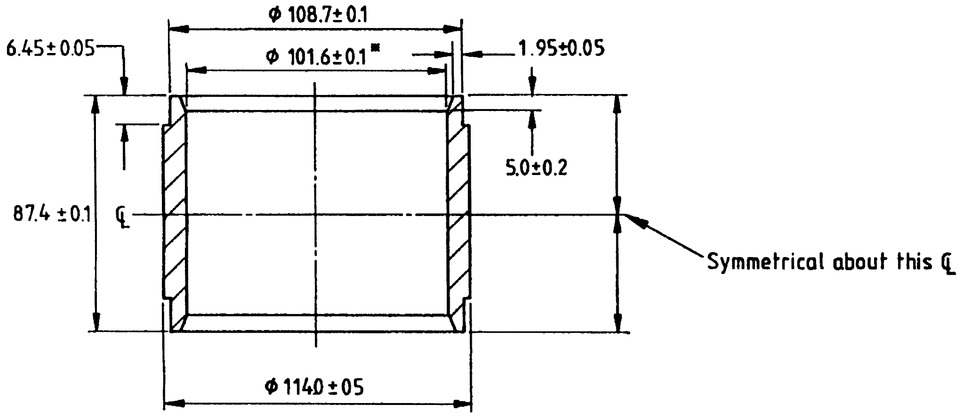
NOTE 4. Complete assembly to consist of the details shown plus 8 No 10 - 32 UNF X 12.7 mm long fully threaded socket cap screws.

Figure 1 — Suitable design of whisk for a planetary mixing unit

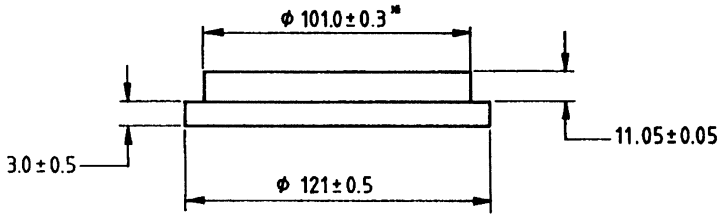


Extension/extraction collar

Extraction plate



Mould cylinder



Mould base

Dimensions are in millimetres.
*Essential dimensions.

NOTE. This design has been found satisfactory. Alternative designs are acceptable providing the essential dimensions are complied with and the mould does not distort during compaction.

