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Guide to specifying the quality of building mortars

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Contents

Foreword

Committees of the British Standards Institution have recently been preparing standards for mortar plasticizers, masonry cement, ready-mixed lime:sand for mortar, and for methods of testing mortar. The Code of Practice for brickwork and blockwork (CP 121 'Walling', Part 1 'Brick and block masonry') has also been revised. This interest in mortar has led to a detailed appraisal of the methods of specifying the quality of mortar by a panel set up to consider long-term developments in the improved use of mortar.

Traditionally, mortar has been specified by simple volumetric proportions of the solid constituents, the water content being controlled by a craftsman by choice of consistence. This method has been adequate for most work in the past and will continue to be so where the properties of the mortar are not critical. However, new developments in building make greater control of the quality of mortar technically and economically worthwhile, and a more refined specification is necessary.

This document records the panel's recommendations for specifying the quality of conventional mortar for present-day applications, such as bedding bricks or blocks, rendering or plastering, and thus to assist specifying authorities in the drafting of specifications for mortar for building purposes.

The document is not itself a specification for the supply of mortar and it cannot be used as such because it requires the specifier to provide information essential to the function of a specification.

Section one outlines the factors to be considered in deciding the form of the specification and the quality to be specified for a particular job; the specification may be either of the 'prescription' or 'performance' types. Section two deals with general clauses for all specifications; section three gives details for the prescription type of specification and section four for the performance type.

BS 4551, 'Methods of testing mortars and specification for mortar testing sand, BS 4721, 'Ready-mixed lime:sand for mortar' and BS 4887, 'Mortar plasticizers' have already been published, and this document also refers to a British Standard for masonry cement which is in course of preparation.

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

Guide to specifying the quality of building mortars

0. Introduction

Mortar is a relatively simple material but may have to fulfil many functions during its service. The requirements of both the fresh and the hardened mortar are complex and interacting so that it is often necessary to adopt some compromise. Insufficient knowledge is yet available to be able to advise in detail on how all these characteristics can be adequately specified by requirements either for composition or performance.

Some characteristics of the mortar are sensitive to its working properties while still fresh and traditionally the craftsman has been left to adjust the proportions to produce a mortar which he could handle easily and which, in his experience, would be adequate. However, requirements for strength or other important properties may not be satisfied by this approach. While it is necessary for a mortar to be of a suitable consistence for the craftsman, this requirement should be consistent with the production of mortar which will behave adequately in other essential respects.

On the other hand, it is fortunate that some properties of mortar are relatively insensitive to normal prescription or performance requirements. For example, the thermal properties of a mortar are not greatly affected by the relative proportions of the materials or by the strength, but are affected significantly by the choice of dense or lightweight aggregate and, to a limited extent, by any air entrained.

Strength of mortar, in a general sense (whether expressed in terms of measured values of compressive or bending strength or in terms of richness of cement in compositional requirements), is an important characteristic. For some purposes, bedding mortars need to be strong in order to achieve the required loadbearing capacity of the wall; for other purposes, too strong a bedding mortar can be an important factor in encouraging cracking of the construction. Similarly, the strength of mortars for rendering and plastering in relation to the substrate to which they are applied affects the adhesion and the likelihood of cracking in the hardened mortar.

This document gives detailed advice on the writing of a specification for the quality of mortar to be handled by a craftsman using a trowel when bedding units for brickwork or blockwork or when rendering or plastering. It is not intended to apply to the use of slurries, grouts or dry mortar for packed joints, nor to mortar for floor screeds or for the bedding of paving flags. It does not necessarily apply to mortars containing gypsum.

It is not intended that all, or even most, of the outline requirements referred to in this document are necessary or desirable in a specification for any one particular job.

Section one. General considerations

1. Forms of specification

The specifier should accept responsibility for the adequacy of the requirements to cover all aspects of the quality of the mortar provided it is made in accordance with these requirements.

The specification may take either of two principal forms, 'prescription' or 'performance', or be an appropriate combination of each, provided conflicting requirements are not thereby included. Normally a prescription type of specification will be satisfactory for rendering and plastering mortars and for bedding mortars for traditional brickwork and blockwork; a performance type of specification may be preferable for bedding mortars to be used for calculated loadbearing brickwork or blockwork.

The supervision, inspection and testing required for the enforcement of the requirements should be appropriate to the particular type. Each should include requirements for quality of materials and for workmanship, which may be the same irrespective of the form, but each should have an appropriate preamble outlining the basis on which the specification will be operated.

1.1 Prescription specification. The prescription type of specification should be drafted so that the quality of mortar is controlled by stated requirements for the composition of the material only and is enforced by regular inspection that these requirements are being complied with. If the specifier requires confirmation that the requirements are adequate for his purpose he may arrange for preliminary tests to be made (see Clause **4**).

