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Mortar testing

Typical mortar testing facilities

In the UK factory produced mortar must comply with the requirements of the European Standard BS EN 998-2 Specification for mortar for masonry, Part 2: Masonry mortar. The standard, details the properties to be measured and the procedures that are required before a product can commence manufacture and be offered for sale. The tests specified in the standard are used during the Initial Type Testing (ITT) phase after product development; this establishes the individual property values to enable a formal declaration of performance (DoP) to be made and the issue of CE marks. Values obtained during ITT are used for factory production control and for comparison against other future test results.

Mortar testing is undertaken on material in its fresh[1] state or on hardened mortar.

General information

Testing mortar is undertaken for a variety of reasons which include the evaluation of conformity to a specification or standard, to control and monitor the consistency of a product or process, to examine performance against project specific requirements and as part of an investigation in to a specific issue or to understand a defect.

Testing, whether on site or in a laboratory, should always be carried out by suitably trained, experienced and supervised staff with appropriate, well maintained testing equipment and resources. Care should always be taken in the storage and transport circumstances of all samples to avoid unintentionally affecting the test results.

The four principle forms of testing which can be undertaken:

i) Production Control Testing: The manufacturer of finished construction materials and components will routinely undertake testing to monitor and control production processes. For example, a producer of aggregates for mortar will measure particle size distribution on a regular basis and use variations in results to adjust the production process.

ii) Performance Testing: Assesses the end performance of a construction material against established criteria. For example, strength testing hardened mortar is becoming increasingly important as new product standards enable mortar to be designed to a minimum strength rather than being supplied to a recipe (prescription).

iii) Compliance Testing: This involves testing materials or components against the requirements of a contract specific specification or a published standard.

iv) Analytical Testing: This involves investigating problems in order to resolve causes of issues for example, chemical analysis of hardened mortar to determine the cement content of a prescribed mortar.

[1] Mortar described as fresh includes material that has been retarded for a required period of time and remains in a usable / plastic state.

Standards

The two standards that are applicable for testing mortar are, BS EN 1015 - Methods of test for mortar for masonry (a multi-part standard) and BS 4551 - Methods of test for mortar – Chemical analysis and physical testing. Table 1, below, lists all the applicable test method standards:-

Table 1: Mortar test method standards

BS EN 1015 - 1	Determination of particle size distribution (by sieve analysis)
BS EN 1015 - 2	Bulk sampling of mortars and preparation of test mortars
BS EN 1015 - 3	Determination of consistence of fresh mortar (by flow table)
BS EN 1015 - 4	Determination of consistence of fresh mortar (by plunger penetration)
BS EN 1015 - 6	Determination of bulk density of fresh mortar
BS EN 1015 - 7	Determination of air content of fresh mortar(i)
BS EN 1015 - 9	Determination of workable life and correction time of fresh mortar
BS EN 1015 - 10	Determination of dry bulk density of hardened mortar
PBS EN 1015 - 11	Determination of flexural and compressive strength of hardened mortar
BS EN 1015 - 17	Determination of water-soluble chloride content of fresh mortar
BS EN 1015 - 18	Determination of water absorption due to capillary action of hardened mortar
BS EN 1015 - 19	Determination of water vapour permeability of hardened rendering and plastering mortar
BS EN 451	Mortar - methods of test for mortar - Chemical analysis and physical testing

The test methods for all parts stated above can be found within the Standard itself. Outline guidance on the test methods is also available in MIA learning text 08 via the MIA website at www.mortar.org.uk/resources'

Testing mortar constituents

Testing the performance of the cement component of mortar is made by measuring the strength of the finished mortar under specified laboratory conditions.

The various constituents used to produce mortar are routinely tested to established standards by the constituent manufacturer in order to demonstrate the grade or type. However, mortar manufacturers will also test the main constituents on a routine basis. This is because minor variations in their properties can have a significant impact on the finished mortar. The main components of mortar are fine aggregate (usually referred to as sand) and cement. The test to assess sand is the determination of particle size distribution also known as the 'sieve test or grading' this test assesses the amount of individual size fractions the sand contains, as a percentage of each size that passed a certain test sieve. If sand becomes 'fine', the percentage of the smaller size fractions increase, the finished mortar may appear stiffer than normal and require more water to give the same workability, which would adversely affect the water:cement ratio of the mortar and hence its' strength and other characteristics. If the sand becomes 'coarse' the percentage of the larger size fractions increases, the finished mortar may become excessively wet with the same water addition, again affecting the mortar characteristics adversely.

