

TROWEL TIPS

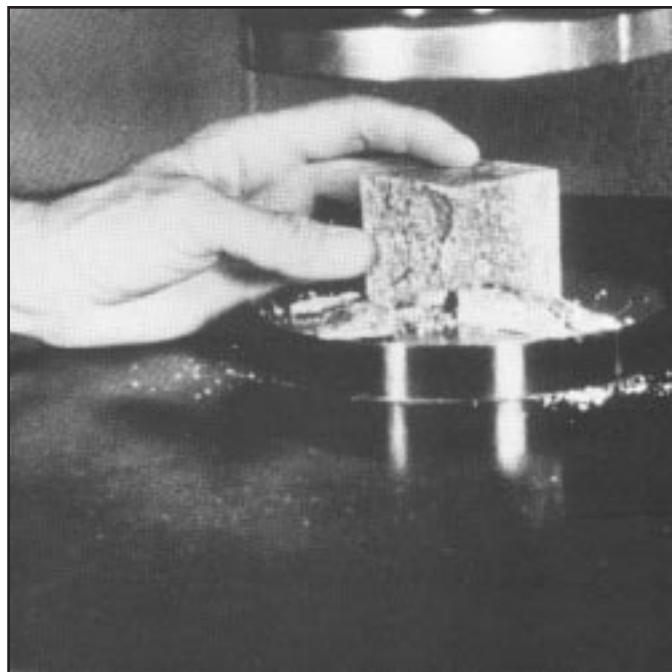
an aid to the masonry industry

Field Testing Masonry Mortar

With the exception of masonry constructed in seismic zones, field testing of masonry has generally been limited to an occasional evaluation of masonry mortar. More frequently than not, even this testing is done improperly and interpreted incorrectly, resulting in needless controversy and waste. As ACI 530/ASCE 5/TMS 402 (*Building code Requirements for Masonry Structures*) and ACI 530.1/ASCE 6/TMS 602 (*Specification for Masonry Structures*) requirements for quality assurance are implemented into construction documents, field testing of masonry components and assemblies will become more commonplace. Specifiers, contractors, and project inspectors need to be familiar with the testing procedures and understand the meaning of laboratory and field results.

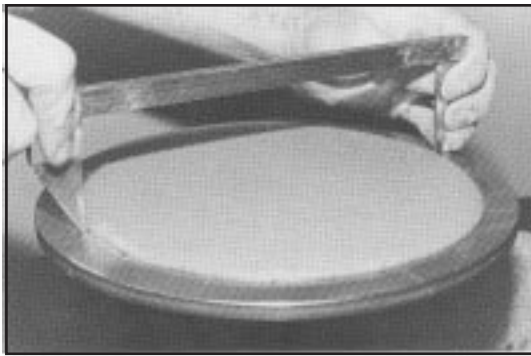
Field testing of mortar is included in project specifications as a quality control measure. Properly conducted, it must involve preparation prior to construction. The contractor selects the ingredients and the mix design in accordance with the project specifications. A preconstruction evaluation of mortar is conducted to develop data that serves as a benchmark for future evaluation of mortar produced during construction. The testing is to be conducted in accordance with the *Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry* (ASTM C780) and should be performed by an accredited laboratory conforming to the *Standard Practice for the Accreditation of Testing Agencies for Unit Masonry* (ASTM C1093). As stated in Article 3.6B of the *Commentary on Specification for Masonry Structures* (ACI 530.1/ASCE 6/TMS 602) “**ASTM C270 specifies mortar testing under laboratory conditions only for acceptance of mortar mixes under the property specification. Field sampling and testing of mortar is conducted under ASTM C780 and is used to verify consistency of materials and procedures, not mortar strength.**”

Unfortunately, the preconstruction evaluation is often omitted and many times laboratory field technicians do not use ASTM C780 testing procedures properly. These deficiencies, compounded by misunderstanding of the significance of mortar test results by project inspectors and engineers, often produce needless and costly construction delays. Sometimes unwarranted “corrective measures” are taken that further escalate costs. These problems can be avoided if all involved understand the following basic concepts with respect to the performance of masonry:



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- Compressive strength is only one of several important mortar properties. Workability and water retentivity often have a greater impact on the quality of the masonry constructed. Other properties such as shrinkage characteristics and resistance to freeze-thaw deterioration can also affect the long term performance of the masonry.
- Field test results of compressive strength of mortar do not represent laboratory mortar strengths and are not required or expected to meet ASTM C270 property specification limits.
- Performance requirements for masonry mortar cannot be equated to those for concrete.
- Field test results of compressive strength of mortar are not representative either of in-place compressive strength of the mortar or in-place compressive strength of the masonry.
- Field test results of compressive strength of mortar are dependent on several variables. These include test procedures and test conditions in addition to proportions and properties of mortar materials.