1.2 Performance specification. The performance type of specification should be drafted so that the quality of mortar is controlled by stated requirements for the properties of the mortar as determined by specified tests on samples taken during the course of the work. The procedure for checking performance requirements should be specified to relate (*a*) to simple visual inspection with the testing of a sample of any suspect quantity or consignment of mortar, or (*b*) to visual inspection with infrequent but regular testing of samples or (*c*) to the statistical analysis of the results of tests on random samples taken over a period of production.

Method (*c*) involves a greater amount of testing than methods *(a)* or *(b)*; hence it is only likely to be appropriate for controlling the quality of mortar produced in considerable quantities where strict control is economically or technically desirable. However, statistical procedures can give warning of adverse trends before the results are too serious, and an adjustment of the composition may be the only action required if mortar is found not to comply.

2. Assessment of the job

The choice of type of specification, the detailed requirements and the methods of enforcement should be based on an assessment of the work to be covered by the specification in which the following circumstances are taken into consideration.

2.1 Essential characteristics of the mortar. The specification should include only those requirements which are of significance to the quality of the work and which are the responsibility of the contractor or supplier of materials.

2.2 Relation between properties of mortars and characteristics required. Table 1 gives the main properties of mortar and Table 2 the main properties which affect each characteristic. Where test methods have been standardized the property may be specified in relation to the procedure given in the stated clause of BS 4551; where test methods have not yet been standardized it may be possible to select compositional requirements on the basis of a qualitative assessment of the relevant properties.

2.3 Relevance of performance requirements to essential characteristics. Strength has been found to be a convenient property to specify in performance specifications because limiting values can be chosen as a means of controlling the quality of mortar relevant to more than one essential characteristic when there is some degree of correlation between them. For example, it may be appropriate to specify a minimum compressive strength for a bedding mortar to ensure adequate strength of the wall or to ensure that the mortar of a particular type, such as a non-plasticized as opposed to a plasticized mortar, will be durable – either might be the limiting criterion. Furthermore, it may even be desirable to specify a maximum strength to reduce the danger of cracking.

2.4 Characteristics not easily specified. If certain features are difficult to specify precisely in words, e.g. characteristics affecting finish, it may be necessary to require that preliminary tests or trials are made to establish criteria for acceptable ranges of these features.

2.5 Action to be taken in case of non-compliance. If there is serious danger that structural collapse could occur in the immediate future or, because of inadequate durability, in years to come, the faulty work may have to be removed and replaced; in other situations, the likely consequence may be less serious and some immediate repair, such as raking out bedding joints and repointing, may be adequate; in others still, the faults may be difficult to correct, in which case financial penalties may be imposed. With the performance type of specification based on regular random sampling, the action may simply be to demand a change of composition of the mortar which would be expected to raise the quality sufficiently to ensure that future material will comply with the requirements.

2.6 Systems of inspection and/or testing. If the importance or size of the work does not warrant much inspection, it is pointless to draft other than the simplest type of specification with requirements which imply a high probability against the work being unsatisfactory in any of all the essential characteristics.

2.7 Cost of control. If it is not possible to ensure satisfactory behaviour by means of a simple specification because of the sensitivity of the construction to the quality of the mortar, it will be necessary to employ more effective, and hence more expensive, inspection and even testing associated with performance requirements. The cost may be justified if the overall savings to be expected from this control procedure would be greater than its cost. The savings could include reduced materials costs because of lower factors of safety appropriate to the greater certainty of the quality of the mortar. The construction may only be feasible if the material is used to its full potential, which implies maximum control to keep variability to a minimum; or the financial risks from unsatisfactory work or delay in applying remedial measures may demand a realistic expenditure on control which can be utilized for specification purposes also.

3. Drafting of specifications

The specification should be free of vague and non-committal phrases such as 'to the specifier's satisfaction' because a contractor should not be held responsible for complying with a requirement that the specifier has not clearly expressed. Some characteristics, such as colour of mortar or properties of the mortar affecting decorative rendering, cannot easily be specified in words. Where they are important, preliminary trials should be demanded as part of the contract and agreed limits of variation determined in relation to reference samples. Any action required of the contractor for this purpose, e.g. provision of samples of materials, or making, sampling and testing of mortar, should be specified.

The specification should be drafted with a clear and realistic concept of the way it can be enforced. This implies that it should be possible to check whether every requirement is being met, and that if any breach of the requirements is discovered, suitable remedial action can be demanded. The action to be taken should be related to the probable consequences of the lack of compliance with the requirements. As a specification should be a document expressing intent, where possible it should include a statement of the risks the contractor faces in the event of non-compliance.

Section two. General clauses for all specifications

4. Preamble

The specification for the quality of mortar should include an introductory preamble indicating to the contractor any general requirements relevant to the work which will not be covered by the detailed technical requirements. Where appropriate, it should state:

(1) any special facilities to be provided by the contractor;

(2) what materials, equipment or methods of operation are to be subject to approval by the specifier before being used or changed;

(3) any preliminary testing or trial operations which are to be made before the work is started so that limits on methods of operation can be agreed;

(4) action which may be required if the work is found not to comply with the requirements of the specification.