Figure 2 — Suitable design of compaction equipment

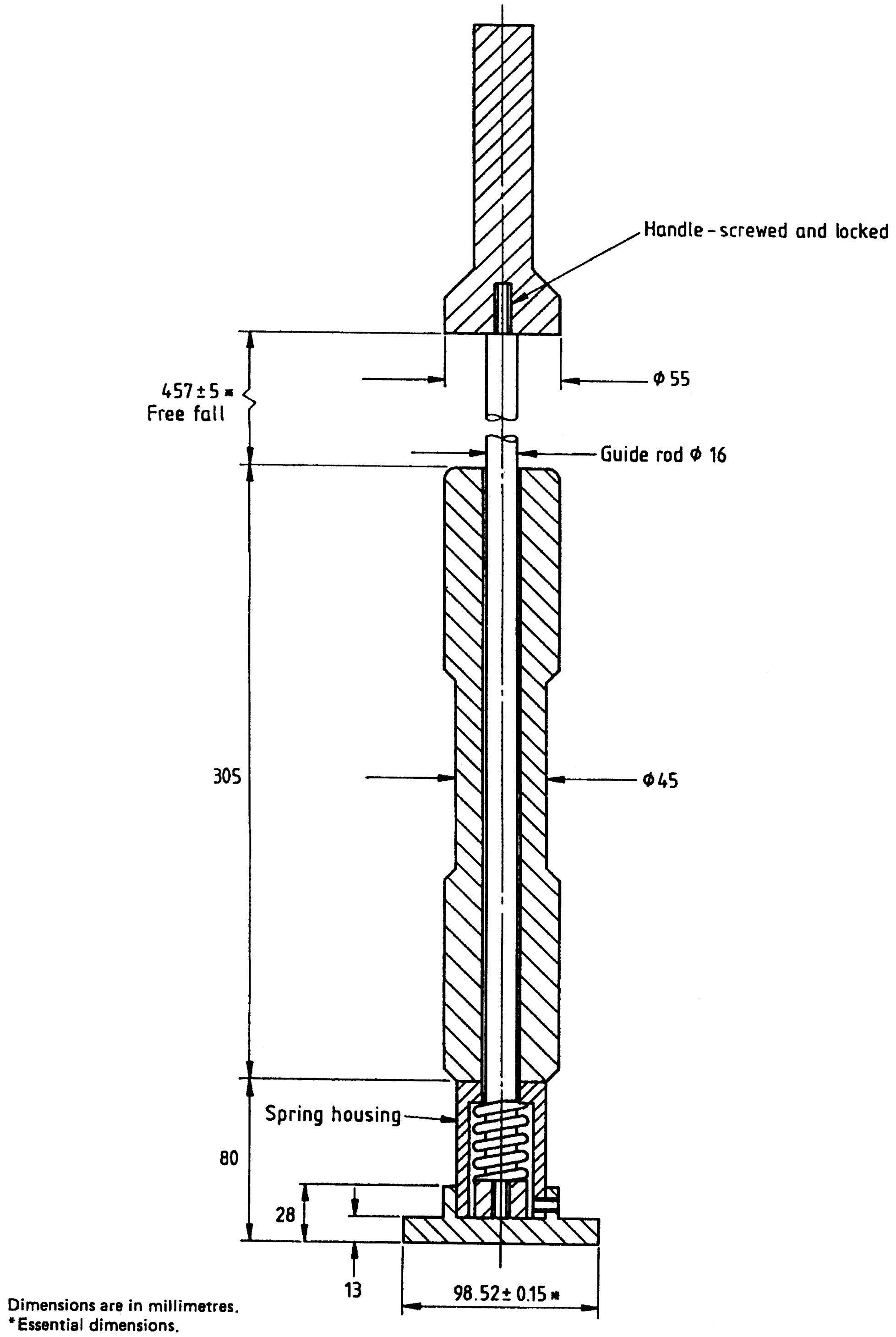
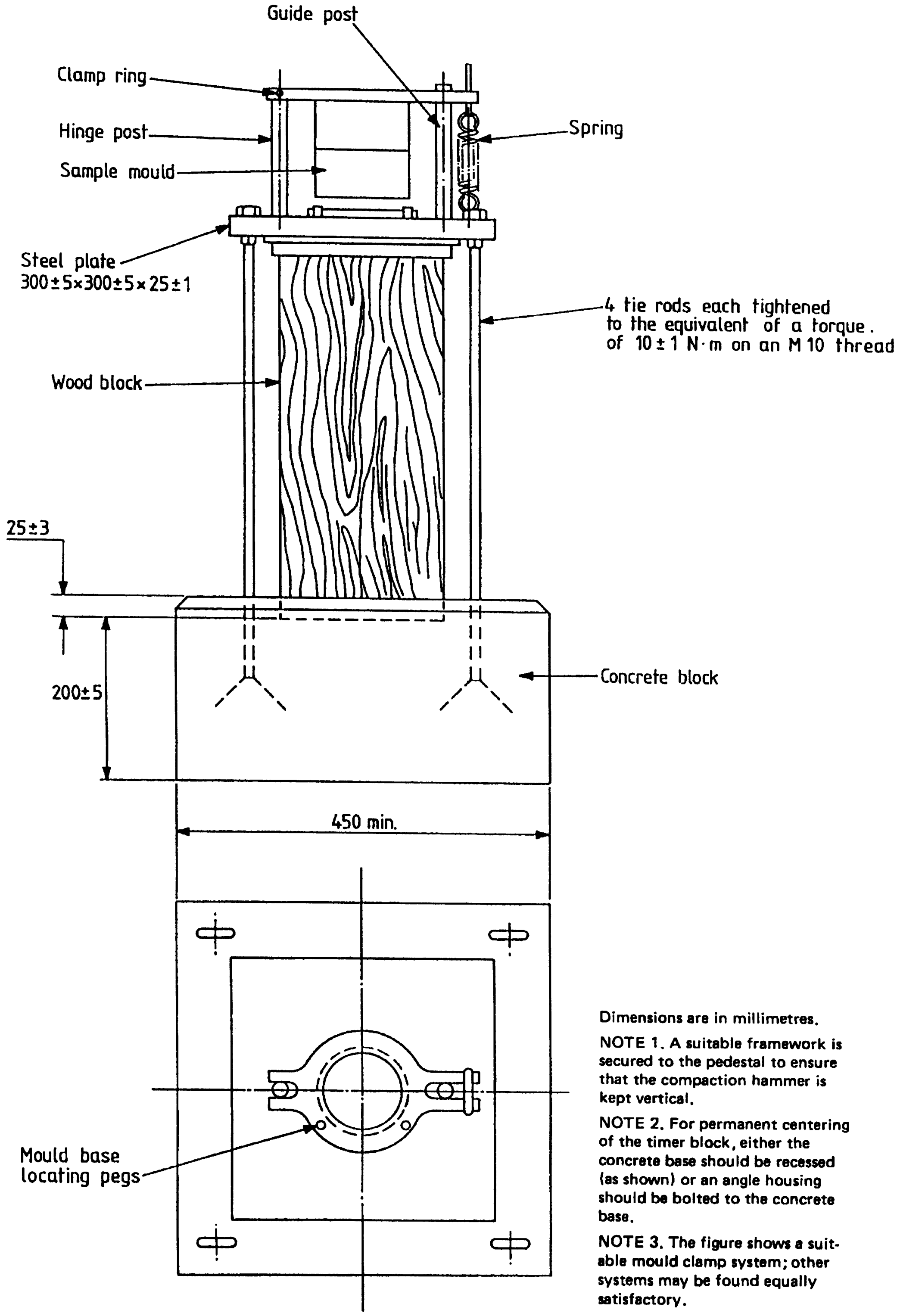


