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Methods of testing cement —

Part 3: Physical tests —

Section 3.4 Strength tests

IMPORTANT NOTE It is recommended that this Section be read in conjunction with the information in the "General Introduction" to BS 4550 and with the information in BS 4550-3.1, which are both issued separately.

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Summary of pages

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This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1 Compressive strength of concrete cubes

1.1 Test principle. The strength of cement is determined by compressive strength tests on 100 mm concrete cubes, made with specified coarse and fine aggregates, mixed by machine and compacted manually with a compacting bar.

1.3 Apparatus. The following apparatus is required.

1.3.1 *Moulds.* The moulds shall be of 100 mm cube size complying with **3.1** of BS 1881-108:1983.

1.3.1.1 *Size.* The moulds shall be 100 mm cubes.

1.3.1.2 *Construction.* The mould shall be of ferrous metal (preferably cast iron or cast steel) and rigid enough to prevent distortion. The surface hardness of each internal face shall be at least 95 Rockwell (Scale B) hardness value. It shall be constructed in such a manner that it facilitates the removal of the moulded specimen without damage. The parts of the mould, when assembled, shall be positively and rigidly held together by suitable means, both during the filling and on subsequent handling of the filled mould.

Each mould shall be provided with a steel base plate which shall be rigidly attached to the mould and shall support it without leakage or distortion.

1.3.1.3 *Tolerances.* The mould shall be such that, when assembled ready for use, the dimensions and internal faces are accurate within the following limits.

a) *Dimensions.* The depth of the mould and the distance between either pair of opposite internal faces, each based on the average of four symmetrically placed measurements, shall be 100.00 ± 0.15 mm.

b) *Flatness.* The surface of each internal face shall lie between two parallel planes 0.03 mm apart. The joints between the sections of the mould and between the bottom surface of the mould and the top surface of the base plate shall lie between two parallel planes 0.06 mm apart.

c) *Squareness.* The surface of each internal face shall lie between two parallel planes 0.5 mm apart which are perpendicular to the bottom surface of the mould and also to the adjacent internal faces.

d) *Parallelism.* The top surface of the mould shall lie between two parallel planes 1.0 mm apart, parallel to the bottom surface.

e) *Surface texture.* The surface texture of each internal face shall be 3.2 µm CLA.

1.3.1.4 *Assembly.* In assembling the cleaned mould ready for use, the joints between the sections of the mould and between the bottom of the mould and the base plate shall be sealed by a thin film of grease or other suitable method to prevent escape of water. Any excess grease shall be carefully removed. The internal faces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of the concrete.

1.3.2 *Mixer.* The concrete mixer[1)] shall be of suitable capacity to mix a complete batch in one operation. It shall comprise a rotating mixing pan with a contra-rotating mixing paddle and a scraper blade. The sizes and tolerances shall be as shown in Figure 1.

The mixing pan (preferably removable) shall rotate at 18 ± 1 r/min. The mixing paddle (offset from the pan centre) shall rotate at 90 ± 5 r/min.

The mixing paddle and scraper blade shall be positively spring loaded to ensure they do not jam during mixing. Simple and positive means of vertical adjustment shall be provided on the mountings of the mixing paddle and scraper blade. The clearances F_1, F_2 and G shall be checked every month or after every 100 mixing operations whichever represents the more frequent use.

The mixer shall preferably be fitted with an automatic timing device otherwise a stop clock shall be provided.

1.3.3 *Trowel.* The trowel shall have a cast steel blade; a suitable type is shown in Figure 2.

1.3.4 *Compacting bar.* The compacting bar shall be a steel bar weighing 1.8 ± 0.1 kg and having a ramming face 25.0 ± 0.5 mm square.

1.3.5 *Tank.* The tank shall contain clean tap water, which shall be renewed at least every seven days with water at the specified temperature.

Specimens made with high alumina, supersulphated or Portland-type cements shall not be placed in the same tank.

[1)] For information on the availability of suitable mixers apply to Enquiry Section, BSI, Linford Wood, Milton Keynes MK 14 6LE, enclosing a stamped addressed envelope for reply.