5. Materials

The specification should state whether particular types of mortar, i.e. a cement:lime:sand mortar, a masonry cement:sand mortar or a Portland cement:sand mortar with air-entraining plasticizer, are required, permitted or forbidden. If alternative types are acceptable, the equivalent mix for each permitted type should be given when stating any prescription requirements. Notes on the composition of mortar mixes of approximately equivalent strength, expressed by volume proportions, are given in Table 3. Reference is made to the choice of types of mortar in **11.1**.

Constituent materials may need to be specified as in **5.1** to **5.7** or in accordance with the manufacturer's instructions. The selection from these clauses will depend on the number of types of mortar permitted.

Where there is no appropriate British Standard but an Agrément Certificate is available for a material, the specification should require the use of the material to be in accordance with the recommendations of that Certificate.

5.1 Cement. The specification should state whether particular types of cement are required, permitted or forbidden and, where possible, should require that cements comply with the requirements of any relevant British Standard.

The following British Standards are at present available for cements which are likely to be used for mortar:

Portland cement (ordinary and rapid-hardening) (white and coloured cements, other than any pigmented with carbon black, are now covered by this standard)	BS 12
Portland-blastfurnace cement	BS 146
high alumina cement	BS 915
sulphate-resisting Portland cement	BS 4027
supersulphated cement	BS 4248

The specification may also need to state whether other cements, for which there are at present no British Standards, are to be subject to any special requirements; such cements may include water-repellant or hydrophobic Portland cements, which may be expected to comply with the strength requirements for ordinary Portland cement given in BS 12, or masonry cement for which a British Standard is in course of preparation.

Cements containing calcium chloride should not be used in situations where the use of calcium chloride as an admixture would not be permitted (see **5.5**).

Where more than one type of cement is permitted, any limitations on the mixing of different types should be stated. For example, high alumina cement should not normally be mixed with any of the Portland cements nor with lime, nor should gypsum plaster be incorporated in any mixes containing Portland cements.

5.2 Lime. The specification may need to state:

(1) that lime is to comply with the requirements of BS 890;

(2) whether particular forms of lime, i.e. hydrated lime powder or lime putty, are required or permitted;

(3) whether particular types of lime, i.e. high-calcium lime, high-calcium by-product lime, semi-hydraulic lime or magnesian lime, are required, permitted or forbidden.

The working properties of mortar are improved if hydrated lime powder is first made into lime putty or coarse-stuff (see **6.2.1**).

5.3 Sand. The specification should state requirements for the properties of the sand. Normally sand should be required to comply with the relevant requirements of the appropriate British Standards, as follows:

for rendering and plastering	BS 1199
for bedding masonry units	BS 1200

In some cases, however, sands not complying with the requirements of these British Standards may be permitted, but alternative requirements may need to be specified, e.g. for the quality of the mortar.

Special requirements may need to be stated as follows:

(1) nominal maximum size of particles (related to the use and type of finish on some decorative renderings and plaster);

(2) grading, e.g. where close control is required to ensure consistent strength and working properties;

(3) clay content separately from silt content (although there is no standard test to distinguish between them); some silt, which could improve the working properties of the mortar, might be permitted while limiting the amount of undesirable clay;

(4) limitations on impurities, e.g. impurities affecting the hydration of cement, the appearance of rendering or plaster or the corrosion of embedded metals (lime present in a mortar acts as an antidote to organic impurities in natural sands which otherwise might adversely affect the hydration of cement);

(5) colour and uniformity of colour.

The specification may need to state any requirements for mineral fillers, e.g. pulverized-fuel ash or ground chalk or limestone; pulverized-fuel ash should comply with the requirements of BS 3892.

5.4 Pigments. The specification may need to state that any pigments required are to comply with the requirements of BS 1014.

5.5 Other admixtures. The specification should state whether admixtures of particular types, e.g. air-entraining plasticizers, water-retentive admixtures or retarders, are required, permitted, or forbidden. Requirements for the quality of permitted admixtures should be stated where appropriate, e.g. by reference to BS 4887.

Mortar plasticizers should not be used with masonry cements because these cements contain air-entraining agents as part of their formulation.

Water-retentive admixtures can be a help when mortars are used in association with high-suction units to improve the bond. Retarders are included in a mortar required to stand for relatively long periods before use as, for example, in retarded, ready-mixed cement:sand mortars. Admixtures of different types should not be mixed in a mortar unless the relative proportions are approved.

It is recommended that the specification should forbid the use of calcium chloride, or admixtures containing calcium chloride, especially if the mortar is to contain lime. It should forbid the use of calcium chloride in mortar made with high alumina cement or sulphate-resisting Portland cement. If, however, calcium chloride is to be permitted the specification should state that it is to comply with the requirements of BS 3587.