Figure 3 — Hand compaction hammer



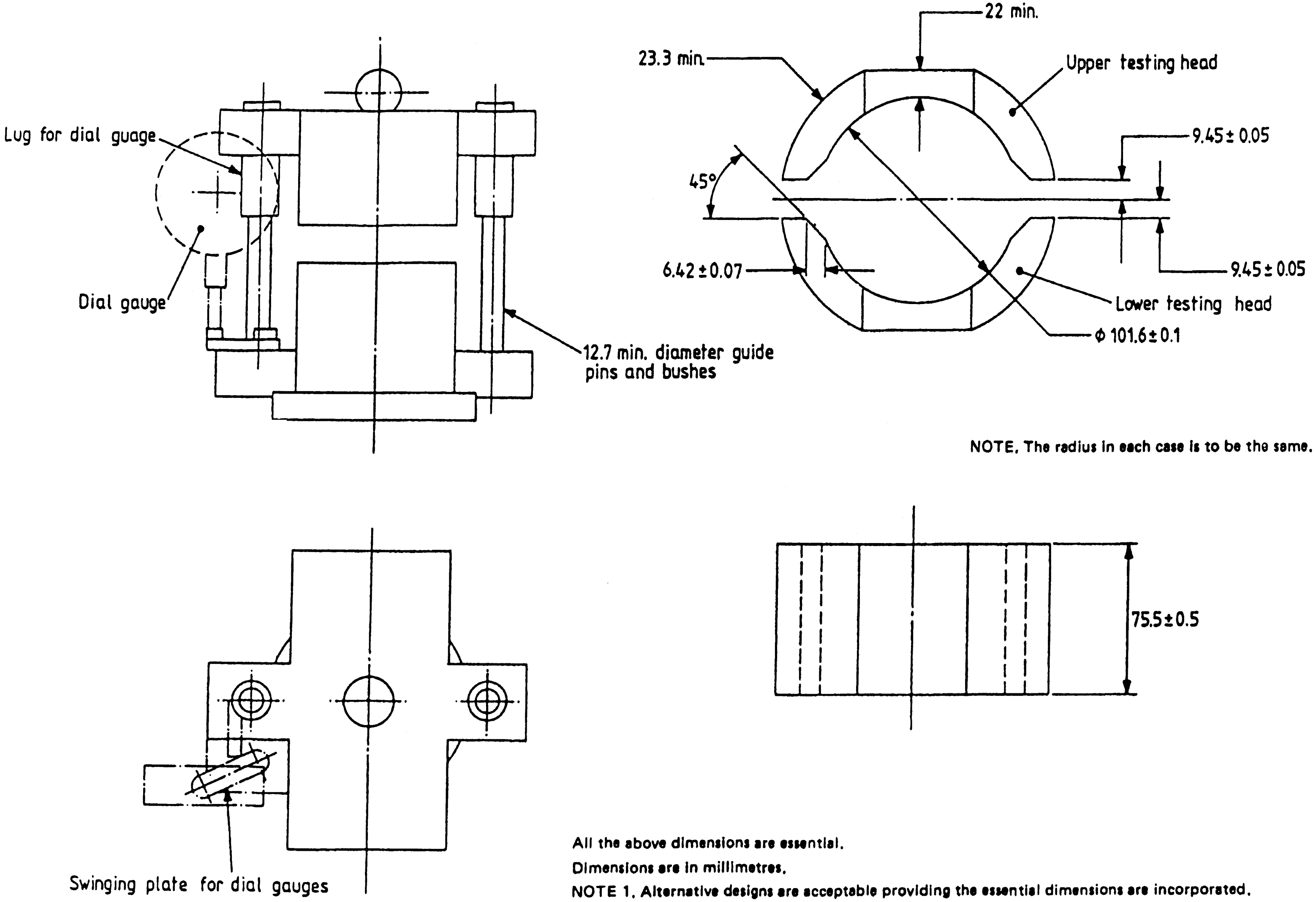
Dimensions are in millimetres.

NOTE 1. A suitable framework is secured to the pedestal to ensure that the compaction hammer is kept vertical.

NOTE 2. For permanent centering of the timer block, either the concrete base should be recessed (as shown) or an angle housing should be bolted to the concrete base.

NOTE 3. The figure shows a suitable mould clamp system; other systems may be found equally satisfactory.

Figure 4 — Compaction pedestal



All the above dimensions are essential.

Dimensions are in millimetres.

NOTE 1. Alternative designs are acceptable providing the essential dimensions are incorporated.

NOTE 2. Maximum mass of the upper platen assembly is 7500 g.

NOTE 3. An easy means of locating the testing head centrally on the machine platen is to be provided.

Figure 5 — Testing head

5 Preliminary test procedures on constituent materials

5.1 Sampling

Take representative samples of the coarse aggregate, fine aggregate and filler, sufficient to carry out the required tests and to make the requisite specimens for test in accordance with the methods described in BS 812-102. Take sufficient of the binder to carry out the required tests and to make the requisite specimens in accordance with the method for sampling described in BS 3690-1.

5.2 Testing

Carry out the following test. Conduct the tests on the coarse aggregate, fine aggregate and filler in accordance with BS 812. Carry out the tests shown as optional only if the additional information covered by appendix B of BS 594-1:1985 is to be obtained.

NOTE 1 If the constituent aggregates are received in the form of combined coarse and fine aggregate then they should be split on a 2.36 mm sieve before carrying out the sieve analysis.

NOTE 2 In some cases the information can be obtained from tests necessary to determine the compliance of the constituents with the requirements of the standard.

a) *Coarse aggregate*

  1) sieve analysis;

  2) relative density on an oven-dried basis (optional);

  3) apparent relative density (optional);

  4) water absorption (optional);

b) *Fine aggregate*

  1) Sieve analysis: determination of the material passing the 75 μm test sieve in accordance with BS 812-103.1:1985.

  2) Apparent relative density (optional).

