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Guide to the specification of masonry mortar

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Contents

Foreword

This Published Document has been prepared under the direction of Subcommittee B/519/2. It supersedes PD 6472:1974, which is withdrawn.

Changes in mortar standardization in the United Kingdom occurred with the introduction of the European specification for mortar for masonry, BS EN 998. It covers factory made mortar, however, it does not give guidance on site made mortar.

This Published Document gives some guidance on the specification of factory made masonry mortar conforming to BS EN 998-2 but is mainly aimed at providing guidance on the specification of site made masonry mortar.

This guidance on the specification of site made masonry mortar takes into account the requirements of BS EN 998-2 and takes information from the withdrawn PD 6472, a guide to specifying the quality of building mortars.

This Published Document also takes into account the guidance given in the code of practice for use of masonry, BS 5628.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

This Published Document is not to be regarded as a British Standard.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to ii, pages 1 to 27 and a back cover.

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Introduction

Traditionally in the United Kingdom mortar has been primarily specified in terms of volume or mass proportions, the "prescriptive" or "recipe" approach, so called because it gives a prescription for the mix proportions. This method is used in the code of practice for use of masonry BS 5628, and was used in the specification for ready-mixed building mortar BS 4721 and in the specification for prepacked mortar mixes BS 5838-2.

The alternative method of specifying mortars, based on measured parameters such as minimum compressive strength, is known as the "design" or "performance" approach. For example, BS 4721 required that a minimum compressive strength was achieved. The performance approach is specified in BS 5628-3.

BS EN 998 is the new British Standard for the specification of mortar for masonry, including the specification of constituent materials. It specifies requirements for designed mortars and, to a lesser extent, prescriptive mortars. Its publication has brought about a need to withdraw or update existing British Standards. Therefore, BS 4721:1981 and BS 5838-2:1980 have been superseded by both BS EN 998-1:2003 and BS EN 998-2:2003.

1 Scope

This Published Document gives guidance on the specification of prescribed and designed:

a) factory made masonry mortar conforming to BS EN 998-2; and

b) site made masonry mortar.

This Published Document is intended to be used in conjunction with the code of practice for masonry, BS 5628 and the specification for masonry mortar, BS EN 998-2.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 3177, *Method for determining the permeability to water vapour of flexible sheet materials used for packaging.*

BS 5628-1:2005, *Code of practice for the use of masonry — Part 1: Structural use of unreinforced masonry*.

BS 5628-2:2005, *Code of practice for the use of masonry — Part 2: Structural use of reinforced and prestressed masonry.*

BS 5628-3:2005, *Code of practice for the use of masonry — Part 3: Materials and components, design and workmanship.*

BS 8500-2:2002, *Concrete — Complimentary British Standard to BS EN 206-1 — Part 2: Specification for constituent materials and concrete.*

BS 6100 (all parts), *Glossary of building and civil engineering terms.*

BS EN 459-1, *Building lime — Part 1: Definitions, specifications and conformity criteria.*

BS EN 934-3, *Admixtures for concrete, mortar and grout — Part 3: Admixtures for masonry mortar — Definitions, requirements, conformity, marking and labelling.*

BS EN 998-2:2003, *Specification for mortar for masonry — Part 2: Masonry mortar.*

BS EN 1008, *Mixing water for concrete — Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.*

BS EN 1015-1, *Methods of test for mortar for masonry — Part 1: Determination of particle size distribution (by sieve analysis).*

BS EN 1015-2, *Methods of test for mortar for masonry — Part 2: Bulk sampling of mortars and preparation of test mortars.*

BS EN 1015-3, *Methods of test for mortar for masonry — Part 3: Determination of consistence of fresh mortar (by flow table).*

BS EN 1015-4, *Methods of test for mortar for masonry — Part 4: Determination of consistence of fresh mortar (by plunger penetration).*

BS EN 1015-6, *Methods of test for mortar for masonry — Part 6: Determination of bulk density of fresh mortar.*

BS EN 1015-7, *Methods of test for mortar for masonry — Part 7: Determination of air content of fresh mortar.*

BS EN 1015-9, *Methods of test for mortar for masonry — Part 9: Determination of workable life and correction time of fresh mortar.*

BS EN 1015-10, *Methods of test for mortar for masonry — Part 10: Determination of dry bulk density of hardened mortar.*

BS EN 1015-11, *Methods of test for mortar for masonry — Part 11: Determination of flexural and compressive strength of hardened mortar.*

BS EN 1015-17, *Methods of test for mortar for masonry — Part 17: Determination of water-soluble chloride content of fresh mortars.*

BS EN 1015-18, *Methods of test for mortar for masonry — Part 18: Determination of water absorption coefficient due to capillary action of hardened mortar.*

BS EN 13055-1, *Lightweight aggregates — Part 1: Lightweight aggregates for concrete,mortar and grout.*

BS EN 13139, *Aggregates for mortar.*

3 Terms and definitions

For the purposes of this Published Document, the terms and definitions given in BS EN 998-2, BS 6100 and the following apply.

3.1
addition
finely divided material used in mortar in order to improve certain properties or to achieve special properties

3.2
binder
material used to hold solid particles together in a coherent mass

NOTE Examples of binders include cement and building lime.

3.3
CE marking
mark signifying that a product conforms to the essential requirements of the relevant European Directive(s) and that the product has been subject to the appropriate conformity assessment procedure(s)

NOTE Harmonized European Standards are standards that include essential requirements from relevant European Directives. The level of attestation of conformity for CE marking purposes applicable to a particular product is decided by the European Commission and is included within the appropriate harmonized European product standard. There are six levels of attestation of conformity, some requiring third party involvement.

3.4
combination
restricted range of Portland cements and additions, which have been combined in the mortar mixer

3.5
designed masonry mortar
mortar with a composition and method of manufacture that is chosen by the producer in order to achieve specified properties

[BS EN 998-2, definition **3.2.1**]

3.6
factory made masonry mortar
mortar batched and mixed in a factory

NOTE Factory made mortar can be either "dry" mortar which is ready-mixed and requires only the addition of water or "wet" mortar which is supplied ready for use.

[BS EN 998-2, definition **3.4.1**]

3.7
factory production control
system consisting of procedures for the internal control of production, which has the objective of ensuring that products placed on the market conform to standard requirements and the declared values

3.8
fresh masonry mortar
plastic masonry mortar
mortar completely mixed and ready for use

NOTE The term plastic masonry mortar is sometimes used instead of fresh masonry mortar, particularly for mixes containing a cement set retarder.

3.9
initial type testing
testing undertaken prior to placing a product on the market and when changes occur, either in the basic materials or manufacturing procedures, which could affect the characteristics of the product

3.10
manufacturer
person who makes mortar either in a factory or on site

NOTE Traditionally the term associated with site made mortar production has been producer rather than manufacturer.

3.11
prebatched semi finished factory made masonry mortar
mortar with constituents wholly batched in a factory, supplied to the building site and mixed there according to the manufacturer's specification and conditions

[BS EN 998-2, definition **3.4.2.1**]

3.12
premixed lime:sand
semi finished factory made masonry mortar with constituents wholly batched and mixed in a factory, supplied to the building site where further constituents specified or provided by the factory are added

[technically equivalent to BS EN 998-2, definition **3.4.2.2**]

NOTE Historically this material has sometimes been known as ready-mixed lime:sand.

3.13
site mixed lime:sand
semi finished site made masonry mortar with constituents wholly batched and mixed on a building site where further constituents are added

NOTE Historically this material has sometimes been known as coarse stuff, a term which is now deprecated.

3.14
prescribed masonry mortar
mortar made in predetermined proportions, the properties of which are assumed from the stated proportions of the constituents

[BS EN 998-2, definition **3.2.2**]

3.15
reference panel
panel of masonry erected and retained on a building site, used to establish the visual acceptability of materials and workmanship to be maintained during construction work

[BS 5628-3, definition **3.48**]

3.16
workable life
time from the end of manufacture or final mixing of the masonry mortar until the mortar reaches a defined limit of resistance to penetration of a rod forced into it

NOTE The workable life of mortar is determined in accordance with BS EN 1015-9.

4 General

The relationship between fresh (plastic) mortar and hardened mortar is complex. The properties of fresh (plastic) mortar affect the properties of the hardened mortar and the two cannot be considered in isolation.

Traditionally the craftsman has been left to adjust the proportions of the constituents to produce a mortar which can be handled easily and in the experience of the craftsman would be adequate. However, requirements for strength or other important properties cannot be satisfied by this approach, as it can unduly consider the short term properties of the fresh mortar at the expense of the properties of the hardened mortar. While it is important for a mortar to be of suitable consistence for the craftsman to use, this requirement should not conflict excessively with the desired hardened properties.