1.3.6 *Compression testing machine.* The compression testing machine shall be of suitable capacity[2] for the test and shall comply with BS 1881-115. Over the scale range(s) used, the machine shall be capable of applying load at the rate given in **1.7** and shall comply with grade 1.0 of BS 1610-1:1985 as regards repeatability and accuracy. The lower limit of verification for the scale range used shall be below the expected maximum load on any specimen tested on that scale range.

1.4 Temperature and humidity conditions. The temperature throughout the entire test procedure shall be controlled about a midpoint of 20 °C with permitted variations as shown in Table 1. The minimum relative humidity shall be as given in Table 1.

Table 1 — Temperature and humidity conditions

Situation	Permitted temperature variation	Minimum relative humidity
	°C	%
Mixing room	± 2	50
Moist curing chamber	± 1	90
Water curing tank	± 1	—
Compression testing room	± 2	50

NOTE 1 A record should be kept for reference purposes of the actual temperature and relative humidity conditions.

NOTE 2 The high humidity required in moist air curing rooms is normally produced by spraying water as a fine aerosol. The bacterium *Legionella pneumophila* is widespread in nature and is present in the water systems of many buildings. Scale in pipework and chemical nutrients in the water supply may encourage growth of this organism which multiplies between 25 °C and about 45 °C. Inhaling infected aerosols is a known route for transmission of legionellosis. It is therefore advisable to maintain cold water supplies below 20 °C where possible and to store hot water above 60 °C. Cold water supplies may be disinfected by chlorination to at least 5 mg/L free chlorine. Regular periodic checking for the presence of *Legionella* species in industrial water supplies is a sensible precaution.

Before use, all materials, moulds and other appliances shall be brought to the same temperature as the air in the mixing room, by storing them in the room for a sufficient time.

1.5 Preparation of specimens. The specimens shall be prepared as follows.

1.5.1 *Number of cubes.* Make batches of six, nine or twelve cubes, three for testing at each of the specified ages.

1.5.2 *Aggregates.* The coarse aggregate and the sand shall comply with the requirements of Part 4 and Part 5 of this British Standard.

Sieve the coarse aggregate on 10 mm and 5 mm sieves with square holes so that it is substantially free from oversized and undersized particles.

1.5.3 *Proportioning.* The masses of the individual materials for batches of six or nine cubes are given in Table 2 and Table 3.

1.5.4 *Mixing.* Place the weighed materials in the mixer pan in the following order:

sand, cement, coarse aggregate.

Hold the mixing water ready and start the mixer. After 15 s add the water uniformly during the next 15 s; then continue mixing for a total time of 180 ± 5 s. After the machine mixing turn the concrete over in the pan a few times with a trowel to remove any slight segregation. If this is not possible, transfer the concrete to another suitable vessel and turn it over similarly therein.

1.5.5 *Compacting.* Half fill the cube moulds as quickly as possible. Compact each with exactly 35 strokes of the compacting bar, uniformly distributed over the cross section of the mould. Place a further quantity of concrete in each mould to form the top layer and compact similarly. Then strike off the top of each cube and smooth with the trowel so that the surface of the concrete is level with the top of the mould. Complete the entire operation within 15 min from the completion of the mixing.

1.6 Storage of specimens. Immediately after preparation, place the moulds in a single layer on a level surface in the moist curing chamber. In order to reduce evaporation, cover the exposed top of the cubes with a flat impervious sheet (e.g. of clean thin rubber or plastics, or lightly oiled steel) making contact with the upper edge of the mould. After 24 ± 0.5 h mark the cubes for later identification and remove from the moulds[3]. Immediately submerge all specimens, except those to be tested at 24 h, in the tank and arrange them in such a way that the temperature variation specified in Table 1 is not exceeded. Leave the cubes in the tank until just prior to the test.

Specimens to be tested at 24 h are marked and demoulded[3] 15 min to 20 min before the test and are covered with a damp cloth so that they remain in the moist condition.

If the concrete has not achieved sufficient strength after 24 h to be handled without fear of damage, delay the demoulding for a further period of 24 h but state this fact in the test report.

[2] i.e. that the expected maximum load on a specimen lies between 20 % and 100 % of the selected scale range of the machine.

[3] It is recommended that the cubes should be weighed at this stage since this may reveal errors in the procedure at an early stage.