  NOTE The use of apparent relative density gives more reproducible results than relative density on an oven-dried basis but the value of void content of the mix calculated from this density is slightly higher.

c) *Filler*

  1) sieve analysis (by wet sieving);

  2) relative density (optional).

d) *Binder*

  1) penetration at 25 °C in accordance with BS 2000-49;

  2) softening point (R and B) in accordance with BS 2000-58;

  3) relative density in accordance with BS 4699 (optional);

  4) ash content of lake asphalt/bitumen blends in accordance with BS 2000-223, if used as the binder.

6 Preparation of constituent materials

Proceed as follows.

a) Keep all the constituent materials separate.

b) Dry the aggregate to constant mass in the oven (**4.2**) controlled to maintain a temperature of 105 ± 5 °C.

c) Blend each aggregate thoroughly and obtain a representative sample by riffling in accordance with BS 812-102.

d) Sieve the coarse aggregate to remove the material passing the 2.36 mm BS test sieve (**4.18**). The portion retained on the sieve is used for the manufacture of specimens for the mix-design procedure.

e) Sieve the fine aggregate to separate the material retained on the 2.36 mm BS test sieve from that passing the sieve to reduce the risk of segregation during sampling. Combine the two portions in the correct proportions (as determined by the sieve analysis on the fine aggregate) for the manufacture of specimens for the mix-design procedure.

f) Proportion the aggregate for each mixing batch, by mass as indicated by columns A, B and C of Table 1 by weighing to the nearest gram a sufficient quantity of each fraction into an aggregate container, so that the overall grading of the combined aggregates complies with Table 3 and Table 4 of BS 594-1:1985.

NOTE 1 If the constituent aggregates have been received in the form of combined coarse and fine aggregate the procedures d) and e) need not be carried out. The combined coarse and fine aggregate should be separated on a 2.36 mm sieve and recombined to provide a grading as described in clause **6**f).

NOTE 2 Gradings which are at or close to the limits given in Table 3 and Table 4 of BS 594-1:1985 may result in reduced tolerances on plant mixes and should, therefore, be avoided.

g) Make up each mixing batch of just sufficient material for one single compacted specimen of 101.6 mm diameter by 63.5 ± 3 mm in height.

NOTE The quantity of aggregate required to make up each mixing batch may be estimated from the results of past experience, calculation or trial mixes. For trial mixes the masses of aggregate given in Table 2 are suggested.

h) Heat the combined aggregate for each mixing batch in the oven (**4.2**) thermostatically controlled to maintain a temperature of 110 ± 3 °C above the softening point (R and B) of the binder used for the manufacture of the specimens, for a minimum of 4 h.

i) Heat the binder in bulk to a temperature between 75 °C and 100 °C above the softening point to enable it to be stirred and then pour in to a number of small cans and cover (**4.15**).

j) Heat the binder in loosely covered small cans to a temperature of 110 ± 3 °C above its softening point (R and B). Reject all binder not used after 8 h at that temperature. Do not reheat the binder.

Table 1 — Aggregate proportions for mix-design procedure

Nominal content of coarse aggregate: % by mass of total mix	Coarse aggregate retained on a 2.36 mm BS test sieve: % by mass of total aggregate, A^a	Fine aggregate passing a 2.36 mm and retained on a 75µm BS test sieve: % by mass of total aggregate (wet sieving), B^a	Material passing a 75 µm BS test sieve: % by mass of total aggregate, C^a
0	0	85.0	15.0
30	34.0	56.0	10.0
35	39.0	52.0	9.0
55	59.0	35.0	6.0

NOTE 1 When the binder is refined bitumen, calculate the proportion of the constituents shown in the table from the following equations:

$$Y = \frac{100(100L - 100C - LA)}{(100L - 100H - KL)}$$

$$Z = \frac{100C - HY}{L}$$

$$X = 100 - Y - Z$$

where

A is the percentage by mass of coarse aggregate given for A appropriate to the nominal content of coarse aggregate selected;

C is the percentage by mass of material passing a 75 µm BS test sieve given for C appropriate to the nominal content of coarse aggregate selected;

X is the percentage by mass of coarse aggregate retained on a 2.36 mm BS test sieve;

Y is the percentage by mass of fine aggregate containing H % by a mass of Y of material passing a 75 µm BS test sieve and K % by mass of Y material retained on a 2.36 mm BS test sieve;

Z is the total percentage by mass of filler containing L % by mass of Z of material passing a 75 µm BS test sieve.

NOTE 2 When the binder is a lake asphalt/bitumen blend it is necessary to allow for the mineral matter in the lake asphalt as given in Table 3. It is essential to ensure that the ash content of the lake asphalt/bitumen complies with the requirements given in Table 5 of BS 3690-3:1983, i.e. 16 % to 19 %, if the values for the calculation of the proportions indicated in columns 3, 4 and 5 of Table 3 are to be applicable. Calculate the proportions of aggregate in the mixture for each binder from the following equations;

$$Y = \frac{100(100E - 100C + BL + CL - DL - EL)}{(100L - 100H - KL)}$$

$$X = \frac{100A - KY}{100}$$

$$Z = 100 - X - Y - D - E$$

where

B is the percentage by mass of fine aggregate given for B appropriate to the nominal content of coarse aggregate selected;

D and E are as given in Table 3.