It is seen therefore that whilst the craftsman can clearly be permitted to exercise choice with respect to the fresh (plastic) properties, some of the hardened properties should also be considered. This means that specifications for mortar need to state limiting values for mix proportions which should not be reduced or exceeded.

It is fortunate that some properties of mortar are relatively insensitive to normal performance or prescriptive requirements. For example, the thermal properties of a mortar are not greatly affected by the strength or the relative proportions of the materials, but are affected significantly by the choice of the density of the aggregate and to a much more limited extent by any air entrainment.

5 Methods of specifying masonry mortar

5.1 General

BS 5628 gives guidance on the design of masonry structures, including the design of masonry mortar.

The type of masonry mortar recommended for use differs for various conditions of design and exposure. This means that differing structural requirements give rise to the need for different mortar types. Similarly the durability environment will also impose requirements on the mortar type. These two influences mean that a mortar should be specified to take each need into account, without prejudicing the other.

An overview of the methods by which mortar can be specified is given in **5.2**, **5.3** and **5.4**.

5.2 Prescribed mortars

A “prescriptive” or “recipe” approach to mortar production involves detailing all of the constituent materials for the mortar and the recipes used to combine them.

BS 5628 describes a prescriptive approach to mortar production that is in line with the British Standard for masonry mortar, BS EN 998-2.

BS EN 998-2 allows for the specification of prescribed factory made mortars, with a requirement that the manufacturer declares the mix proportions by volume or by weight of all the constituents.

A prescribed mortar specification should be drafted so that the quality of the mortar is controlled by stated compositional requirements. Where prescribed mortar is produced, the manufacturer will verify conformity of the mortar to the specification by referring to any production records and delivery documentation.

CE marking of a prescribed factory made mortar signifies that the product conforms to the essential requirements of the European Commission’s Construction Products Directive (CPD) [1] unlike site made mortar, to which CE marking does not apply. Producing prescribed factory made mortar in accordance with BS EN 998-2 ensures that the mortar conforms to the CPD and can therefore be CE marked.

Conformity evaluation methods for both factory and site made masonry mortar can range from examination of production records to testing and comparison of the results with tabulated values for known compositions. Historically the assessment of conformity to a prescribed specification could only be achieved by the use of chemical analysis to BS 4551. An alternative now is to infer the mix proportions of the mortar from compressive strength. BS EN 998-2 states the relationship between compressive strength and mix proportions for a limited range of strengths and mortar compositions.

5.3 Designed mortars

A "design" or "performance" approach to mortar production involves specifying the final performance to be achieved by the mortar.

BS 5628 describes a design approach to mortar production that is in line with the British Standard for masonry mortar, BS EN 998-2, which specifies requirements for designed factory made mortars.

All the BS EN 998-2 requirements for properties that are considered relevant for the factory or site made mortar should be included in a designed mortar specification. The manufacturer is responsible for the evaluation and certification of conformity to the stated requirements.

CE marking of a designed factory made mortar signifies that the product conforms to the essential requirements of the European Commission's Construction Products Directive (CPD) [1] unlike site made mortar, to which CE marking does not apply. Producing designed factory made mortar in accordance with BS EN 998-2 ensures that the mortar conforms to the CPD and can therefore be CE marked.

Where designed mortars are manufactured on site, and not within a factory control system, the mortar specification should state how conformity is to be assessed. This can range from infrequent but regular testing of samples to visual inspection and random testing of samples with statistical analysis of results.

5.4 Factory made and site made mortar

The prescriptive and design approach to specifying mortar can be used to specify both factory made mortar and site made mortar.

The prescriptive and design approach to factory made masonry mortar is covered by BS EN 998-2.

There is no standard for site made mortars. However, the scope of BS EN 998-2 permits the use of national codes of practice or specifications for site made mortars. Therefore, specific guidance on the specification of site made masonry mortar is given in Clause **8**. This guidance is based on BS 5628 and the principles and requirements of BS EN 998-2. It is intended that this guidance is used by manufacturers of site made mortar in the United Kingdom.

5.5 Specifying masonry mortar using BS EN 998-2

5.5.1 *Category of use*

BS EN 998-2 classifies masonry mortar in terms of its proposed application. The three categories that have been identified are:

a) general purpose;

b) thin layer; and

c) lightweight.

5.5.2 *Mode of manufacture*

BS EN 998-2 defines mortar according to three different modes of manufacture. These are:

a) factory made;

b) semi finished factory made; and

c) site made.

Factory made mortars can be either dry mixed materials requiring only the addition of water at the site, or ready-to-use mixes containing a cement set retarding admixture which are delivered in tubs or bags and should be used within a stated time period. Semi finished factory made materials can be prebatched at the factory and delivered in silos only requiring the addition of water, or can be delivered in other containers and requiring the addition of other constituents, e.g. cement.

The scope of BS EN 998-2 does not include site made mortars although it is the only specification standard for masonry mortar in the United Kingdom and so the requirements of BS EN 998-2 can be used as the basis for specifying site made mortar.

Where a specifier draws up a specification for site made mortar the selection should be made from appropriate clauses from BS EN 998-2. Although the superseded UK specification for ready-mixed building mortars, BS 4721, was clearly written to cover only factory made mortars, in practice it was often invoked where mortars were made on site. It is anticipated that much of BS EN 998-2 will similarly become used for site made mortars.

If the specifier has not drafted a site made mortar specification based on the principles of BS EN 998-2 or used requirements from BS EN 998-2, the specifier should draft a detailed materials and conformity specification that conforms to BS 5628-3.

5.5.3 *Prescriptive approach*

Historically mortars were generally specified in terms of a prescription or recipe as, for example, in BS 5628.

The new British Standard for masonry mortar, BS EN 998-2, is a performance based standard. It recognises the prescriptive concept but gives no guidance on prescribed mortar mix proportions. BS EN 998-2:2003, **5.3** does however require that:

a) the proportions of all prescribed mortar mixes shall be declared by the manufacturer; and

b) the compressive strength of all prescribed mortar mixes shall be declared using publicly available references that establish relationships between mix proportions and compressive strength, e.g. Table 1 and Table 2.

Both items a) and b) apply when specifying prescribed factory made mortar in accordance with BS EN 998-2. Both items a) and b) should also apply when specifying prescribed site made mortar using the principles of BS EN 998-2.

Where specifiers require the use of site made mortars that conform to the traditional recipes (mortar designations) in BS 5628, the specifier should ensure that the mortar conforms to the mix proportions and consists of raw materials recommended in BS 5628. The specifier should specify that manufacturers are also responsible for combining and mixing the constituent materials in accordance with BS 5628 and ensuring that no extraneous materials are added to the mix.

The relationship between BS 5628 prescribed site made mortars and compressive strength is given in Table 1 and Table 2.

Compressive strength is required by BS EN 998-2 to be determined using prism specimens in accordance with BS EN 1015-11. The results obtained from this method are not directly comparable with test cube results obtained using the procedure given in BS 4551-1:1998, therefore, a conversion factor needs to be determined (or obtained from an authoritative reference) and applied where cube specimens are used to assess compressive strength.

NOTE BS 4551-1:1998 has been superseded by BS 4551:2005. The determination of the compressive strength of mortar is not given in BS 4551:2005 because this is covered by BS EN 1015-11.

5.5.4 *Performance approach*

A mortar specification for mortars conforming to BS EN 998-2 should contain requirements that refer to specific BS EN 998-2 clauses rather than repeating the BS EN 998-2 requirement in full. Specific reference to BS EN 998-2 clauses will also invoke many general requirements for constituent materials, production and conformity thereby negating the need to prepare an overly detailed specification.

The specification should include any special requirements for the site made mortar, e.g. for obtaining an aesthetic effect, that are not covered in BS EN 998-2.

A move to the use of performance based mortar specifications from traditional prescriptive mortar specifications simplifies the requirements of specification drafting. This is because the specifier has only to specify the performance requirements and the manufacturer takes responsibility for achieving them.

Therefore, for designed mortars it is the mortar manufacturer that selects which materials to use to ensure that the delivered product conforms to the specifier's requirements. A mortar specification should only include requirements for what constituent materials to use when special requirements exist, e.g. for obtaining an aesthetic effect, or a prescribed mortar is specified.