Table 2 — Mixes for concrete cubes

Mix type (see note to **1.1**)	Material	Proportions by mass	Mass		
			6 cubes	9 cubes	12 cubes
			g	g	g
C1	Cement	1.0	2 200 ± 5	3 200 ± 5	4 200 ± 5
	Sand	2.5	5 500	8 000	10 500
	Coarse aggregate	3.5	7 700 ± 10	11 200 ± 10	14 700 ± 10
	Water	0.60	1 320 ± 5	1 920 ± 5	2 520 ± 5
C2	Cement	1.0	2 200 ± 5	3 200 ± 5	4 200 ± 5
	Sand	2.5	5 500	8 000	10 500
	Coarse aggregate	3.5	7 700 ± 10	11 200 ± 10	14 700 ± 10
	Water	0.55	1 210 ± 5	1 760 ± 5	2 310 ± 5
C3	Cement	1.0	2 940 ± 5	4 270 ± 5	5 600 ± 5
	Sand	1.875	5 500	8 000	10 500
	Coarse aggregate	2.625	7 700 ± 10	11 200 ± 10	14 700 ± 10
	Water	0.45	1 320 ± 5	1 920 ± 5	2 520 ± 5

Table 3 — Mass of individual fractions of sand

	Mass		
	6 cubes	9 cubes	12 cubes
	g	g	g
Fraction A (2.36 mm to 1.18 mm)	550 ± 5	800 ± 5	1 050 ± 5
B (1.18 mm to 600 µm)	1 100 ± 5	1 600 ± 5	2 100 ± 5
C (600 µm to 300 µm)	1 650 ± 5	2 400 ± 5	3 150 ± 5
D (300 µm to 150 µm)	1 375 ± 5	2 000 ± 5	2 625 ± 5
E (150 µm to 90 µm)	825 ± 5	1 200 ± 5	1 575 ± 5

1.7 Testing of specimens. Determine the compressive strength of the cubes, under the temperature and relative humidity conditions specified in Table 1 for the compression testing room, at the specified age, calculated from the time of adding the water to the other materials, by the procedure specified in clauses **5** to **8** of BS 1881-116:1983 except that the load shall be applied at a rate of approximately 0.25 N/(mm^2 s) and using the auxiliary platens.

Test the specimens within the following limits:

24 ± 0.5 h

3 days (72 ± 1 h)

7 days (168 ± 2 h)

and 28 days (28 days ± 4 h)

1.8 Calculation. Calculate the average of the individual results of the set of three specimens tested at the same age, and express the result to the nearest 0.5 N/mm^2. If one result within the set varies by more than ± 5 % from the average of the set, discard the result and recalculate the average of the remaining results. If more than one result varies by more than ± 5 % from the average, discard the set of results.

1.9 Report. Report the individual results and the average compressive strength to the nearest 0.5 N/mm^2, indicating if any result has been discarded.

2 Compressive strength of mortar cubes

2.1 Test principle. The strength of cement is determined by compressive strength tests on 70.7 mm mortar cubes, made with a specified sand, mixed by hand and compacted by means of a standard vibration machine.

2.2 References. The titles of the standards publications referred to in this clause of this Section are listed on the inside back cover.

2.3 Apparatus. The following apparatus is required.

2.3.1 *Moulds*

2.3.1.1 *Size.* The moulds shall be 70.7 mm cubes, the area of each face being 5 000 mm^2.

2.3.1.2 *Construction.* The mould shall be of metal that is not attacked by cement mortar and rigid enough to prevent distortion. It shall be constructed in such a manner as to facilitate the removal of the moulded specimen without damage. The parts of the mould, when assembled, shall be positively and rigidly held together, by suitable means, both during the filling and on subsequent handling of the filled mould. Each mould shall be provided with a steel base plate to support it without leakage. The weight of the mould and base plate shall be such as to comply with the requirements given in **2.3.3**, for the mass of the machine.

2.3.1.3 *Tolerances.* The mould shall be such that, when assembled ready for use, the dimensions and internal faces are accurate within the following limits:

a) *Dimensions.* The depth of the mould and the distance between either pair of opposite internal faces, each based on the average of four symmetrically placed measurements, is 70.7 ± 0.1 mm [4].

b) *Flatness.* The surface of each internal face shall lie between two parallel planes 0.03 mm apart. The joints between the sections of the mould and between the bottom surface of the mould and the top surface of the base plate shall lie between two parallel planes 0.06 mm apart.

c) *Squareness.* The surface of each internal face shall lie between two parallel planes 0.5 mm apart which are perpendicular to the bottom surface of the mould and also to the adjacent internal faces.