Testing fresh mortar

Testing mortar in its fresh state is covered in both BS 4551 and BS EN 1015. Fresh mortar properties are those that affect the ability to use mortar for its intended application. Fresh mortar test methods are used; to design new mortar mixes, to assess alternative constituents and as a performance indicator when undertaking factory production control testing. They can also be used to assess compliance with a standard and as an investigation tool.

Dropping ball apparatus used in the testing of fresh mortar

Most factory produced mortars contain precisely dosed admixtures that provide, when mixed as intended by the manufacturer, an optimum mortar for the end user. Incorrect mixing either to excess or less than required during test specimen preparation may alter the fresh mortar properties.

Testing fresh mortar must be performed within a defined period of time and before the mortar has begun to set.

Workable life of mortar is a measurement of the time taken for a sample of mortar, prepared to a defined level of workability, to stiffen to a point where it is no longer usable for its intended application.

The test for water soluble **chloride content** of fresh mortar ensures that masonry containing embedded metal, such as wall ties, remains durable and is not prone to corrosion. Maximum total chloride contents by mass of cement are specified in the relevant code of practice. Chloride content is the only chemical test method within the BS EN 1015 series of Standards.

The **consistence** of fresh mortar is measured using the Flow Table, the Plunger Penetration or the Dropping Ball test methods, these methods are performed in a laboratory with results compared against established values or routine production control results. Variation from established values may indicate a change in the physical properties of one of the constituents.

Bulk density and **air content** measurements are made to assess fresh mortar performance against specified values. Bulk density measurements are generally only performed in a laboratory since it requires the use of accurate weighing equipment.

Air content can be determined at the point of use on the construction site.

Testing hardened mortar

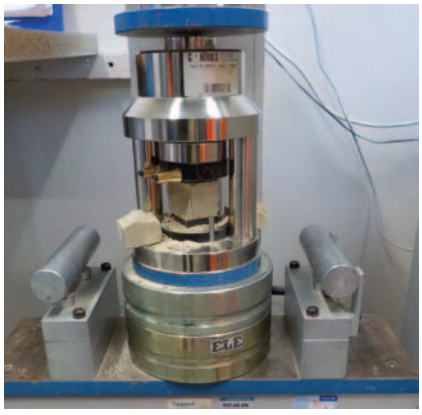
The properties of hardened mortar are measured or declared as a Compressive strength.

Other values such as Bond strength, Water absorption, Water vapour permeability, Density, Thermal conductivity (applicable for mortars intended to be used in elements subject to thermal requirements) and Durability require specialized testing, further details are to found in BS EN 998-2.

For prescribed mortars the original mix proportions can be estimated when a hardened mortar sample is chemically analysed using the methods provided in BS 4551.

The majority of hardened mortar testing is undertaken by a Mortar Manufacturer during the development of a new product. Following this development stage, the performance of the product is confirmed through Initial Type Testing (ITT), all of this testing is undertaken before a new product is offered for sale. Once available, some of the tests used as part of the development and ITT of the product, are then routinely performed for production control.

Compressive strength is a test routinely used to measure the end performance of hardened mortar. It is applicable for production control, performance and compliance testing. With regards to analytical investigation and the assessment of in situ mortar, compressive strength cannot be determined due to insufficient specimen size of the placed mortar. However, test data recorded at or around the time the mortar under consideration, was produced, as part of the manufacturers routine testing, can be taken into account as part of an investigation.



The determination of compressive strength relies upon fresh mortar being sampled and then placed into test specimen moulds. BS EN 1015-11 requires that specific mortar prism moulds are used. These have the following internal dimension 40mm x 40mm x 160mm and are usually configured in a gang of 3 individual specimens per mould.

Making representative compressive strength specimens of masonry mortar relies heavily upon the skills of the Technician; there are several issues that can influence the final strength of the mortar, these include:-

- The treatment of the mortar sample. Fresh mortar that is transported in a vehicle to a laboratory has the potential to segregate under the vibration of the vehicle. The sample is remixed until it is representative of the bulk material it was sampled from. Equally, care should be taken when remixing site made dry silo mortar, not to over work the material causing excessive air to be entrained above the air content levels measured on the construction site. A higher than normal air content will result in an under measurement of the compressive strength.