Table 1 — BS 5628 prescribed mortar designations (mixed by volume) and their compressive strength

	BS 5628 prescribed mortar designation	BS EN 998-2 compressive strength class	Prescribed mortars (proportion of materials by volume)				Compressive strength at 28 days
			Cement[a]: lime: sand with or without air entrainment	Cement[a]: sand with or without air entrainment	Masonry cement[b]:sand	Masonry cement[c]:sand	N/mm^2
↓ Increasing ability to accommodate movement, e.g. due to settlement, temperature and moisture changes	(i)	M12	1 : 0 to ¼ : 3	—	—	—	12
	(ii)	M6	1 : ½ : 4 to 4½	1 : 3 to 4	1 : 2½ to 3½	1 : 3	6
	(iii)	M4	1 : 1 : 5 to 6	1 : 5 to 6	1 : 4 to 5	1 : 3½ to 4	4
	(iv)	M2	1 : 2 : 8 to 9	1 : 7 to 8	1 : 5½ to 6½	1 : 4½	2

NOTE 1 All proportions are by volume and should be interpreted as discussed in **8.7.2**. Proportioning by mass will give more accurate batching than proportioning by volume, provided that the bulk densities of the materials are checked on site.

NOTE 2 When the sand portion is given as, for example, 5 to 6 the lower figure should be used with sands containing a higher proportion of fines whilst the higher figure should be used with sands containing a lower proportion of fines.

[a] Cement or combination of cement in accordance with **8.2.2**, except masonry cements.
[b] Masonry cement in accordance with **8.2.2**, (inorganic filler other than lime).
[c] Masonry cement in accordance with **8.2.2**, (lime).

Table 2 — BS 5628 prescribed mortar designations (mixed by mass) and their compressive strength

	BS 5628 prescribed mortar designation	BS EN 998-2 compressive strength class	Prescribed mortars (proportion of materials by mass)									Compressive strength at 28 days
			Cement (C)[a]: lime (L): sand (S) with or without air entrainment kg			Cement (C)[a]: sand (S) with or without air entrainment kg		Masonry cement (MC)[b]: sand (S) kg		Masonry cement (MC)[c]:sand (S) kg		
			C	L	S	C	S	MC	S	MC	S	N/mm^2
↓ Increasing ability to accommodate movement, e.g. due to settlement, temperature and moisture changes	(i)	M12	190	20	655	190	675	—	—	—	—	12
	(ii)	M6	135	25	700	155	710	165	700	115	745	6
	(iii)	M4	105	35	725	110	755	120	745	80	785	4
	(iv)	M2	70	50	740	85	775	95	770	60	805	2

NOTE 1 All proportions are by volume and should be interpreted as discussed in **8.7.2**. Proportioning by mass will give more accurate batching than proportioning by volume, provided that the bulk densities of the materials are checked on site.

NOTE 2 The quantities of cement have been stated to the nearest 5 kg, however, only complete bags of cement should be used in each batching operation. These quantities with the addition of water will yield approximately 1 000 kg of mortar.

NOTE 3 Where a BS EN 197-1 cement of less than strength class 42.5 N is used in cement:lime:sand mortar or cement:sand with plasticized mortar, in order to achieve the required compressive strength it may be necessary to increase the cement content of the mortar by approximately 10 % and adjust the other proportions accordingly.

NOTE 4 For BS 5628 mortar designations (ii), (iii) and (iv) the binder weights, i.e. the weights of C, L or MS, given are those for the leaner mixes shown in Table 1 as these are the most widely used in practice.

[a] Cement in accordance with **8.2.2**, except masonry cements.
[b] Masonry cement in accordance with **8.2.2**, (inorganic filler other than lime).
[c] Masonry cement in accordance with **8.2.2**, (lime).

5.5.5 *Factory production control and initial type testing*

Where site made mortar, specified in accordance with the principles of BS EN 998-2, is not produced under a factory production control system, the specification should describe the supervision, inspection and testing that is required in order to confirm that the mortar conforms to the specifiers chosen BS EN 998-2 requirements. However, where mortar is produced to a factory production control system, these additions to the mortar specification are unnecessary as they would duplicate the requirements of BS EN 998-2.

In the case of factory made mortars conforming to BS EN 998-2 conformity is demonstrated by initial type testing and factory production control. The schedule of tests required to be undertaken for initial type testing and the elements to be included in a factory production control system are specified in BS EN 998-2:2003, Clause **8**.

BS EN 998-2:2003, Annex ZA specifies that if designed mortar carries the CE mark, the factory production control system will have been certified by a notified body (third party certification body). However, for prescribed masonry mortars conforming to BS EN 998-2 to carry the CE mark, the factory production control system is not required to have been certified by a notified body.

5.5.6 *Designation, marking and labelling*

Factory made masonry mortar conforming to BS EN 998-2 will be designated, marked and labelled in accordance with BS EN 998-2:2003, Clauses **6** and **7**.

For factory made masonry mortars which are supplied as conforming to BS EN 998-2, the properties of the mortar that are designated by the manufacturer and included in the marking and labelling will be appropriate to the uses for which the mortar is marketed.

A site made masonry mortar specification written using the requirements of BS EN 998-2 need not include BS EN 998-2 requirements for designating, marking and labelling.

The properties covered by BS EN 998-2 that may be particularly common in designation, marking and labelling for masonry mortar are listed in Table 3.

Table 3 — Properties of mortar

Properties of fresh mortar	Properties of hardened mortar
Air content	Bond strength
Workable life	Compressive strength
Chloride content	Density
	Thermal conductivity
	Water absorption

6 The specification of masonry mortars

6.1 General

Mortar is a relatively simple material but might have to fulfil many functions during its service life. The requirements for both the fresh and hardened mortar are both complex and interacting, therefore, it is frequently necessary to adopt some compromise to ensure that one requirement does not unduly adversely affect another.

The decision on what type of mortar to specify, performance or prescription, should be based partly on an assessment of what work the specification is intended to cover, e.g. the size and/or importance of the job. Some general guidance on what to consider when specifying the physical properties of site made mortar and how to assess these properties is given in **6.2** to **6.8**.

6.2 Essential characteristics of the mortar

The specification should only include those requirements that are of significance to the quality of the work and are the responsibility of the contractor or supplier of materials.

6.3 Relationship between mortar properties and characteristics

BS EN 998-2:2003, Clause **5** specifies requirements for the properties of prescribed and designed factory made masonry mortars. These same requirements can be used as a basis for specifying prescribed and designed site made mortars.

Any requirements that are additional to the requirements of BS EN 998-2 should be clearly indicated as such.

The main properties of masonry mortar are listed in Table 4 alongside the relevant subclauses in BS EN 998-2 and any associated test method standards. The relationship between these properties and how they affect the characteristics of the mortar is shown in Table 5.

Table 4 — Properties of mortar

Item	Description	BS EN 998-2 subclause	Test method
1	Consistence		
	a) by flow table	—	BS EN 1015-3
	b) by plunger	—	BS EN 1015-4
	c) by dropping ball	—	BS 4551
2	Water retentivity	—	BS 4551
3	Air content	**5.2.3**	BS EN 1015-7
4	Correction time	**5.5.3** (thin layer masonry mortars only)	BS EN 1015-9
5	Workable life	**5.2.1**	BS EN 1015-9
6	Chloride content	**5.2.2**	BS EN 1015-17
7	a) Compressive strength	**5.4.1**	BS EN 1015-11
	b) Flexural strength	—	BS EN 1015-11
8	Dry bulk density	**5.4.5**	BS EN 1015-10
9	Water absorption	**5.4.3**	BS EN 1015-18
10	Water vapour permeability	**5.4.4**	BS EN 1745:2002, Table A.12
11	Bond strength	**5.4.2**	BS EN 1052-3
12	Thermal conductivity	**5.4.6**	BS EN 1745:2002, **4.2.2**
13	Colour (if applicable)	—	—

Table 5 — Properties of mortar affecting its characteristics

Item	Characteristics	Properties affecting characteristics[a]
A	Working and handling	1, 2, 3, 5, 4 (thin layer only)
B	Bond to units	1, 2, 3, 7, 11
C	Bond to ties or reinforcement	1, 2, 3, 4, 5, 7
D	Mechanical properties:	
	a) Compressive strength	2, 3, 7
	b) Flexural strength	7
E	Durability:	
	a) Freeze/thaw	3, 7
	b) Chemical	3, 7, 9, 10
	c) Corrosion of metal	6, 9, 10
	d) Movement	7, 11
F	Appearance:	
	a) Efflorescence and lime bloom	9, 10
	b) Decoration, dirt retention	9, 10, 13
G	Resistance to rain penetration	3, 9, 10 [see also B and Ed)]
H	Thermal insulation	8, 9, 10, 12
I	Fire resistance	12 (see also B and H)

[a] The letters and numbers listed in this column are cross-references to items in both this table and Table 4.