Example. A rolled asphalt with a nominal stone content of 30 % is to be designed with a fine aggregate having 3.6 % of material retained on a 2.36 mm BS test sieve and 2.7 % passing a 75 µm BS test sieve. The filler contains 88 % of material passing a 75 µm BS test sieve.

$$Y = 100\ \frac{(100 \times 88 - 100 \times 10.0 - 88 \times 34)}{(100 \times 88 - 100 \times 2.7 - 3.6 \times 88)} = 58.5$$

$$Z = \frac{(100 \times 10.0) - (2.7 \times 58.5)}{88} = 9.6$$

$$X = 100 - 58.5 - 9.6 = 31.9$$

[a] These percentages are derived from the appropriate columns of Tables 3, 4, 5 and 6 of BS 594-1:1992, as amended by Amendment No. 1.

Table 2 — Mass of aggregate for trial mixes

Nominal content of coarse aggregate: % by mass	Mass of aggregate in each specimen
	g
0	980
30	1 080
35	1 090
55	1 140

7 Mixing and compaction

7.1 General

Proceed as follows.

a) Mix and compact three specimens for each binder content. Sufficient mixes to cover the desired range of binder contents necessary to determine the optimum are required, including at least nine binder contents at intervals of 0.5 % of total mix with at least three binder contents on each side of the optimum value. Table 3 gives the mass of binder to be added to each 100 g of aggregate to produce these required intervals of binder content.

b) Mix and compact the specimens in progressively increasing or decreasing order of binder content.

NOTE If there is no past experience or other information available for the aggregates to be employed, the binder contents given in Table 4 are suggested as the middle of the range to be tested. In this case it may be necessary to test more than nine binder contents.

c) Make a group of three specimens consecutively, with each containing the same content of binder, so that the interval of binder content between each group of three specimens shall be 0.5 % by mass of the total mix.

d) Complete the total time of manufacture, from the start of mixing of the first specimen to the finish of compaction of the last specimen in less than 8 consecutive hours.

Table 3 — Binder proportions required for mix-design procedure

1	2	3	4	5
Binder content: % by mass of total mix, M[a]	Mass of bitumen or pitch/bitumen to be added to 100 g of aggregate, N[a]	Mass of 50 : 50 lake asphalt/bitumen to give the same soluble binder as N in column 2, P[a]	Amount of material retained on a 75 µm BS sieve but passing a 2.36 mm BS sieve in TLA/bitumen, D	Amount of material passing a 75 µm BS sieve in lake asphalt/ bitumen, E
%	g	g	g	g
4.0	4.2	5.4	0.2	1.0
4.5	4.7	6.1	0.3	1.1
5.0	5.3	6.8	0.3	1.2
5.5	5.8	7.6	0.4	1.4
6.0	6.4	8.3	0.4	1.5
6.5	7.0	9.0	0.4	1.6
7.0	7.5	9.8	0.5	1.8
7.5	8.1	10.5	0.5	1.9
8.0	8.7	11.3	0.6	2.0
8.5	9.3	12.1	0.6	2.2
9.0	9.9	12.8	0.6	2.3
9.5	10.5	13.6	0.7	2.4
10.0	11.1	14.4	0.7	2.6
10.5	11.7	15.2	0.8	2.7
11.0	12.4	16.1	0.8	2.9
11.5	13.0	16.9	0.9	3.0
12.0	13.6	17.7	0.9	3.2
12.5	14.3	18.6	1.0	3.3
13.0	14.9	19.4	1.0	3.5

[a] For bitumens or pitch/bitumens $N = 100M/100 — M$ and for 50 : 50 lake asphalt/bitumen blend with a solubility of 77 % $P = 100M/77 - 0.77M$.

Example. For a mix with a nominal stone content of 30 %, 7.0 % soluble binder content (M) and an aggregate mass of 1080 g, the mass of binder N (in g) required for each specimen is 1 080 × 7.5/100 = 81.

Table 4 — Middle of the range binder contents

Nominal content of coarse aggregate: % by mass of total mix	Suggested binder content for middle of range to be tested: % by mass of total mix
0	10
30	7.5
35	7.0
55	5.5

7.2 Mixing procedure

Proceed as follows.

a) Adjust the mixing bowl heater so that the temperature of the mix after it has been transferred to the mould, immediately prior to and without delaying the start of compaction is 92 ± 2 °C above the softening point (R and B) of the binder.

b) Charge the mixing bowl with heated aggregate, mix thoroughly with the spatula size 1 (**4.17**) and form a crater to receive the binder.

c) Stir the heated binder in its container. Weigh by difference the required amount of binder, to the nearest gram, into the mix.

d) Mount the bowl in the mixer, fit the whisk (see Figure 5) and mix for 60 ± 5 s. Using the size 2 spatula (**4.17**), ensure that the material is thoroughly and evenly mixed and any lack of uniformity adjusted with the spatula within the next 60 s.

7.3 Compaction procedures

Proceed as follows.

a) Clean the steel mould cylinders (**4.5**), bases [**4.9**a)], extension collars (**4.5**) and steel blocks (**4.8**) thoroughly and apply about 2 g of silicone-grease releasing agent to the inside surface of the moulds and the top surfaces of the bases; lightly coat the remaining surfaces with silicone grease (**4.16**). Place this equipment in the oven (**4.2**) controlled at a temperature in the range given in clause **6**h) for not less than 1 h prior to use. Heat the hammer foot (**4.6**) by lowering it on to the heated steel block for 5 ± 1 min before the start of the compaction of the first specimen or if the delay between the manufacture of specimens exceeds 10 min.