5.6 Water. The specification should state any restrictions which are to be placed on the source of water to be used for mixing. The water should normally be clean and free from impurities liable to have a deleterious effect on the mortar; in particular, sea water or brackish water might increase the risk of efflorescence or of the appearance of dampness. Any tests required to check the suitability of a source should be in accordance with BS 3148.

5.7 Ready-mixed materials. The specification should state whether any ready-mixed materials, e.g. ready-mixed lime:sand for mortar, dry bagged ready-mixed mortar or wet retarded cement:sand mortar (with or without lime) are required, permitted or forbidden. It should state the requirements for the quality of the constituent materials, normally in terms of the relevant recommendations of **5.1** to **5.6**.

Ready-mixed lime:sand for mortar should comply with the requirements of BS 4721.

6. Storage and preparation of materials

The specification should state any necessary requirements for the storage and preparation of the constituent materials of the mortar. They should be given in detail in a prescription type of specification to ensure that the quality of the materials does not deteriorate from that specified for the supply of the materials. These requirements may also be given in a performance type of specification involving a small amount of testing; however, with regular testing they may be left to the discretion of the contractor, and the adequacy of the measures taken determined only by checking that the mortar produced complies with the test requirements.

6.1 Storage of materials. Where appropriate, the specification should require that materials are to be stored as follows.

6.1.1 Cement, hydrated lime powder, dry fillers and pigments are to be stored under cover and away from possible contact with dampness and other materials which may damage them. Cement and hydrated lime powder are, as far as possible, to be stored so that they are used in order of delivery.

6.1.2. Sand is to be stored so that excess water can drain away, and material drawn only from parts which have drained and are free from the accumulation of dirt etc., which collects in the bottom layers. Special sands containing pigments are to be protected against rain.

Precautions are to be taken to prevent the sand from becoming frozen. Even though the air temperature does not fall below freezing point, the material at the surface of exposed stockpiles can become frozen on a clear night unless the stockpile is covered.

6.1.3 Admixtures are to be protected from extremes of temperature. If they become frozen, they should be used only if treated according to the manufacturer's instructions.

6.1.4 Ready-mixed lime:sand for mortar is to be stored on a clean impermeable surface, and the stockpile covered to protect it from rain or excessive evaporation of water. Prolonged storage before use, leading to excessive carbonation of the surface of the stockpile, is to be avoided.

6.2 Preparation of materials. Where appropriate, the specification should require that materials are to be prepared as follows.

6.2.1. Lime putty is to be made by adding hydrated lime powder to water (not water to the lime) and mixed thoroughly until the putty has the consistence of thick cream. Coarse-stuff is to be made by mixing hydrated lime powder with the sand, first without and then with the addition of water. Both lime putty and coarse-stuff are to be allowed to stand for at least 16 h before use and, if left longer than about a day, are to be protected from drying out.

6.2.2 Liquid admixtures are to be stirred, or the container is to be shaken, where necessary, to ensure the uniform distribution of the constituents. Unless otherwise recommended, powdered admixtures are, where possible, to be dissolved in part of the mixing water.

6.2.3 Requirements may need to be stated for work which is to continue in cold weather. If the work is to continue when the air temperature is likely to fall below 2 °C, it may be desirable to heat the mixing water or sand to a temperature not exceeding 70 °C, so that the temperature of the mortar will be at least 7 °C. Cement, including masonry cement, and lime should not be heated.

7. Batching of materials

The specification may need to state whether particular materials are to be batched by mass or by volume and include required or acceptable procedures.

If the quality of mortar is to be specified by prescription the specification should state unambiguously the procedure to be adopted on site for batching all constituent materials. If the quality is to be specified by performance the specification may also include similar requirements, especially if the amount of testing envisaged is small.

Cement, hydrated lime powder, lime putty, sand, ready-mixed lime:sand for mortar, coarse-stuff, fillers and powdered pigments and admixtures may, and generally will, all be batched by volume. A higher level of control of quality is possible, however, if these materials are batched by mass, so weigh batching should be permitted as an alternative. Water and liquid admixtures are normally batched by volume but may be batched by mass.

7.1 Batching by volume. The specification should not permit the batching of binders and aggregates by shovelfuls.

7.1.1 *Containers for volume batching.* Gauge boxes and similar containers to be used for volume batching are to be adequately rigid and, where appropriate, watertight, and are to be deep in relation to the cross-sectional dimensions at the top. The volume of each box or container is to be such that a whole number of volumes of each material is required for each batch of mortar. A straight-edged board or rigid strip is to be provided and used for striking off excess material flush with the top. The volume of each container, flush with the top, is to be checked.