6.4 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 these. For example it might be appropriate to specify a minimum compressive strength for a masonry mortar in relation to the required strength of the wall or to specify the use of a particular type of mortar, such as a non plasticized as opposed to a plasticized mortar, to ensure adequate durability.

Performance specifications for factory made mortars conforming to BS EN 998-2 are required to specify the mortar in terms of the compressive strength mortar classes given in BS EN 998-2.

Performance specifications that specify site made mortars in terms of the compressive strength mortar classes given in BS EN 998-2 might need to require preliminary testing to assess whether the mortar conforms to the required compressive strength. It should be noted that this might only be practical for larger contracts. Where the specification includes requirements for preliminary testing, these requirements should also be included as part of the contractual requirements.

6.5 Characteristics not easily specified

Generally specifiers should avoid drafting requirements that cannot be quantitatively assessed.

Many specifications will need to include aesthetic requirements for the masonry work in its entirety, including the mortar joints. Where mortar characteristics such as colour or finish have to be specified these should be, where possible, related to manufacturer's standard colour ranges or the specifier will need to enter into discussions with the manufacturer on the preparation of reference panels. These reference panels should be retained for the duration of the contract. The specification should state the distance from which the acceptability of the reference panel and subsequent work will be judged. In any event, the production of these reference panels might well be an aid to subsequent brickwork quality issues on site.

NOTE Guidance on the production of reference panels is given in **8.1**c).

The specifier should remember that the evaluation of conformity of a mortar property that is not specified in a quantitative manner will be subjective, which could lead to a product that does not meet expectations.

6.6 Action to be taken in the case of nonconformity

Nonconformity is the failure to fulfil a specified requirement. In the context of this standard nonconformity could range from a minor deviation from a non core property to a more major deviation from an essential requirement such as compressive strength. In the case of a performance type of specification where a regular random sampling plan is in operation the necessary action might simply require a change in composition of the mortar, which should be expected to raise the quality sufficiently to ensure that future material will conform to the requirements of the specification.

Where a prescriptive type of specification has been used, the action to be taken should involve a review of operating procedures and checks on the calibration and tolerances of batching equipment.

Where there is a risk of some degree of structural failure in either the immediate future or in years to come, the faulty work might have to be removed and replaced although this situation is likely only to occur infrequently. In the vast majority of situations the likely consequences will be less serious and some immediate remedial action, such as raking out bedding joints and repointing, may be adequate. In general these situations result in a non critical shortfall in compressive strength or mix proportions which does not have a major implication for structural masonry strength but might affect durability.

6.7 Systems of inspection and testing

Where the importance or size of work does not warrant much inspection, the simplest possible type of specification should be drafted. Complicated requirements could lead to a high probability of the work being completed unsatisfactorily.

6.8 Cost of production (quality) control

The specification of a factory made mortar eliminates the necessity for the specifier to consider the cost of production (quality) control as a separate issue; the mortar manufacturer will have included all these costs within his overhead costs. Nevertheless some conservative designers might wish to incur the cost of further testing for conformity.

Where mortar is to be produced on site, the specifier should consider if the contract can be operated on a simple specification. If this is not possible 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 higher level of control could be justified if the predicted savings work out to be greater than the cost of this higher level of control. The savings could include reduced materials costs because of better factors of safety appropriate to the greater certainty of the quality of the mortar.

A construction might only be feasible if the material used to build it, including the mortar, is used to its full potential. This implies a need for maximum production (quality) control to keep variability to a minimum. Also, the construction might only be feasible if the financial risks from unsatisfactory work or delay in applying remedial measures demand a realistic expenditure on production (quality) control which can be utilized for specification purposes. The specifier should undertake a risk assessment to determine the consequences of nonconformity to the specification and consider the simplest and most cost effective way of ensuring conformity.

7 Drafting a specification

The specification should be free of vague requirements that cannot be measured, such as “to the specifier’s satisfaction”, because a manufacturer should not be held responsible for conforming to a requirement that the specifier has not defined in quantitative terms. Some characteristics, such as colour of mortar, cannot easily be specified in words.

The specification should be drafted with a clear and realistic concept of the manner in which it can be enforced. This implies that where it is necessary for the specification to include requirements that are additional to those specified in BS EN 998-2, the specification should provide methods for evaluating the conformity of the end product. A primary rule of specification drafting is that if a property cannot be quantitatively assessed it should not be specified. The specification should include information on what to do when the product does not conform to the specification requirements.

8 General clauses to be included in all site made masonry mortar specifications

8.1 Preamble

The site made masonry mortar specification 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:

a) any special facilities to be provided by the manufacturer;

b) what materials, equipment or methods of operation are to be subject to approval by the specifier prior to the commencement of work and prior to any change;

c) any preliminary testing or approval of site workmanship that is required (e.g. through the use of reference panels conforming to BS 5628-3:2005, **D.2.2**);

NOTE The standard of workmanship required to be employed to produce reference panels needs to be realistic and relate to normal workmanship standards. It is unrealistic to require the production of reference panels which are of a standard that is not representative of normal operating conditions.

d) action that might be required if the work is found not to conform to the requirements of the specification;

NOTE The type of action required in the event of nonconformity could range from acceptance under a concession to appropriate remedial action.

e) that the speed of set of all mortars is affected by temperature, specifically, masonry constructed in ambient temperatures lower than 3 °C can lead to difficulties (see BS 5628-3:2005, **A.5.1.1.1**).

8.2 Materials

8.2.1 *General*

Prescribed mortar specifications should state whether particular types of mortar, e.g. cement:lime:sand mortar, masonry cement mortar, cement mortar incorporating an air entraining plasticizer or lime based mortar, are required, permitted or prohibited. If alternative types of mortar are acceptable, this should be stated.

Where mortar is specified by prescription, the specifier is responsible for ensuring that the selected materials and mix proportions will achieve the intended performance with an adequate safety margin. This may involve the specifier or manufacturer undertaking initial testing.

The use of a prescriptive specification ensures that the quality of the materials used in site made mortar does not deviate from that which is required by the specifier. The requirements in the prescriptive specification may also be given in a performance specification involving infrequent testing, however, with frequent testing these requirements may be left to the discretion of the manufacturer and the adequacy of the measures taken by the manufacturer determined only by checking that the mortar produced conforms to the specification.

Table 1, Table 2 and Table 6 give guidance on the composition of BS 5628 prescribed masonry mortar mixes expressed by volume proportions and mass. Table 1 and Table 2 show the relationship between prescribed mortars and compressive strength. Table 6 shows the lime:sand mix proportions for these prescribed mortars for both site made and factory made mortars.

The constituent materials of site made mortar are batched and mixed on site, therefore, it is particularly important that for prescribed mortars the constituent materials are clearly specified. They can be specified in accordance with **8.2.2** to **8.2.10** or in accordance with the constituent material manufacturer's instructions. The decision as to which of the subclauses, **8.2.2** to **8.2.10**, are included in the specification depends on the number of types of mortar permitted.

Where there are no appropriate British, European or international standards but a technical approval[1)] is available for a material, the specification should require that the material is used in accordance with the recommendations of that certificate or technical approval.

[1)] A technical approval is a national or European certificate issued by a European Technical Approvals (ETA) issuing body. A list of ETA issuing bodies is maintained by the European Organisation for Technical Approvals, www.eota.be.

Where mortar is to be used in locations that could be exposed to aggressive chemical environments, e.g. on contaminated ground, the specifier might need to consider the necessity to specify materials that will minimize the occurrence of the ettringite or thaumasite forms of sulfate attack.

Where factory produced mortars are specified, the mortar manufacturer will be able to advise the specifier in detail on the mortar's performance for all of the main properties that are normally included in the specification. Where the mortar is to be mixed on site the specifier might need to specify the requirements in greater detail.

8.2.2 *Cement*

Unless there are special requirements, performance specifications should permit the producer to select an appropriate cement or equivalent combination. If there are special requirements, the specification should state which types of cement or combination are required, permitted or prohibited.