2.3.1.4 *Assembly.* When the cleaned mould is being assembled ready for use, the joints between the sections of the mould and between the bottom of the mould and the base plate shall be sealed by a thin film of grease[5] to prevent escape of water. Any excess grease shall be carefully removed. The internal faces of the assembled mould shall be thinly coated with mould oil[5] to prevent adhesion of the mortar.

2.3.2 *Trowels.* The trowels shall have a cast steel blade; a suitable type is shown in Figure 2.

2.3.3 *Vibration machine.* The vibration machine shall consist of a table mounted on coil springs to carry the cube mould, and a revolving shaft provided with an eccentric. By means of a balance weight beneath the base plate attached rigidly to the table, the centre of gravity of the whole machine, including the cube and mould, shall be brought either to the centre of the eccentric shaft or within a distance of 25 mm below it. In consequence of this, the revolving eccentric imparts an equal circular motion to all parts of the machine and mould, this motion being equivalent to equal vertical and horizontal simple harmonic vibration 90° out of phase. The minimum running speed of the machine shall be well above its natural frequency on its supporting springs, so that the amplitude of vibration is independent of the speed. The motor shall be preferably of the synchronous type and the drive is by means of an endless belt running on a crowned pulley on the motor and a crowned pulley on the vibrator. The machine shall be provided with a suitable clamp to hold the assembled mould firmly on the table, and with a suitable hopper to facilitate filling of the mould.

The machine shall be constructed to comply with the following essential requirements.

Mass of machine on its supporting springs (excluding mass of solid eccentric but including mass of mould, mould clamp, hopper and cube)	29 kg approx.
"Out-of-balance" moment of eccentric shaft	0.016 N m
Normal running speed of eccentric shaft	12 000 ± 400 r/min

A typical vibration machine[5] of the type described above is shown in Figure 3.

2.3.4 *Tank.* The tank shall contain clean tap water which shall be renewed at least every seven days with water at the specified temperature.

Specimens made with high alumina, supersulphated or Portland-type cements shall not be placed in the same tank.

[4] This tolerance should be considered in conjunction with those for flatness and squareness.

[5] For information on the availability of suitable grease, mould oil and vibration machines apply to Enquiry Section, BSI, Linford Wood, Milton Keynes MK 14 6LE, enclosing a stamped addressed envelope for reply.

2.3.5 *Compression testing machine.* The compression testing machine shall be of suitable capacity[6] for the test and shall comply with BS 1881-115. Over the scale range(s) used the machine shall be capable of applying loads at the rate given in **2.7** and shall comply with grade 1.0 of BS 1610-1:1985 as regards repeatability and accuracy. The lower limit of verification for the scale range used shall be below the expected maximum load on any specimen tested on that scale range.

2.4 Temperature and humidity conditions. The temperature throughout the entire test procedure shall be controlled about a midpoint of 20 °C with permitted variations as shown in Table 4. The minimum relative humidity shall be as given in Table 4.

Table 4 — Temperature and humidity conditions

Situation	Permitted temperature variation	Minimum relative humidity
	°C	%
Mixing room	± 2	50
Moist curing chamber	± 1	90
Water curing tank	± 1	—
Compression testing room	± 2	50

NOTE A record should be kept, for reference purposes, of the actual temperature and relative humidity conditions.

Before use, all materials, moulds and other appliances shall be brought to the same temperature as the air in the mixing room, by storing them in the room for a sufficient time.

2.5 Preparation of specimens. The specimens shall be prepared as follows.

2.5.1 *Number of cubes.* Make three cubes for testing at each of the specified ages.

2.5.2 *Aggregate.* The sand shall comply with the requirements of Part 6 of this British Standard.

2.5.3 *Proportioning.* The mass(es) of cement, sand and water for each cube are given in Table 5.

Table 5 — Mixes for mortar cubes

Mix type	Material	Proportions by mass	All cements other than high alumina cement: mass
			g
V1	Cement	1.0	185 ± 1
	Sand	3.0	555 ± 1
	Water	0.4	74 ± 1
			High alumina cement: mass
			g
V2	Cement	1.0	190 ± 1
	Sand	3.0	570 ± 1
	Water	0.4	76 ± 1

2.5.4 *Mixing.* Before mixing, clamp the assembled mould on the table of the vibration machine and attach the hopper to the top of the mould.