7.1.2 *Condition of materials at the time of batching.* As the actual quantity of material batched by volume can depend very significantly on the condition of the material because it affects the bulk density at the time of batching, the specification may need to state limitations on the conditions of the various materials to be batched by volume. Cement and hydrated lime powder vary in density according to the amount of aeration of the material. Sand, lime putty, coarse-stuff and ready-mixed lime:sand for mortar vary in density according to the moisture content of the material.

Alternatively, where the variation in the condition of a material will have a significant effect on the accuracy of batching the specification should state that the bulk density is to be determined at intervals and if the values fall outside stated limits, stated adjustments are to be made in the volumes of the materials to be batched. The bulk density of a material is to be determined by batching a quantity, as required by the specification, and measuring the mass of material batched; the bulk density is to be calculated as the measured mass divided by the volume of the container.

7.1.3 *Batching procedure.* The batching container is to be empty and clean. It is to be slightly overfilled with the appropriate material using a procedure which can be relied upon to impart about

the same amount of compactive effort every time the container is filled; if the container is filled by the shovelful the container should be so placed that the material discharged from the shovel falls through about the same height in each cycle of filling. The excess material is to be screeded off with the straight-edge flush with the top of the container.

7.2 Batching by mass. Where conditions are appropriate the specification may permit the batching of cement, hydrated lime powder and other materials by complete packages for each batch provided they are prepacked by mass in suitable quantities; otherwise, it should require the use of weigh batching as follows.

7.2.1 *Weigh batching equipment.* Weighing equipment is to be carefully maintained and periodically checked for accuracy. The weighing container and other moving parts are to be kept clean and lubricated where appropriate.

7.2.2 *Weighing procedure.* Before starting to weigh a particular material, the container is to be checked to ensure that it is empty and the recording device checked that it is reading zero. After filling the container so that the correct mass is recorded, the contents of the container are to be discharged completely.

7.3 Batching of water. Unless special conditions warrant otherwise, the specification should state that the amount of water finally required in the mortar is to be determined by the craftsman who is to use the mortar on the basis of his judgement of the consistence needed to carry out the work.

Retempering of mixes, including the addition of further water, should be permitted for a stated time after mixing. Normally, retempering of mortars containing cements may be allowed up to 2 h from the time of first mixing cement and water but this period may need to be reduced in hot weather; if they are retarded, the time may be extended. Any attempt to control the quantity of water required entirely by other means is likely to lead to some properties of the mortar being adversely affected. Extra water may well be needed when retempering, to replace any lost by evaporation or other cause, but if the amount of water that has to be added is excessive, the mortar should be discarded.

8. Mixing

The specification should state whether mixing is to be by hand or by machine, or whether it may be either. Normally mortar should be mixed by machine, and hand mixing only permitted in special cases, e.g. for small quantities of mortar. Hand mixing should be avoided if the mortar is to contain masonry cement or air-entraining plasticizers.

It should state that hand mixing is to be carried out on a clean watertight platform and that a mixer is to be cleaned out before use and before changing mixes.

The specification may need to state limitations on the amount of mixing. Mixing should be continued until all the materials are thoroughly mixed together, especially if the mortar is to be coloured. Mixing for longer periods should be permitted; no limit other than that referred to in **7.3** need be placed on time of mixing non-air-entrained mortars. With air-entrained mortars the specification may need to state that checks are to be made to ensure that the air content does not exceed a stated limit as a result of prolonged mixing.

9. Use of the mortar

The specification should include any requirements which are necessary to ensure that the mortar is used in accordance with the relevant code of practice for the type of work. Codes of practice recommendations to which reference should be made are as follows:

brick and block masonry	CP 121: Part 1 : 1973	Clauses **4.4.5** and **4.13**
masonry walls	CP 121.201 : 1951	Clause **506** and **516**
internal plastering	CP 211 : 1966	Clause **505**
external rendered finishes	CP 221 : 1960	Clause **407**

The specification may need to cover aspects such as the following.

The fresh mortar is to be protected from rain.

Unless the construction is protected, work is to be discontinued during heavy rain and newly completed work is to be covered; protection is to be provided against snow and frost. In frosty weather, heated mortar should not be exposed so long that it will cool excessively before use.

Where the appearance of the mortar is important, finished work is to be protected against splashing by rain from the ground or scaffolding or by other constructional activities.

Where appropriate, the specification should state that in hot, dry weather, air-entrained mortars are to be protected from drying out; this is necessary to minimize loss of consistence from the collapse of air bubbles, which cannot easily be re-introduced, as well as from loss of water.

Section three. Prescription specifications

10. Basis of prescription

The specification should state the required composition of the mortar in terms of specified proportions of the constituents by volume or by mass according to the procedure to be used for batching. For most work, including mortar for rendering, plastering and bedding units in traditional construction, the specification of volume proportions will normally be adequate. If, however, a high degree of control of quality is required, the proportions of the major constituents should be specified by mass.