Prescriptive specifications should specify an appropriate cement or equivalent combination. The following cements, listed alongside their associated British/European standards, are likely to be specified for use in mortar.

a) Portland cement:	BS EN 197-1, CEM I.
b) Sulfate-resisting Portland cement:	BS 4027.
c) Portland slag cement:	BS EN 197-1, CEM II/A-S or II/B-S.
d) Portland fly ash cement:	BS EN 197-1, CEM II/A-V or II/B-V.
e) Portland limestone cement:	BS EN 197-1, CEM II/A-LL(L).
f) Masonry cement (inorganic filler other than lime):	BS EN 413-1, Class MC.
g) Masonry cement (lime):	BS EN 413-1, Class MC.

Prescriptive specifications should specify the strength class of the cement to the relevant standard and that appropriate corrections should be made to the proportion of cement or equivalent combination to be batched where strength classes of less than strength class 42.5 N are used.

Whilst they are not specified for use in BS 5628 prescribed mortars, there is limited experience of the use of CEM III/A blastfurnace cement conforming to BS EN 197-1 and BS EN 197-4 and the equivalent combinations in mixes for mortar.

Cements containing calcium chloride should not be used in mortar.

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 Portland cements nor with lime, nor should gypsum plaster be permitted in any mixes containing Portland cement.

8.2.3 *Additions*

The specification might need to include requirements for additions. The following are examples of types of additions, listed where possible alongside associated British/European standards, that are likely to be specified for use in mortar.

a) Pozzolanic material:	BS EN 450-1 for fly ash.
b) Latent hydraulic material:	BS 6699 for ground granulated blast-furnace slag.
c) Limestone fines:	BS 7979.

d) Mineral fillers (e.g. ground limestone or chalk) with an established history of use.

Where a cement conforming to BS EN 197-1 is combined in a mixer with an addition conforming to BS EN 450-1, BS 6699 or BS 7979 the resulting cementitious material is described as a combination. Combinations should conform to BS 8500-2:2002, Annex A.

8.2.4 *Lime*

Where the specification is for lime mortar or includes lime, it should specifiy:

a) lime conforming to BS EN 459-1;

b) whether particular types of lime, e.g. dolomitic lime, hydraulic lime, hydrated lime powder or lime putty, are required, permitted or prohibited;

c) whether lime binders need to be mixed to a paste (or putty) in advance;

d) any specific mixing requirements.

When using air limes, hydraulic limes or other lime based binders, specifiers and users should refer to manufacturer's data sheets where available for correlatoin to BS 5628 mortar designations.

Although strength development is normally measured at 28 days for cement based mortars, lime based mortars continue to gain strength over a long period and it might be appropriate to consider the strength development profile for the mortar in relation to its use.

Where site made lime mortar is to be used in restoration the working properties of the mortar are improved if hydrated lime powder is first made into lime putty or site mixed lime:sand (see **8.3.3.2** and **8.3.3.3**).

Traditionally lumps of quicklime were slaked (mixed with an excess of water) in metal troughs or pits dug into the ground. This ages (cures) the lime putty in a manner that increases its plasticity. After slaking, the resulting lime putty was allowed to mature for several days or even weeks, with more water being added as necessary. The use of pulverized quicklime increases the rate of slaking.

The slaking process is complicated and protracted, therefore, lime putty is now only used for special applications and the specifier should consult the manufacturers of this material prior to drafting the specification. Moreover the benefits of using this material are unclear.

Where hydraulic lime mortars are to be specified it is very important to take account of their reduced rate of strength development, particularly in cold weather conditions. Where minimum compressive strengths in the case of cement-based mortars are specified at an age of 28 days, hydraulic lime mortars will normally be tested at 90 days. The strength development of hydraulic lime mortars is very dependent on temperature with little or no hardening taking place at less than about 5 °C. This means that within the United Kingdom, it is rarely practical to continue construction with these materials during the winter months. Generally, if it is necessary to specify the use of hydraulic lime, advice should be sought from a specialist.

8.2.5 *Fine aggregate (sand)*

The British Standard for aggregates for mortar, BS EN 13139, uses the term "fine aggregate" for aggregate sizes less than or equal to 4 mm rather than the term "sand" which has traditionally been used in the United Kingdom.

Performance specifications should permit the producer to select an appropriate fine aggregate unless there are special requirements.

Prescriptive specifications should normally specify that fine aggregate conforms to the relevant gradings in BS EN 13139.

NOTE Guidance on the use of BS EN 13139 is given in PD 6682-3.

In some cases, fine aggregate not conforming to BS EN 13139 may be specified in a prescriptive specification. In such cases the requirements should ensure that the quality of the mortar is suitable for its intended end use, with particular consideration given to including requirements for:

a) nominal maximum size of particles (related to the type of use and type of finish for thin layer masonry mortar);

b) grading, e.g. where close control is required to ensure consistent strength and working life;

c) harmful fines content (considered separately from the total fines content fines);

NOTE Where the limit on the total fines content is exceeded, the use of the fine aggregate may be permitted where a satisfactory history of use exists. High levels of harmful fines, such as clay, can affect air entraining plasticizers and lead to a significant reduction in workability.

d) limitations on impurities, e.g. impurities affecting the hydration of cement, the appearance of exposed work or the corrosion of embedded metals;

e) colour and uniformity of colour.

A well graded fine aggregate generally has the potential to produce mortar of high workability. Some angular aggregates despite being well graded produce mortar of poor workability and the addition of an air entraining plasticizer can be beneficial.

8.2.6 *Lightweight aggregate*

The specification may state that lightweight aggregates, where present, should conform to BS EN 13055-1.

NOTE Guidance on the use of BS EN 13055-1 is given in PD 6682-4.

8.2.7 *Admixtures*

Performance specifications should permit the producer to select appropriate admixtures unless there are special requirements. If the latter is the case, the specification should state which types of admixture are required, permitted or prohibited.

Generally, where either a performance or prescriptive specification requires the use of admixtures, the specification should require that admixtures conform to BS EN 934-3.

Air entraining admixtures or dual function admixtures that both plasticize and entrain air should not be used with masonry cements because these cements already contain air entraining admixtures as part of their formulation.

The addition of air entraining admixtures to cement:lime:sand mortars improves the resistance of the mortar to frost attack and can also improve the working properties of poorly graded fine aggregates. With pigmented mortars control of air entrainment is necessary to ensure uniformity of colour in the finished product.

Water retaining admixtures can improve the bond when mortars are used in association with high suction units. Care should be taken to ensure that water retaining admixtures do not entrain air.

Cement set retarding admixtures are included in factory made wet ready-to-use mortars that are designed to remain useable for a period of hours/days after delivery. These admixtures may also be used in site made mortar.

Admixtures of different types should not be mixed unless specialist advice has been sought as to their compatibility.

Mortar specifications should prohibit the use of calcium chloride, or admixtures containing calcium chloride.

8.2.8 *Pigments*

Pigments can be added to lime:sand for site made mortar in which case it is the responsibility of the user to control the water and cement addition on site to maintain the uniformity of the colour. Pigments can also be added to factory made mortar by the manufacturer. It is essential that the amount and type of pigment added has no detrimental effects on the properties of the mortar.

Where pigments are to be included in the mortar, the specification should require that they conform to BS EN 12878.

8.2.9 *Water*

The specification should require the use of water that has an established suitability and/or history of use. However, for site made mortar, the specification might need to specify restrictions on the source of water to be used in the production of the mortar.

Generally, water that is fit for drinking is satisfactory. The water should normally be clean and free from impurities liable to have a deleterious effect on the mortar. In particular, seawater or brackish water can increase the risk of efflorescence, the appearance of dampness or other undesirable effects. Where testing is required to assess the suitability of a source of water, the tests should be undertaken in accordance with BS EN 1008.

8.2.10 *Fibres*

Where fibres are to be incorporated in the mortar, the specification should require that fibres conform to a technical approval.[2)]

[2)] A technical approval is a national or European certificate issued by a European Technical Approvals (ETA) issuing body. A list of ETA issuing bodies is maintained by the European Organisation for Technical Approvals, www.eota.be.

8.3 Storage and preparation of material

8.3.1 *General*

The specification should state any requirements that are needed for the storage, handling and preparation of the constituent materials of site made mortar.

The specification should include any requirements that are needed for storage and/or handling after production to maintain the properties of the mortar.

The requirements for a production control system for factory made mortar are specified in BS EN 998-2 and can be used in a specification for site made mortar.

8.3.2 *Storage of materials*

8.3.2.1 *General*

The specification should contain requirements for how to store materials. The requirements should be based on the advice given in **8.3.2.2**, **8.3.2.3**, **8.3.2.4** and **8.3.2.5** for particular types of material.