NOTE The hammer shaft and guides should be cleaned and lightly oiled except for the parts where manufacturers' instructions stipulate otherwise.

b) Place the collar on the mould assembly and place a thin disc of tough, impermeable material such as non-absorbent paper, slightly less than 100 mm diameter, on the mould base prior to filling. This is to prevent adhesion between the specimen and the mould base.

c) Transfer all the mixed material into the mould as quickly as possible.

NOTE A metal funnel to fit the mould, with a mouth about 200 mm in diameter, heated similarly to the mould, facilitates this operation.

d) In order to prevent bridging of aggregate, spade the mixture with the size 1 spatula (**4.17**) 15 times round the perimeter and 10 times over the interior of the mould and form the top of the mixture into a dome.

e) Measure the temperature of the mixture using a thermometer midway between the centre and the wall of the mould. Thermometers with a long response time should be maintained at a temperature approximating to that of the mixed material. The temperature for each specimen tested shall be within the range given in **7.2**a) and shall be recorded. Place a 100 mm diameter paper disc, similar to that used on the base of the mound, on top of the material to prevent adhesion of the material to the face of the hammer.

NOTE The compaction of the moulded specimens (and hence the density and stability) depends critically on temperature and it is essential to ensure that compaction is carried out within the correct temperature range.

f) Transfer the mould assembly to the compaction pedestal and locate it in the mould holder.

g) Apply 50 blows with the compaction hammer at a rate of 60 ± 5 blows per minute.

h) Remove the extension collar, invert the mould assembly and remove the mould base with a twisting action. Replace the mould base on the opposite face of the mould, replace the extension collar and locate the assembly on the compaction pedestal.

NOTE With richer mixes it may be found that a rim of mixed material will squeeze up between the hammer foot and the edge of the mould. This rim should be removed with the size 1 spatula before reversing the mould.

i) Apply the same number of blows as in **7.3**g) to the face of the reversed specimen.

j) Remove the extension collar and discs and immerse the mould with the specimen and the base in cold water for at least 10 min.

NOTE With richer specimens cooling times of up to 30 min may be necessary to avoid distortion. In these cases, the mould bases should be left in position for the full time of cooling.

k) Place the extractor collar on the mould, remove the base and disc. Extrude the cooled specimen with the minimum amount of force from its mould without distortion or shock. Remove burrs on the specimen with the size 1 spatula. Examine each specimen and reject any that have been damaged during extrusion or have obvious defects. Do not use the compaction hammer for demoulding the specimens.

l) Wipe the specimens with an absorbent cloth to remove any surface moisture and store at ambient temperature, flat face down, on a flat surface covered with absorbent paper, until ready for test.

NOTE A check on the height of the first specimens made should be carried out at this stage to ensure that the whole series is within the specified limit.

m) Clean the mould and base and then prepare for re-use by applying a thin film of silicone grease.

8 Procedure for measuring relative density and for calculating compacted aggregate density

Proceed as follows.

a) Weigh the dry specimen in air to an accuracy of 0.1 g.

b) Determine the volume of the specimen in mL by weighing the specimen immersed in water at 20 ± 1 °C to an accuracy of 0.1 g from:

volume of specimen = mass of specimen in air – mass of specimen in water

c) Determine the relative density of the specimen from:

relative density of specimen (S_M) = mass in air/volume of specimen.

d) Calculate the compacted aggregate density (S_A) of the specimen from:

$$S_A = S_M\left(\frac{100 - w_B}{100}\right)$$

where

w_B is the percentage by mass of binder used in the specimen.

9 Procedure for the measurement of stability and flow values

Proceed as follows.

a) Test the compacted specimens after not less than 8 h from the time of manufacture.

b) Immerse the test specimens completely in the water bath (**4.11**) at the test temperature of 60 ± 0.5 °C and maintain at that temperature for not less than 45 min and not more than 75 min.

c) Thoroughly clean the inside surfaces of the testing head and lightly oil the guide rods so that the upper half of the testing head (**4.12**) slides freely over them. At the start of testing a batch of specimens or in the event of a delay of more than 3 min between tests heat the testing head to 60 ± 0.5 °C.

d) Remove the specimen from the water and place it centrally on its side in the lower segment of the testing head. Place the upper half of the testing head on the specimen and place the complete assembly centrally on the testing machine (**4.13**).

e) If measuring equipment connected to a chart is being used, check that the correct range for the expected stability has been selected and that the recorder is zeroed.

f) If dial gauges are used for measurement check and zero the gauge in the proving ring and the gauge used to measure the flow value.

g) Apply the load to the specimen to achieve a constant rate of strain of 50 ± 3 mm/min and record the maximum value of the load applied to the specimen. Also record the movement of the top of the testing head from the instant of application of the load to the point when maximum load is reached. Figure 6 shows the measurement of these stability and flow values when a load cell and chart recorder are used.

h) Complete the entire procedure for a single test, from the removal of the specimen from the water bath to the recording of the readings within 40 s.

i) Clean the inner surfaces of the testing head after testing each specimen with a cloth lightly soaked in white spirit complying with BS 245.

NOTE 1 This procedure depends for its consistency and reliability on a combination of speed and accuracy. Both are equally important, especially when associated with the cooling of heated materials. If the test proceeds satisfactorily there will be no unplanned waiting periods and the whole test procedure will take approximately the same time on each occasion. It is important for good comparison or averaging of results that each stage of the procedure, including the interval between manufacture and testing of the specimens, takes approximately the same interval of time. Small details affect the final result.