11. Choice of prescribed proportions

The choice of mortar designation should be based on a consideration of the characteristics required of the mortar to ensure satisfactory strength and durability of the work. Reference should be made to codes of practice for guidance on the choice of mortars, as follows:

loadbearing walls	CP 111 : Part 2 : 1970	Clauses **315** and **503**
brick and block masonry	CP 121:Part 1 : 1973	Clause **3.11**
masonry walls	CP 121.201 : 1951	Clause **312**
internal plastering	CP 211 : 1966	Section **4**
external rendered finishes	CP 221 : 1960	Section **3**

11.1 Volume proportions of cement, lime and sand. The specification should state the prescribed volume proportions of the solid constituents of the mortar on the basis of stated assumed characteristics of the materials; it should require prior notification of proposed changes of source or type of materials.

Where alternative types of mortar are permitted the specification should state the required equivalent volume proportions. Table 3 gives equivalent mortar mixes and comments on minor differences. The volume proportions should be interpreted as follows, where densities are given to the nearest 25 kg/m^3.

(1) The density of the cement at the time of batching is 1450 kg/m^3; in practice, the density of cement, as batched by volume, may be as low as 1200 kg/m^3.

(2) The lime is in the form of lime putty; if the lime is to be batched as hydrated lime powder the proportion by volume may be increased by up to 50 % to obtain adequate workability.

(3) The sand is dry; because of the bulking of damp sand, which may amount to 40 % or 50 % if it is fine, the volume proportions may be increased in proportion to the bulking.

(4) The range of volume proportions for sand is to accommodate variation of sand grading within the range permitted; the higher values should be used for sand that is well graded and the lower values for coarse or uniformly fine sands.

Where the specification permits the use of coarse-stuff made on site or ready-mixed lime:sand for mortar, it should state the equivalent proportions to be used with these materials and the appropriate quantities of lime and sand to be used for making suitable coarse-stuff.

Guidance on the lime:sand mixes required for specified cement:lime:sand mortars and on the volume proportions for gauging cement with lime:sand mixes is given in Table 4*a* for site-mixed coarse-stuff and in Table 4*b* for ready-mixed lime:sand for mortar. It may be assumed that, provided

the material is well compacted in the batching operation, each volume of coarse-stuff, or of ready-mixed lime:sand for mortar, contains that same volume of dry sand; the lime and water can be contained entirely within the voids of the sand. Under these conditions, the bulk density can be as high as 2000 kg/m^3. If, however, the material is of stiff consistence and not fully compacted when batching, the value may be as low as 1500 kg/m^3.

The manufacturer of ready-mixed lime:sand for mortar should be approached for advice about suitable mix proportions incorporating his material.

11.2 Proportions by mass of cement, lime and sand. The specification should normally state that the specified proportions by mass are to be the subject of agreement following preliminary trials to determine the proportions required.

Alternatively, it should state the prescribed proportions by mass of the solid constituents of the mortar, giving the equivalent values for any alternative types permitted.

The specified proportions by mass may be based on the volume proportions given in Table 3, converting them to proportions by mass on the basis of assumed bulk densities, as follows:

Portland cement	1450 kg/m^3
masonry cement	1300 kg/m^3
lime putty	1350 kg/m^3
dry sand	1675 kg/m^3

and assuming that lime putty contains the equivalent of 50 % by mass of hydrated lime powder, i.e. the equivalent of 1 m^3 of lime putty is 675 kg of hydrated lime powder, and no further additional quantity is required.

Where the specification permits lime and sand to be combined into coarse-stuff on site, the required relative proportions by mass of lime, sand and water and the proportions by mass of cement and coarse-stuff should be specified.

Where the specification requires or permits the use of ready-mixed lime:sand for mortar, the proportion of cement to be gauged with the material by mass should be based on the recommendations of the manufacturer. Where the work requires a high degree of quality control, the manufacturer of the ready-mixed lime:sand for mortar may also be asked for co-operation in supplying material having uniform consistence and available lime content.

11.3 Proportions of admixtures and pigments. The specification should require that either the proportions of admixtures and pigments be according to the relevant manufacturer's instructions, or the proportions are subject to agreement following preliminary site trials.

Where the strength or bond of the mortar is critical, it may be desirable to limit the maximum proportion of pigment by mass of the cement to 10 %. There is some evidence that for black pigments based on carbon the maximum should be 3 %, although iron oxide or manganese dioxide black pigments are satisfactory.

12. Control

12.1 General supervision. The specification may need to require that control of the supply of constituent materials, batching and mixing be the responsibility of a supervisor competent to carry out the work to its requirements. It should indicate any special duties to be undertaken.

12.2 Batching by volume. The specification may need to require that the contractor ensures (*a*) that the batching containers are calibrated, maintained in good condition and used properly for producing every batch of mortar, and (*b*) where necessary, that the variations in the moisture content and grading of the sand and in the consistence of lime putty, coarse-stuff or ready-mixed lime:sand for mortar are limited so that the amount of each material batched is maintained within stated limits, as determined by check tests.