Mix the mortar for each cube separately on a non-porous surface that has been wiped over with a damp cloth. Mix the cement and the sand dry, for 1 min, by means of the two trowels. Then add the water and mix the whole for 4 min with the two trowels.

2.5.5 *Compacting.* Place the whole of the mortar in the hoopper of the mould by the use of a suitable scoop as quickly as possible and compact by vibration for a period of 120 ± 5 s.

2.6 Storage of specimens. Immediately after vibration, remove the hopper and place the moulds in a single layer on a level surface in the moist curing chamber. In order to reduce evaporation, cover the exposed top of the cubes with a flat impervious sheet (e.g. clean thin rubber or plastics, or lightly oiled steel) making contact with the upper edge of the mould. After 24 ± 0.5 h mark the cubes for later identification and remove from the moulds[6]. Immediately submerge all specimens, except those to be tested at 24 h, in the tank and arrange them in such a way that the temperature variation specified in Table 4 is not exceeded. Leave the cubes in the tank until just prior to the test.

Specimens to be tested at 24 h are marked and demoulded[7] 15 min to 20 min before the test and are covered with a damp cloth so that they remain in the moist condition.

If the mortar has not achieved sufficient strength after 24 h to be handled without fear of damage, delay the demoulding for a further period of 24 h but state this fact in the test report.

[6] i.e. that the expected maximum load on a specimen lies between 20 % and 100 % of the selected scale range of the machine.

[7] It is recommended that the cubes should be weighed at this stage since this may reveal errors in the procedure at an early stage.

2.7 Testing of specimens. Determine the compressive strength of the cubes, under the temperature and relative humidity conditions specified in Table 4 for the compression testing room, at the specified age, calculated from the time of adding the water to the other materials, by the procedure specified in clauses **5** to **8** of BS 1881-116:1983 and using the auxiliary platens, except that the load is applied at a rate of approximately 0.6 N/(mm^2 s).

Test the specimens within the following limits:

24 ± 0.5 h

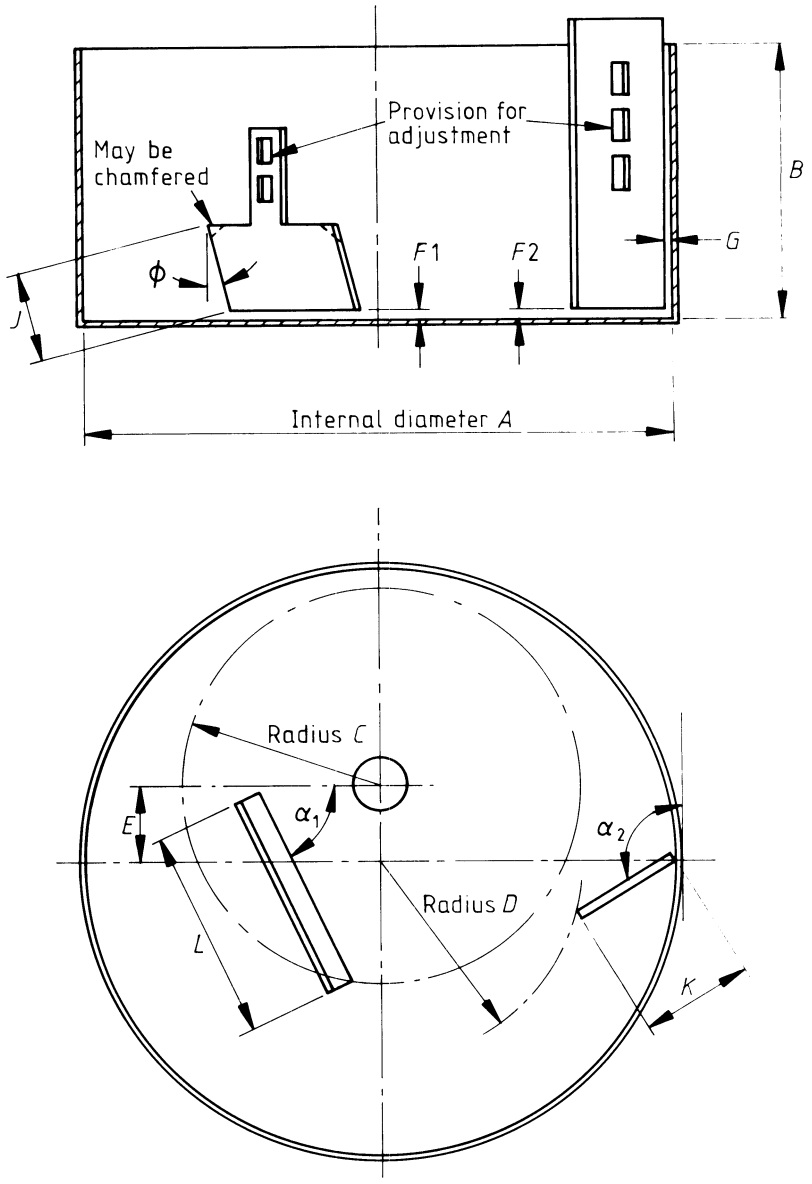
3 days (72 ± 1 h)