NOTE 2 Due to the risks of deformation of test specimens made with the richest mixes it is recommended that these be tested first. All the specimens in the bath are to be tested before further specimens are added to the bath.

NOTE 3 Regular checks should be made to ensure that all the equipment complies with the specification. Particular attention should be paid to temperature, load measuring devices, the shape of the moulds and the testing head.

10 Evaluation of design binder content

10.1 Stability

Determine the maximum load for each test specimen and correct for variations in volume (see clause **8**) by multiplying the stability by the correction factor given in Table 5.

Calculate the mean stability of the three specimens of similar composition and plot the mean values against binder content. Draw a smooth curve through the plotted values and record the binder content for maximum stability to the nearest 0.1% of total mix (see Figure 7). If the stability curve shows more than one peak, choose the value which most closely coincides with the binder content for maximum density of the mix.

10.2 Mix density

Calculate the mean mix density of each of the sets of three specimens of similar composition, plot the mean values against binder content and record the binder content for maximum density (see Figure 7).

Table 5 — Correction factors for stability values with variation in height or volume

Height of specimen	Volume of specimen	Stability correction factor
mm	mL	
60.5	490 to 491	1.08
	492 to 494	1.07
	495 to 497	1.06
	498 to 500	1.05
62	501 to 503	1.04
	504 to 506	1.03
	507 to 509	1.02
	510 to 512	1.01
63.5	513 to 517	1.00
	518 to 520	0.99
	521 to 523	0.98
	524 to 526	0.97
65	527 to 529	0.96
	530 to 532	0.95
	533 to 535	0.94
	536 to 538	0.93
66.5	539 to 540	0.92

Table 6 — Factors for the calculation of design binder content

Coarse aggregate content	Addition factor
%	
0	0
30	0.7
35	0.7
55	0

10.3 Aggregate density

Calculate the mean aggregate density of each of the sets of three specimens of similar composition, plot the mean values against binder content and record the binder content for maximum aggregate density. Where no peak is obtained take the value at which the curve starts to fall away from the horizontal (see Figure 7).

10.4 Flow value

Calculate the mean flow value of each of the sets of the three specimens of similar composition and plot the mean values against binder content (see Figure 7).

10.5 Design binder content

Calculate the design binder content as the mean value of the binder contents determined for maximum stability, maximum mix density and maximum aggregate density with the addition of a factor, dependent on the coarse aggregate content of the mix, as given in Table 6.

11 Reporting

The following information shall be reported:

a) nominal percentage of coarse aggregate;

b) proportioning of coarse aggregate, fine aggregate and filler;

c) overall grading of combined aggregates;

d) binder type, penetration and softening point (R and B);

e) binder content for maximum stability;

f) binder content for maximum mix-density;

g) binder content for maximum aggregate density;

h) mean design soluble binder content;

i) stability at design binder content;

j) flow value at design binder content;

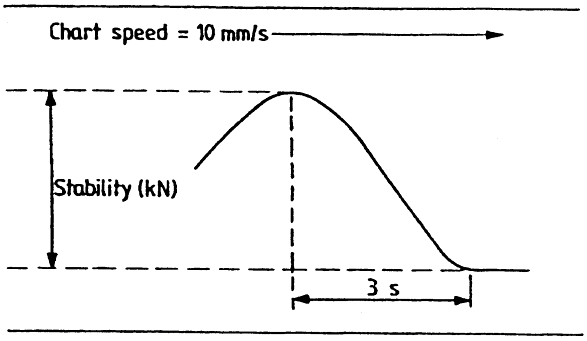
k) graphs of soluble binder content plotted against:

  1) stability;

  2) mix-density;

  3) aggregate density;