12.3 Batching by mass. The specification may need to require that the contractor ensures (*a*) that the weighing equipment is calibrated, maintained in good condition and operated correctly for producing every batch of mortar, and (*b*) where necessary, that required adjustments are made to the mass of sand if the moisture content falls outside stated values.

13. Inspection

The specification should state that the specifier is to employ an inspector to ensure that its requirements are being met. It should also state how, in the event of apparent failure to comply with the requirements, any dispute is to be resolved.

For example, it may state that if the inspector suspects that the mortar is not satisfactory, he may take a sample of the mortar, representative of a stated amount of the work, details of which are recorded, and arrange for it to be analysed.

It should state that the sampling, testing and interpretation of the results is to be in accordance with BS 4551. It should also state that preliminary tests are to be made on the prescribed mortar, made on the site with the materials to be used, to establish that the proportions as determined by the tests are consistent with the composition specified. The skill required to conduct such analyses demands that appropriate laboratory facilities are made available on site or are readily accessible.

Section four. Performance specifications

14. Basis of performance

Performance specifications will usually be adopted for work where the strength of mortar will be critical, such as in calculated loadbearing masonry, and strength will be the basis of performance. If so, the specification should state whether flexural or compressive strength is to be measured and the age at test; if compressive strength, it should state whether specimens are to be cubes or prisms, and if prisms which method of curing is to be adopted.

A specified limiting value of strength should be based on the required strength and durability characteristics of the mortar and on the system of inspection to be specified, which may be primarily visual, with sampling and testing of suspect mortar only, or regular testing of random samples. Where appropriate (see **15.1**), the specification should state what supplementary tests and limiting values are required if the visual inspection leads to doubt about the quality of the sand.

The specification should state whether preliminary trial mixes are to be made in a laboratory or on site to confirm whether the materials and proportions proposed to be used will produce mortar with properties sufficiently within the specified limits to accommodate the variations likely to be encountered during the course of the work.

The specification may also require limiting values for other properties such as air content, water retentivity or flow.

It should require that mortar is to be sampled and tested according to the requirements of BS 4551, with specific reference to the particular test or tests, and stating specific procedures where alternatives are given.

The specification should state any relevant prescription requirements additional to the performance requirements and not inconsistent with them.

15. Control

The specification may need to state some or all of the relevant standards of control as required by Clause **12**. In addition, the specification should require that records be kept of the extent of the completed work containing batches of mortar which have been sampled for test.

15.1 Visual inspection with testing of suspect mortar. The specification may need to state that if the inspector suspects that the quality of any mortar does not comply with the performance requirements he may require a sample to be taken for test; the sample is to be representative of a recorded extent of the work. Subsequently, if the sample is found not to comply with the requirements of the specification, the necessary action is to be limited to the work represented by the sample.

15.2 Regular check testing of samples. The specification may need to state that the inspector is to be expected to take samples of mortar from time to time; otherwise control is to be as stated in **15.1**.

15.3 Regular testing for statistical quality control. The specification may need to state that an inspector is to be employed to check visually that its requirements are being met, and that he is to demand that random batches of mortar be sampled and tested to provide data for a statistical quality control scheme.

The procedure by which the results are to be examined to determine whether they indicate compliance with the requirements should be stated in detail. The specification may need to state that, if the mortar does not comply with the requirements, an adjustment of the composition of the mortar may be demanded, or where individual results are outside stated control limits, other action may be demanded to deal with the work to which that particular sample relates.

Experience of the statistical control of mortars is limited, but procedures, such as those used for concrete, may be adopted.

Table 1. Properties of mortar

Standardized (BS 4551)		Qualitative
Description	Clause No.	
1. Consistence	5	8. Absorption and permeability
2. Flow (plasticity)	8	9. Shrinkage
3. Consistence retentivity and water retentivity	6	10. Coefficient of thermal expansion
		11. Modulus of elasticity
4. Air content	7	12. Poisson's ratio
5. Stiffening time	9	13. Colour
6. Compressive and flexural strength	10	14. Texture and finish
7. Density	7.2	15. Thermal insulation

Table 2. Main properties of mortar affecting its characteristics

Characteristics	B or R/P*	Main properties affecting characteristics (see Table 1)
A. Working and handling	B, R/P	1, 2, 3, 4, 5
B. Bond to units or undercoats	B, R/P	1, 2, 3, 4; see also E*d*
C. Bond to ties or reinforcement	B	1, 2, 3, 4, 5, 9
D. Mechanical properties		
a. Compressive strength	B	6, 11, 12
b. Flexural strength	B, R/P	6
E. Durability		
a. Frost	B, R/P	4, 6
b. Chemical	B, R/P	6, 8
c. Corrosion of metal	B, R/P	8
d. Movement	B, R/P	6, 9, 10, 11, 12
e. Abrasion, impact	B, R/P	6: see also E*a* and E*b*
F. Appearance		
a. Efflorescence and lime bloom	B, R/P	8, 14
b. Decoration, dirt retention	R/P	8, 13, 14
G. Resistance to rain penetration	B, R/P	4, 8; see also B and E*d*
H. Thermal insulation	R/P	7, 15
J. Anti-condensation	R/P	8, 14, 15
K. Fire resistance	R/P	10; see also B and H