8.3.2.2 *Cement, additions and lime*

Cement, additions and lime should be stored in either of the following ways.

a) They should be stored in a weatherproof silo that permits free flow and efficient discharge of its contents. Each silo should be fitted with an independent filter (that is cleaned at regular intervals) or subjected to another method of dust control sufficient to allow the delivery to be maintained at the correct pressure for the silo. The silo should also be fitted with a high level alarm that sounds to prevent an excess of material being blown into the silo and a working pressure relief device which permits material to vent if the pressure in the silo becomes excessive.

b) Bagged material should be stored in such a manner that it does not become damp either from the weather or the ground. The store should be managed so that material is used in the same order in which it is delivered.

There is a legal requirement to ensure that products are not used after their maximum permitted storage period.

Material that has been adversely affected by moisture or other causes should not be used.

8.3.2.3 *Fine aggregate (sand)*

Fine aggregate should be stored in either of the following ways.

a) It should be stored on a hard standing (made, for example, from concrete) to avoid contamination from soil. Adequate drainage should be provided so that excess water coming from the fine aggregate can drain away. Material should only be drawn from the parts of the stockpile that have drained. Precautions should be taken to prevent the fine aggregate from becoming frozen, e.g. by covering.

NOTE Even if the air temperature does not fall below freezing point, the materials at the surface of the exposed stockpiles can become frozen on a clear night unless the stockpile is covered.

b) It should be stored in hoppers raised above the ground. Precautions should be taken to prevent the fine aggregate from becoming frozen.

8.3.2.4 *Admixtures, pigments and fibres*

Admixtures, pigments and fibres should be stored in accordance with the manufacturer's instructions and attention should be given to preserving the legibility of product labels.

Admixtures should be protected from extremes of temperature, e.g. by covering them or placing them in buildings. Where admixtures become frozen the manufacturer should be consulted prior to their use.

8.3.2.5 *Premixed lime:sand*

Premixed lime:sand for mortar should be delivered in a suitable container, for example in:

a) sheeted tipping vehicles from which the material should be discharged onto a clean impermeable surface and the stockpile covered; or

b) sheeted bulk delivery skips.

Covering should be used to protect the material from rain or excessive evaporation of water.

Prolonged storage before use, which can lead to excessive carbonation of the surface of the stockpile, should be avoided unless the material has been closely covered with an impermeable material (e.g. polythene sheeting). Sheeting is particularly important in the case of pigmented lime:sand since rain and weathering can cause loss and segregation of fine material including pigments.

8.3.3 *Preparation of materials*

8.3.3.1 *General*

The specification should contain requirements for how to prepare materials. The requirements should be based on the advice given in **8.3.3.2**, **8.3.3.3**, **8.3.3.4** and **8.3.3.5** for particular types of materials and situations.

8.3.3.2 *Lime putty*

The use of lime putty is very rare these days. However, where lime putty is to be included in mortar, the specification should require that lime putty be made by adding hydrated lime powder to water (not water to the lime) and mixing thoroughly until the putty has the consistence of a thick cream. Lime putty should be covered and allowed to stand for a minimum of 24 h before use.

8.3.3.3 *Site mixed lime:sand*

Site mixed lime:sand should be made by mixing hydrated lime powder with fine aggregate.

Once mixed, the site mixed lime:sand should be covered and allowed to stand for a minimum of 24 h before use.

8.3.3.4 *Admixtures*

Liquid admixtures should be agitated in the containers in which they come to ensure the uniform distribution of the admixtures' constituents. Unless otherwise recommended by the manufacturer powdered admixtures should where possible be dissolved in part of the mortar mixing water before being added to the mortar mix.

8.3.3.5 *Cold weather*

The specification might need to include requirements for work that is to be undertaken in cold weather. For instance, the specification might require that special measures are taken if the work is to continue when the air temperature is likely to fall below 2 °C, a temperature at which mortar production might be affected.

8.4 Batching of materials

8.4.1 *General*

A specification for site made mortar should state whether particular constituent materials are to be batched by mass or by volume. The specification should also either require or recommend procedures for batching.

Prescriptive specifications for site made mortar should state unambiguously the procedure to be adopted on site for batching all constituent materials. Performance specifications for site made mortar may also include similar requirements, especially if the amount of testing envisaged is small.

A higher level of control will be achieved where all materials are batched by mass. Cement, additions and lime powders should always be batched by mass or by the full contents of a manufacturer's package unit (e.g. a full bag).

The specification should not permit the batching of any materials by shovelful.

Lime putty, fine aggregate, premixed lime:sand for mortar, site mixed lime:sand, fillers and admixtures (including liquid admixtures) may be batched by mass or volume. Batching dry products by volume should be avoided.

Powdered pigments should always be batched by mass.

Water may be batched by mass or volume.

8.4.2 *Batching by volume*

8.4.2.1 *Containers for volume batching*

Where batching by volume cannot be avoided, gauge boxes and similar containers used for volume batching should be rigid enough not to distort when filled and, where appropriate, watertight. They should be deep in relation to the cross-sectional dimensions at their tops. The volume of each box or container should 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 should be provided and used for striking off excess material flush with the top. The volume of each container, flush with the top, should be determined and marked on the container.

8.4.2.2 *Condition of materials at the time of batching*

The 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. Therefore, the specification might need to state limitations on the conditions of the various materials to be batched by volume. All dry powders vary in density according to the amount of aeration in the material. Fine aggregate, lime putty, site mixed lime:sand and premixed lime:sand for mortar vary in density according to the moisture content of the material.

Where the variation in the condition of a material will not have a significant effect on the accuracy of batching, the specification should require that the moisture content of materials be determined at regular intervals. If the moisture content falls outside stated limits, stated adjustments should be made to the volume of material being batched.

Where the variation in the condition of a material will have a significant effect on the accuracy of batching, the specification should require that the bulk density of materials should be determined at regular intervals. If the values fall outside stated limits, stated adjustments should be made to the volume of material being batched. The bulk density of a material should be determined by batching a quantity, as required by the specification, and measuring the mass of material batched. The bulk density should be calculated as the measured mass divided by the volume of the container.

8.4.2.3 *Batching procedure*

Before being filled, the batching container should be empty and clean.

The batching container should be filled using an established procedure that can be relied upon to impart approximately a similar amount of compaction every time the container is filled.

The filling process should result in the batching container being slightly overfilled and the excess material screeded off until the material is flush with the top of the container.

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 should be screeded off with the straight edge flush with the top of the container.

8.4.3 *Batching by mass*

8.4.3.1 *Batching by package*

The specification may permit the batching of all materials by complete package (in the case of bagged materials) provided that the packages are available in masses that can be used to match the material mass requirements of the specification.

However, if the specification requires the use of a mass that cannot be matched by the mass of any available packages, the specification should require the use of weigh batching in accordance with **8.4.3.2**.

8.4.3.2 *Weigh batching*

The specification should require that hoppers used for weighing cement, additions and hydrated lime powder should have seals fitted between the loading mechanism and weigh hopper or weigh mechanism, which should not affect the weighing accuracy. The hopper or mechanism should be vented to permit the release of air.

The specification should require that the weigh scale display is legible from the operating position.

The specification should require that weigh batching equipment should be carefully maintained and regularly checked for accuracy. The weigh hopper and other moving parts should be kept clean and lubricated.

The specification should require that prior to weighing, the weigh hopper should be checked to ensure that it is completely empty and that the scale is reading zero. Tare adjustments should be permitted.

After weighing the material the weigh hopper should be completely discharged.

8.4.4 ***Batching of water***

The specification may permit the operative to determine the amount of water to add to the mortar when it is being mixed. The amount of water added may be determined on the basis of the operative's judgement of the consistence needed to carry out the work. Any other methods of controlling the quantity of water required, for instance by specifying the maximum permitted water:cement ratio, are likely to lead to some properties of the mortar being adversely affected.

8.5 Mixing

The specification should state whether any mixing undertaken on site is to be by hand, by machine or by either. Normally, mortar should be mixed by machine and hand mixing should only be 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. Where hand mixing is permitted, the specification should require that it is to be undertaken on a clean non-absorbent platform.

Mixing equipment should be cleaned out before use, prior to changing mixes and at the completion of work. Cleanliness is particularly necessary where colour is important and with pigmented mortar to prevent colour variation.

Water should be added to the mixer followed by some of the lime:sand or aggregate. The binder and the remaining lime:sand or aggregate and water should be ribbon fed in increments until the required quantity and workability is achieved.

The specification might need to state limitations on the amount of mixing. Mixing should be continued until all the materials are thoroughly mixed together and the mortar appears homogenous, this is especially important if the mortar is to be coloured. With air entrained mortars the specification might need to require that checks be made to ensure that the air content does not exceed a stated limit as a result of reduced or prolonged mixing times.