7 days (168 ± 2 h)

and 28 days (28 days ± 4 h)

2.8 Calculation. Calculate the average of the individual results of the set of three specimens tested at the same age and express the result to the nearest 0.5 N/mm^2. If one result within the set varies by more than ± 5 % from the average of the set, discard the result and recalculate the average of the remaining results. If more than one result varies by more than ± 5 % from the average, discard the whole set of results.

2.9 Report. Report the individual results and the average compressive strength to the nearest 0.5 N/mm^2, indicating if any result has been discarded.

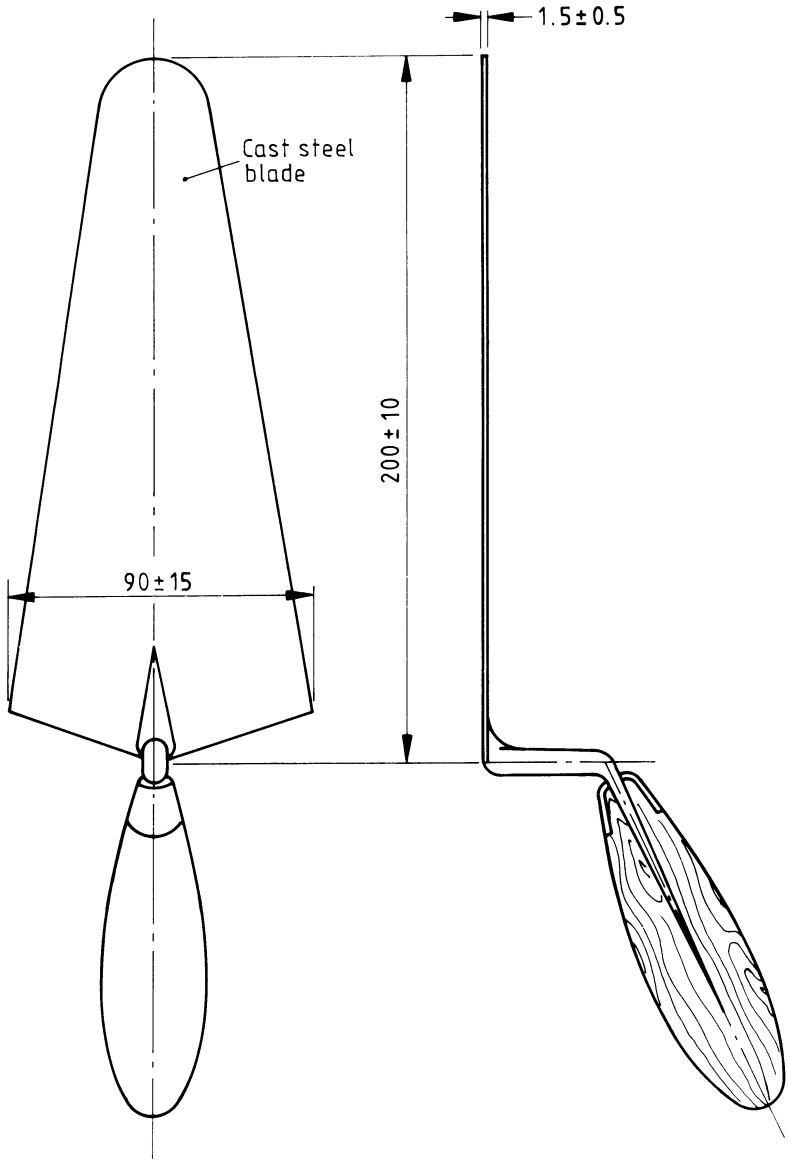


A	B^a	C	D	E	F_1	F_2	G	J	K	L	α_1	α_2	ø
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	degrees	degrees	degrees
450 ± 5	220 ± 10	150 ± 10	155 ± 10	60 ± 10	5 ± 5	2 ± 2	2 ± 2	65 ± 10	95 ± 10	165 ± 10	65 ± 10	120 ± 20	15 ± 10

[a] 260 ± 10 required for 12 cube batches.

NOTE Where tolerances are not given, sizes are indicated for guidance only and are not critical.

Figure 1 — Typical rotating pan concrete mixer



All dimensions are in millimetres.