*B = Bedding R/P = Rendering and plastering

Table 3. Mortar mixes by volume of approximately equivalent strength

Mortar designation	Type of mortar		
	Cement:lime:sand	Masonry cement:sand	Cement:sand with plasticizer
(i)	1 : 0-¼ : 3	1 : 2-2½	1 : 2½-3
(ii)	1 : ½ : 4-4½	1 : 2½-3½	1 : 3-4
(iii)	1 : 1 : 5-6	1 : 4-5	1 : 5-6
(iv)	1 : 2 : 8-9	1 : 5½-6½	1 : 7-8
(v)	1 : 3 : 10-12	1 : 6½-7	1 : 8

NOTE 1. All proportions are by volume and should be interpreted as discussed in **11.1**.
NOTE 2. Mortars approaching the top of the table have increasing strength but decreasing ability to accommodate movements due to such causes as settlement, temperature changes and moisture changes.

Mortars in any one row are approximately equivalent in strength except that the masonry cement and plasticized mortars in the first and second rows are unlikely to have quite as high a strength as the corresponding cement:lime:sand mix especially if they are not subject to reasonable control and inspection. They do not generally differ greatly in most other properties; however, mortars approaching the right hand side of the table have increasing resistance to damage by freezing or sulphate attack, but decreasing ability to bond to units and resistance to rain penetration. These differences can be reduced by the use of appropriate admixtures; for example, the frost resistance cement:lime:sand mixes can be improved by the use of air-entraining agents, and the ability of plasticized mortars to bond to units can be improved by the use of water-retentive admixtures.

Table 4. Lime:sand mixes for specified cement:lime:sand mortars

a. Site mixed coarse-stuff

Mortar designation	Specified cement: lime:sand mortar	Lime-putty:sand	Gauging cement:coarse-stuff
(i)	1 : ¼ : 3	1 : 12	1 : 3
(ii)	1 : ½ : 4-4½	1 : 8-9	1 : 4-4½
(iii)	1 : 1 : 5-6	1 : 5-6	1 : 5-6
(iv)	1 : 2 : 8-9	1 : 4-4½	1 : 8-9
(v)	1 : 3 : 10-12	1 : 3½-4	1 : 10-12

b. Ready-mixed lime:sand for mortar
(if manufacturer's recommendation is not available)

Mortar designation	Specified cement: lime:sand mortar	Category of lime:sand mix	Amount of cement to be gauged with lime:sand mix	
			Normal use	Special use
(i)	1 : ¼ : 3	1 : 12	1 : 3	-
(ii)	1 : ½ : 4-4½	1 : 9	1 : 4½	1 : 4
(iii)	1 : 1 : 5-6	1 : 6	1 : 6	1 : 5
(iv)	1 : 2 : 8-9	1 : 4½	1 : 9	1 : 8
(v)	1 : 3 : 10-12	1 : 4	1 : 12	1 : 10

NOTE 1. All proportions are by volume.

NOTE 2. The proportions given for normal use in column 4 result in mortars with the higher sand content given in column 2; if difficulty were to be experienced in attaining satisfactory strength of the cement:lime:sand mortars, the proportion of cement to lime:sand mix may be increased by adopting proportions as rich as those given for special use in column 5 which result in the lower sand contents given in column 2.

BSI publications referred to in this document

This document makes reference to the following British Standards and Codes of Practice:

BS 12 Portland cement (ordinary and rapid-hardening)
BS 146 Portland-blastfurnace cement
BS 890 Building lime
BS 915 High alumina cement
BS 1014 Pigments for cement, magnesium oxychloride and concrete
BS 1199 Sands for external renderings; internal plastering with lime and Portland cement and floor screeds
BS 1200 Sands for mortar for plain and reinforced brickwork; blockwalling and masonry
BS 3148 Tests for water for making concrete
BS 3587 Calcium chloride (technical)
BS 3892 Pulverized-fuel ash for use in concrete
BS 4027 Sulphate-resisting Portland cement
BS 4248 Supersulphated cement
BS 4551 Methods of testing mortars and specification for mortar testing sand
BS 4721 Ready-mixed lime:sand for mortar
BS 4887 Mortar plasticizers

CP 111 Structural recommendations for loadbearing walls
Part 2. Metric units
CP 121 Walling
Part 1. Brick and block masonry
CP 121.201 Masonry walls ashlared with natural stone or with cast stone
CP 211 Internal plastering
CP 221 External rendered finishes