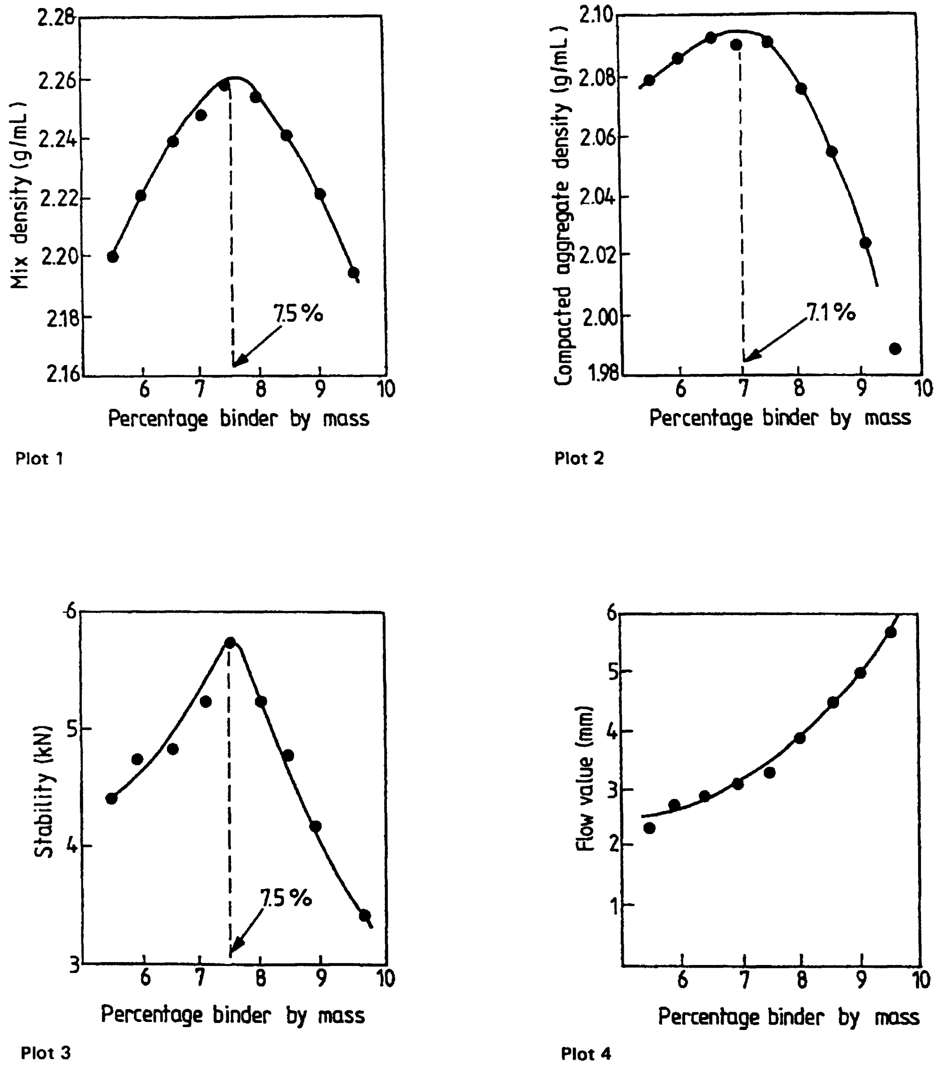
  4) flow value.



For chart recorders, flow value may be calculated from the time to reach maximum stability X rate of compression i.e. 50 mm/min or 0.83 mm/s.

In the example shown in the time is 3 s and hence the flow value is 3 X 0.83 mm = 2.5 mm.

Figure 6 — Example of determination of stability and flow value using a chart recorder and load cell



Plot 1

Plot 2

Plot 3

Plot 4

NOTE 1. The plotted points through which the curves are drawn are averages of three specimens for each binder percentage.

NOTE 2. Plot 4 is not used in the calculation of design binder content but see clause **11**(j).

Example calculation

The optimum binder content for mix density from plot 1 = 7.5 %.
The optimum binder content for compacted aggregate density from plot 2 = 7.1 %.
The optimum binder content for stability from plot 3 = 7.5 %.

The mean of the three optima $\frac{7.5 + 7.1 + 7.5}{3} = 7.4$ % to which is added the appropriate factor from table 6 to arrive at the design binder content.

Figure 7 — Example of mixture design

Appendix A Calibration and checking of oven

A.1 General

A.1.1 The temperature profile of an empty oven shall be verified before first use and after any major repair or replacement of heater elements and/or thermostat.

A.1.2 The set temperature at the mid-point of the usable oven space of an empty oven shall be verified by means of a calibrated temperature measuring device at least once a year.

A.2 Verification of oven profile

A.2.1 Eight calibrated temperature measuring devices shall be used in conjunction with a mid-point device.

A.2.2 Place four temperature measuring devices in the upper one-third of the oven space and four in the lower one-third of the oven space. Each of the devices shall be placed at least 75 mm from the sides of the oven chamber and adequately spaced apart.

A.2.3 The mid-point measuring device shall be placed at the approximate centre of the oven chamber.

A.3 Temperature readings

A.3.1 The temperature recorded at each of the 8 points shall be within ± 5 °C of the verified set temperature as measured at the mid-point of the usable oven space.

A.4 Thermometry

A.4.1 Thermometers/thermocouples shall be calibrated against a reference thermocouple, platinum resistance or reference mercury-in-glass thermometer at least every 6 months.

A.4.2 Reference thermocouples or platinum resistance thermometers shall be re-calibrated at least once every 2 years and reference mercury-in-glass thermometers at least once every 5 years.

blank

Publications referred to

BS 245, *Specification for mineral solvents (white spirit and related hydrocarbon solvents) for paints and other purposes.*

BS 410, *Specification for test sieves.*

BS 594, *Hot rolled asphalt for roads and other paved areas.*

BS 594-1, *Specification for constituent materials and asphalt mixtures.*

BS 812, *Testing aggregates.*

BS 812-102, *Methods for sampling.*

BS 812-103, *Method for determination of particle size distribution.*

BS 812-103.1, *Sieve tests.*

BS 1377, *Methods of test for soils for civil engineering purposes.*

BS 1377-1, *General requirements and sample preparation.*

BS 1610-1, *Specification for the grading of the forces applied by materials testing machines.*

BS 2000, *Methods of test for petroleum and its products.*

BS 2000-49, *Penetration of bituminous materials.*

BS 2000-58, *Softening point of bitumen (ring and ball).*

BS 2000-223, *Ash from petroleum products containing mineral matter.*

BS 3690, *Bitumens for building and civil engineering.*

BS 3690-1, *Specification for bitumens for road purposes.*

BS 3690-3, *Specification for bitumen mixtures.*

BS 4699, *Methods for determination of density or relative density of petroleum and petroleum products (pyknometer methods).*

BS 6100, *Glossary of building and civil engineering terms.*

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