Dry ready-to-use mortar should be mixed and used in accordance with the manufacturer's instructions.

Cement based mortars have to be used before the initial set of the binder has taken place. On no account should the mortar be retempered after the commencement of the initial set.

Remixing of mortar, including the addition of further water to replace any lost by evaporation or by other causes, should be permitted for a stated time after initial mixing.

Normally, remixing of mortars containing cement may be permitted for a period of 2 h from the time of first mixing cement and water but this period might need to be reduced in hot weather. Where the mortar contains a cement set retarding admixture, the time within which remixing is permitted can be extended beyond 2 h. Pigmented mortars should be remixed with care.

Hydraulic lime based mortars and hydrated lime based mortars may be remixed after a longer period of time than 2 h (even after the initial set has started) depending on their hydraulicity.

If the quantity of water that has to be added during remixing is excessive, the mortar should be discarded.

8.6 Use of the mortar

The specification should include any requirements that are necessary to ensure that the mortar is used in accordance with the code of practice for the use of masonry, BS 5628.

The specification should reflect the required strength and durability of the masonry mortar, taking into account the conditions to which it will be exposed.

Consideration should be given to the fact that mortars with a high cement content have higher strengths but can also have poorer working properties. In some circumstances, mortars with a high cement content can crack because of their lack of flexibility.

8.7 Proportions of materials

8.7.1 *General*

Traditionally building mortars and plasters were specified in parts by volume of the constituents. Except for relatively minor variations the ratio of binder to fine aggregate is kept at 1:3.

In the case of cement:lime:sand mortars the volume of total binder (i.e. cement plus lime) is maintained at about one third of that of the fine aggregate but the relative proportions of binder to lime is varied according to the intended use and the requirements of the working properties, strength, durability and the risk of movement and cracking.

In the case of air entrained cement:sand mortars, the entrained air should extend the volume of the cement paste fraction so that it is about one third of that of the fine aggregate.

The range of limits for the lime content of premixed lime:sand for mortar arises because lime putty has a high plasticity and if dry hydrated lime is used, the volume may be increased by up to 50 % to produce similar workability. Similarly a well graded fine aggregate requires less lime than a poorly graded or single size fine aggregate.

8.7.2 *Proportions by volume of cement, lime and fine aggregate (sand)*

Prescriptive specifications should state the prescribed volume proportions of the solid constituents of the mortar on the basis of stated assumed characteristics of the materials. They should require prior notification, to the specifier or their agent, of proposed changes of source or type of materials.

Where specifiers require the use of site made mortars that conform to the traditional recipes (mortar designations) in BS 5628, the specifier should ensure that the mortar conforms to the mix proportions recommended in BS 5628. The volume proportions of BS 5628 mortar designations are given in Table 1.

To meet a special performance requirement, e.g. to obtain a particular aesthetic effect, performance specifications may specify different proportions of cement to those recommended in Table 1. The performance of these modified mortar mixes should be established by site testing of trial mixes.

Different types of prescribed mortar can have similar properties. For example, Table 1 groups together different types of mortar that have similar compressive strengths. Where a prescriptive specification permits the use of alternative types of prescribed mortar, the specification should state the required volume proportions for each type of mortar.

When using volume proportions the specification should advise the manufacturer to take into account each of the following factors.

a) The density of the cement at the time of batching is taken as 1 450 kg/m^3. In practice the density of cement, as batched by volume, can be as low as 1 200 kg/m^3.

b) If the lime is not in the form of lime putty but is to be batched as hydrated lime powder, the proportion by volume may be increased by up to 50 % to obtain adequate workability.

c) Damp fine aggregate bulks. For very fine aggregate, bulking can amount to 40 % or 50 % of its volume. The volume proportions of the fine aggregate given in the specification may be increased in proportion to the bulking.

Where the specification permits the use of site mixed lime:sand for mortar (historically known as coarse stuff) or premixed lime:sand for mortar, it should state the equivalent proportions of cement (if required) to be used with these materials. Where the specification permits the use of site mixed lime:sand, it should state the quantities of lime and sand required. Guidance on the volume proportions for gauging cement with the lime:sand mixes described in Table 1 for BS 5628 mortar designation is given in Table 6. The volume proportions of the lime:sand mixes given in Table 6 are the same for both site mixed lime:sand and premixed lime:sand mixes.

The mortar manufacturer should order only the required lime:sand mix by the prescription given in Table 6. The manufacturer should then supply the lime:sand mix such that a sample taken in accordance with BS EN 1015-2 will conform to the mortar specification. The lime:sand mix can be expected to yield mortars that conform to the mortar specification when gauged with cement in the volume proportions given in Table 6.

It may be assumed that, provided the material is well compacted in the batching operation, each volume of site mixed lime:sand, or of premixed lime:sand for mortar, contains that same volume of dry fine aggregate; the lime and water can be contained entirely within the voids of the fine aggregate. Under these conditions,

the bulk density of the site mixed lime:sand or of premixed lime:sand can be as high as 2 000 kg/m^3. However, if the material is of low consistence and not fully compacted when batching, the value can be as low as 1 400 kg/m^3.

Table 6 — Proportions for BS 5628 prescribed cement:lime:sand mortar designation based on site mixed and premixed lime:sand

BS 5628 prescribed mortar designation	Cement:lime:sand mortar	Lime:sand mix	Cement gauged with lime:sand mix	Cement gauged with lime:sand mix	
				Cement kg	Lime:sand kg
(i)	1 : 0 to ¼ : 3	1 : 12	1 : 3	190	675
(ii)	1 : ¼ : 4 to 4½	1 : 9	1 : 4½	135	725
(iii)	1 : 1 : 5 to 6	1 : 6	1 : 6	105	750
(iv)	1 : 2 : 8 to 9	1 : 4½	1 : 9	70	790
NOTE The quantities of cement have been stated to the nearest 5 kg, however, only complete bags of cement should be used in each batching operation. These quantities with the addition of water will yield approximately 1 000 kg of mortar.					

8.7.3 *Proportions by mass of cement, lime and fine aggregate (sand)*

A prescriptive specification should either:

a) state that the proportions by mass are to be subject to agreement following preliminary trials to determine what proportions are needed to achieve the required mortar properties; or

b) state the prescribed proportions by mass of the solid constituents of the mortar, giving the equivalent proportions for any permitted alternative constituents.

The specified proportions by mass may be based on the volume proportions given in Table 1 converting them to proportions by mass on the basis of the assumed bulk densities given in Table 7.

Table 7 — Bulk densities

Material	Bulk density
Portland cement (BS EN 197-1, CEM I)	450 kg/m^3
Portland/slag cement (BS EN 197-1, CEM II/A-S or II/B-S)	1 600 kg/m^3
Portland/fly ash cement (BS EN 197-1, CEM II/A-V or II/B-V)	1 400 kg/m^3
Portland/limestone cement [BS EN 197-1, CEM II/A-LL(L)]	1 400 kg/m^3
Masonry cement (inorganic filler other than lime): BS EN 413-1, Class MC	1 375 kg/m^3
Masonry cement (lime): BS EN 413-1, Class MC	1 050 kg/m^3
Lime putty	1 350 kg/m^3
Hydrated lime powder	520 kg/m^3
Dry fine aggregate	1 675 kg/m^3
Hydraulic lime powder:	
a) BS EN 459-1, NHL 2	550 kg/m^3
b) BS EN 459-1, NHL 3.5	650 kg/m^3
c) BS EN 459-1, NHL 5	700 kg/m^3

An example of mass proportions that have been derived from the BS 5628 volume proportions shown in Table 1 is given in Table 2.

To meet a special performance requirement, e.g. to obtain a particular aesthetic effect, performance specifications may specify different proportions of cement to those recommended in Table 2. The performance of these modified mortar mixes should be established by site testing of trial mixes.

It should be assumed 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.

Where the specification permits site mixed lime:sand, the required relative proportions by mass of lime, fine aggregate and water and the proportions by mass of cement and site made lime:sand should be specified.

Where the work requires a high degree of quality control, the manufacturers of the constituents for mortar may also be asked for co-operation in supplying material that has a uniform consistence and characteristics.

8.7.4 *Proportions of admixtures and pigments*

A prescriptive specification should require that either the proportions of admixtures and pigments conform to the manufacturer's instructions, or the proportions are subject to agreement between the manufacturer and the specifier following preliminary site trials.