- The condition of the specimen moulds is important. Corroded and poorly maintained moulds should not be used. The dimensions of moulds should be routinely checked and recorded.
  The type and quantity of mould release agent used can influence compressive strength. Excessive mould oil can retard the set of the surface of the test specimens. Insufficient oil can result in test specimens adhering to the mould components resulting in excess forces being used to remove them. Both issues could give rise to unrepresentative results.

- If the specimen is excessively tamped, air can be entrained into the mortar which could result in an under measurement of compressive strength. Also if the specimen is under compacted air pockets may be present resulting in a weak or unsuitable test specimen.

- Sample storage and curing is critical. If samples are prepared on the construction site, whilst awaiting collection by the testing laboratory, the storage environment is likely to be outside that which is required in the test method. Storage for prolonged periods (greater than 3 days) under site conditions will result in an unreliable strength measurement. Low temperatures will slow down strength development and equally if the specimens are allowed to dry out in their early life, the 28 day strengths are likely to be compromised.

- Mortar prism specimens should be stored for the first 7 days at a temperature of 20°C ± 2°C and a relative humidity of 95% ± 5%. After 7 days the relative humidity should be reduced to 65% ± 5%.

- When testing for compressive strength the rate of loading of the test specimen is critical. The testing machine must apply the load at a uniform rate within the range 10 N/s to 50 N/s. Failure should occur within 30 to 90 seconds. Shock loading must be avoided.

Independent test laboratories without experience of testing a particular mortar manufacturer's product to BS EN 1015-11, should ensure they contact the mortar manufacturer to obtain detailed product information before carrying out any testing.

The **Chemical analysis** of mortar in order to determine mix proportions is used for the assessment of prescribed mortar, for example traditional mortar designation iii comprising constituents in the ratio of 1:1:5 to 6 (cement : lime : fine aggregate). For designed mortar specified according to end performance, for example M4 designed general purpose factory made masonry mortar, chemical analysis is not appropriate.

Chemical analysis can be an extremely involved and difficult process. Assumptions are required in order to estimate the final mix proportions. Chemical analysis is a method that is mainly used in the analytical examination and investigation of mortar.

Given the complex nature of the procedure outlined in BS 4551 there are many issues that can result in inaccuracies in the final results, some of the main issues are outlined below.

- Poor sampling and insufficient sample size can result in an inaccurate estimate of mix proportions. Five subsamples of minimum 50g should be taken and combined to form a composite sample that represents a single section (maximum section size represented by one composite sample is 50m^2) each subsample is taken by removing a brick or block in a diagonal pattern across the full extent of the elevation. Each subsample should be approximately the same size / mass.

- If only a single sample is taken for analysis it should only be considered to represent the area immediately around the sample location and not be representative of the entire elevation.

- It is important that subsamples are not only taken from locations where the mortar is easily removed as this would most likely result in a composite sample that is not typical of the average composition.

- Another potential inaccuracy in this method is in the way the cement content is calculated. The method uses proportionality whereby the quantities of certain chemicals, usually CaO and SiO_2, contained in 100% of the reference cement is used to calculate the quantity of cement in the test sample via the proportion of CaO and SiO_2 found through analysis. The issue is that the reference cement may be different from that contained in the test sample, which could lead to an inaccurate result.

- It is recommended that samples of the individual constituents (cement and fine aggregate) are provided to the laboratory along with the composite sample.

References

BS EN 998 - 2 - 2010	Specification for mortar for masonry part 2: Masonry mortar
BS 4551:2005 + A1:2010	Mortar – Methods of test for mortar – Chemical analysis and physical testing
PD 6682-3:2003	Aggregates – Part 3 Aggregates for mortar – Guidance on the use of BS EN 13139
BS EN 1015 - 1	Determination of particle size distribution (by sieve analysis)
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BS EN 1015 - 17	Determination of water-soluble chloride content of fresh mortars
BS EN 1015 - 18	Determination of water absorption coefficient due to capillary action of hardened mortar
BS EN 1015 - 19	Determination of water vapour permeability of hardened rendering and plastering mortars

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MPA Mortar is part of the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries.

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Factory produced mortar products will contain either cement or lime, both of which have properties which are hazardous to health. Please refer to the manufacturers or suppliers Material Safety Data Sheet for the specific product/grade to find more information on the nature of the hazardous properties, the risks and health effects of exposure and the recommended safe use and handling procedures.