Figure 2 — Suitable trowel

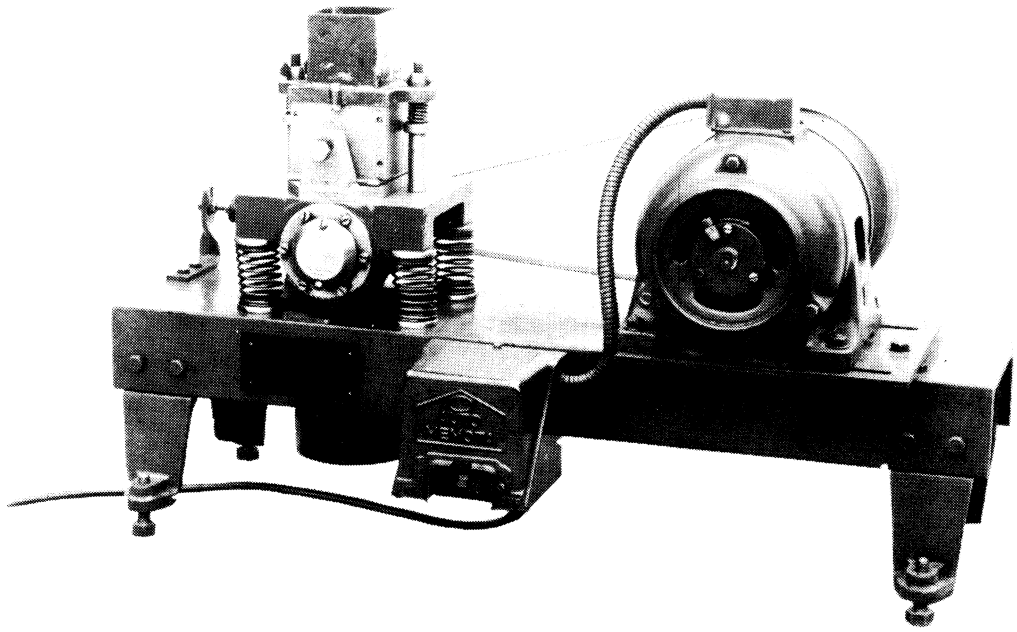


Figure 3 — Typical vibration machine for compacting mortar cubes

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Publications referred to

BS 812, *Methods for sampling and testing of mineral aggregates, sands and fillers.*
BS 812-2, *Physical properties.*
BS 891, *Method for Rockwell hardness test.*
BS 891-1, *Testing of metals.*
BS 1134, *Method for the assessment of surface texture.*
BS 1610, *Methods for the load verification of testing machines.*
BS 1610-1, *Specification for the grading of the forces applied by materials testing machines.*
BS 1881, *Testing concrete.*
BS 1881-108, *Method for making test cubes from fresh concrete.*
BS 1881-115, *Specification for compression testing machines for concrete.*
BS 1881-116, *Method for determination of compressive strength of concrete cubes.*
BS 4550, *Methods of testing cement.*
BS 4550-4, *Standard coarse aggregate for concrete cubes.*
BS 4550-5, *Standard sand for concrete cubes.*
BS 4550-6, *Standard sand for mortar cubes.*

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