There is some evidence that for black pigments based on carbon the maximum proportion of pigment should be limited to 3 % by mass of binder, although iron oxide or manganese dioxide black pigments do not need to be subject to this constraint.

Pigments can be added to lime:sand for site made mortar in which case it is the responsibility of the user to control the water and binder addition on site to maintain the uniformity of the colour. Pigments can also be added to factory made mortar by the manufacturer. It is essential that the amount and type of pigment added has no detrimental effects on the properties of the mortar.

8.8 Control

8.8.1 *General supervision*

The specification for site mixed mortar might 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 by the supervisor, for example, the examination of gauging vessels to ensure cleanliness and an absence of hardened build up.

8.8.2 *Batching by volume*

The specification might need to require that:

a) the batching containers are calibrated, maintained in good condition and used properly for producing every batch of mortar; and

b) where necessary, the variations in the moisture content and grading of the fine aggregate and in the consistence of lime putty, site mixed lime:sand or premixed lime:sand for mortar are limited so that the amount of each material batched is maintained within stated limits.

8.8.3 *Batching by mass*

The specification might need to require that:

a) the weighing equipment is calibrated, maintained in good condition and operated correctly for producing every batch of mortar; and

b) where necessary, required adjustments are made to the mass of fine aggregate if the moisture content falls outside stated values.

8.9 Work on site

8.9.1 *General*

The specification should refer to relevant standards for guidance and requirements on constructing brick and block masonry walls, e.g. BS 5628-3:2005, Annex A.

NOTE 1 Additional guidance on the use of factory made mortars is provided on Mortar Industry Association data sheets.[3)]

NOTE 2 Guidance on the quantities of mortar for use inlaying bricks is given in Annex A.

[3)] Data sheets on factory made mortar can be obtained by writing to the Mortar Industry Association, 38–44 Gillingham Street, London SW1V 1HU or by free download from www.mortar.org.uk.

The specification might need to include the following statements.

a) The fresh mortar should be protected from adverse weather conditions that can affect moisture content or temperature (e.g. extremes of wind, precipitation or sunlight).

b) Unless the construction is protected, work should be discontinued during adverse weather and newly completed work should be covered. Protection should be provided against extremes of temperature. In frosty weather, heated mortar should not be exposed so long that it will cool excessively before use.

c) Where the appearance of the mortar is important, finished work should be protected against splashing or impact by precipitation, from the ground, from scaffolding or by other construction activities.

d) In hot weather, air entrained mortars should be protected from drying out. This is necessary to minimize loss of consistence that occurs from the collapse of air bubbles, which cannot be easily reintroduced, as well as from loss of water.

8.9.2 *Wet ready-to-use mortars*

Ready-to-use cement mortars incorporate a set retarder which extends the working life of the mortar but enables it to set normally when used in masonry. Generally the wet ready-to-use mortars have an extended working life of 36 h, however, periods of up to 72 h are possible.

The specification should state that wet ready-to-use mortars should be stored and used in accordance with the manufacturer's recommendations. These wet ready-to-use mortars are in a plastic state and should be delivered in containers such as skips. The container should be covered when not in use to protect against adverse weather.

Wet ready-to-use mortars should be used before the working life specified by the manufacturer expires. On no account should the mortar be remixed in a mechanical mixer unless specifically approved by the manufactuer.

8.9.3 *Dry ready-to-use mortars*

Dry ready-to-use mortars may be stored in silos or bags, in the former case there is no need for additional protective requirements, however, bags should be stored in dry conditions, protected from inclement weather and used in the order that they are delivered.

Dry ready-to-use mortars should be used before the storage life specified by the manufacturer expires.

NOTE Further information on prepacked dry ready-to-use mortars is given in Annex B.

8.10 Inspection

8.10.1 *General*

The specification may state how, in the event of apparent failure to conform to the requirements, any dispute is to be resolved.

For example it may state that if the mortar is suspected to be unsatisfactory, a sample of the mortar that is representative of a stated amount of the work shall be taken. This may be achieved by requiring that the mortar be sampled at specified time intervals or after the laying of a specified quantity of masonry units. Details of these samples should be recorded and arrangements made for them to be analysed.

8.10.2 *Preliminary testing*

A prescriptive specification for site made mortar should require that preliminary tests, such as determining compressive strength, be performed on the mortar to establish that the proportions as determined by the tests are consistent with the composition specified. The specification should require that the preliminary tests be performed on mortar made at the site and from the constituent materials that are intended to be used. The skill required to conduct such analyses demands that appropriate laboratory facilities are made available on site or are readily accessible.

8.10.3 *Regular testing of samples*

The specification might need to state that the specifier's representative is to be expected to take samples of mortar at regular intervals unless a production control system is in operation.

It should require that the sampling, testing and interpretation of results be in accordance with the relevant part of BS EN 1015.

8.10.4 *Visual inspection with testing of suspect mortar*

The specification might need to state that if the quality of any mortar is suspected not to conform to the performance requirements, a sample shall be taken for testing. The sample should be representative of a stated amount of the work, e.g. the sample can be taken at specified time intervals or after the laying of a specified quantity of masonry units.

Subsequently, if the sample is found not conform to the requirements of the specification, any resulting action should be limited to the work represented by the sample.

The specification should require that records be kept of what work was completed for a particular batch of mortar sampled for testing.

8.10.5 *Regular testing for statistical quality control*

The specification might need to state the detailed procedure by which the results are to be examined to determine whether they indicate conformity to the requirements. The specification might need to state that if the mortar does not conform to the requirements, an adjustment of the composition of the mortar may be requested. Where individual results are outside stated control limits, other actions (such as remedial work) 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 the cumulative summation technique described in BS 5703 may be adopted.

8.11 Basis of performance

Designed mortars will usually be adopted for work where the strength of mortar will be important, such as in loadbearing masonry. If so, the performance specification should state what strength is to be measured and what age the mortar needs to be at the time of testing. It should require that the strength of the mortar is tested in accordance with BS EN 1015-11.

A specified limiting value of strength should be based on the necessary strength and durability characteristics of the mortar and on the system of inspection to be specified, i.e. the more inspection required, the more relaxed the specifier could be about the limiting value.

Inspection may be primarily visual, requiring either the sampling and testing of suspect mortar only or the regular testing of random samples. Where appropriate, the specification should state what supplementary tests and limiting values are required if the visual inspection leads to doubt about the quality of the fine aggregate.

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

It should require that mortar be sampled and tested according to the requirements of the relevant part of BS EN 1015, with specific reference to the particular test or tests, and stating specific procedures where alternatives are given.

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

Annex A (informative)
Quantities of mortar for use in laying bricks and blocks

A.1 Premixed lime:sand for mortar

1 t of premixed lime:sand, when gauged with the correct amount of Portland cement, is sufficient to lay approximately 1 000 traditional format bricks (215 mm × 102.5 mm × 65 mm). The number of concrete blocks that can be laid will be rather less as they are bigger than bricks.

A.2 Wet ready-to-use mortar

1 m^3 of mortar is sufficient to lay approximately 1 800 traditional format bricks (215 mm × 102.5 mm × 65 mm).

Annex B (informative)
Prepacked dry ready-to-use mortars

The material from which the packages of prepacked dry ready-to-use mortars are made should have a water vapour transmission not greater than 20 g/m^2 in 24 h when determined in accordance with BS 3177. This does not apply to packages of less than 5 kg.

The volume yield of a prepacked mortar is the volume of a wet mix of workable consistence obtained from a unit mass of dry material.

The volume yield of a prepacked mortar can be determined in the following way.

a) Prepare a sample of mortar in accordance with BS EN 1015-2 and record the amount of water required to achieve the specified consistence, expressed as a percentage by mass of solid ingredients to the nearest 0.1 %.

b) Determine the bulk density of the wet mortar in accordance with BS EN 1015-6.

c) The volume yield may be calculated to the nearest 0.000 1 m^3 from Equation (1).

$$V = \frac{(R \times 0.01 \times W) + W}{D} \qquad (1)$$

where

V is the volume yield per unit package (m^3);

W is the mass of unit package (kg);

R is the water required to achieve the specified consistence (%);

D is the wet bulk density of the mortar (kg/m^3).

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[1] EUROPEAN COMMUNITIES. 89/106/EEC. Council of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products. Luxembourg: Office for Official Publications of the European Communities, 1988, www.publications.eu.int.

[4)] BS 4551-1:1998 has been superseded by BS 4551:2005.

[5)] BS 4721:1981 and BS 5838-2:1980 were superseded by BS EN 998-1:2003 and BS EN 998-2:2003 in January 2005.

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