Mortar mixed to a laboratory flow consistency of 110 ± 5 percent as required for determination of compressive strength according to ASTM C270 property requirements (illustrated top left and bottom left) approximates the consistency of mortar after it has been in contact with absorptive masonry units. Mortar mixed to a workable consistency suitable for construction (top right and bottom right) has a flow that is much higher — often over 130 percent. Compressive strength tests of mortar mixed to that higher job flow consistency are not required to meet the strength minimums of the property specifications of ASTM C270.

Masonry Mortar Performance Requirements

Comparisons between masonry mortars and concrete are often misleading. While these materials have some similar ingredients, their structural properties differ. Materials and methods that produce strong and durable concrete do not necessarily produce mortar or masonry of similar quality.

As an example, it is recognized that high strength concrete requires a low water-cement ratio. Conversely, quality masonry mortar requires comparatively higher water-cement ratios during placement. Higher water content is necessary for workability and to satisfy the absorptive characteristics of the masonry units. That high water content produces a workable mortar mix that readily flows into the irregular surfaces of masonry units assuring intimate contact between mortar and unit. Since some of the mixing water is absorbed by the masonry unit, in-place mortar has a much lower water-cement ratio than the freshly mixed mortar.

The fact that masonry mortar is placed in relatively thin layers between absorptive units means that its flowability and water retentive characteristics are of primary importance to the construction of quality masonry. These properties of the plastic mortar are often more important than its relative potential compressive strength when molded in non-absorptive cube or cylinder molds. Higher strength mortar does not necessarily produce better or stronger masonry. Mortar properties should be compatible with the units used on a project to achieve optimum performance. Measures to increase the compressive strength of mortar that reduce the workability of the mortar (such as reducing water content or arbitrarily increasing the cement content)

can have an adverse effect on the completed masonry. **For this reason changes to mortar mix designs should not be based on field test results of compressive strength.** The need for changes in mix design should be confirmed by laboratory controlled tests or a combination of laboratory and field tests.

Field Test Procedures

ASTM C780 outlines several test procedures for measuring various properties of field sampled mortar. Each procedure is listed as a separate annex to the standard, as indicated in Table 1. Annex A9 outlines a report form indicating the information to be recorded and reported for each test procedure.

Of the eight test procedures outlined, six are conducted on samples of the mortar while it is still in its plastic state. Two, the compressive strength test and the splitting tensile strength test, are measures of hardened properties of mortar specimens prepared from plastic mortar samples. Of these procedures, only one (the compressive strength test) is commonly performed on masonry mortars. Unfortunately, it is dependent on many related variables (as indicated in Table 1) and test results are not available until 7 or 28 days have elapsed from the test date. These weaknesses greatly diminish the effectiveness of field compressive strength tests of mortar for quality control purposes.

When compressive strength tests are conducted, the procedures outlined in ASTM C780 need to be carefully followed. Particular care should be taken to assure that the proper equipment is used and that specified sampling, curing, and testing procedures are followed. The report form contained in Annex A9 of ASTM C780 should be used

Table 1. ASTM C780 Mortar Test Procedures

Annex	Test Procedure	Significance	Related Variables
A1	Consistency by Cone Penetration Test Method	Similar to laboratory measured flow. Can be used in conjunction with water content determinations and compressive strength tests to provide additional information on relationships between these variables.	Water content, mixing time, air content, sand gradation, sand particle shape, and aggregate ratio.
A2	Consistency Retention of Mortars for Unit Masonry	Used to establish setting and stiffening characteristics of plastic mortar.	Mixing time, air content, sand gradation, sand particle shape, aggregate ratio, and stiffening characteristics of cementitious materials.
A3	Initial Consistency and Consistency Retention or Board Life of Masonry Mortars Using a Modified Concrete Penetrometer	Purpose is similar to Annex A1 and A2 except that method focuses on job site measurement of these properties. Results are perhaps more reflective of board life characteristics of mortar as experienced by mason.	Water content, mixing time, air content, sand gradation, sand particle shape, aggregate ratio, and stiffening characteristics of cementitious materials.
A4	Mortar Aggregate Ratio Test Method	Determines ratio of aggregate to cementitious materials in a plastic mortar sample. Can be used as a quality control test of batching procedures.	Water content, sand gradation, bulking of sand, batching.
A5	Mortar Water Content Test Method	Used in calculation of aggregate ratio test results.	
A6	Mortar Air Content Test Method	Can be used as a quality control test of air content of job mixed mortar.	Mixing time, temperature, sand properties, and properties of cementitious materials.
A7	Compressive Strength of Molded Masonry Mortar Cylinders and Cubes	Provides information on the strength development characteristics of the mortar. When used in conjunction with preconstruction evaluation tests, results can be used to evaluate uniformity of mortar production during construction.	Elapsed time between mixing, sampling, and molding; consistency when molded, air content, water content, aggregate ratio, mixing time, sand properties, and properties of cementitious materials.
A8	Splitting Tensile Strength of Molded Masonry Mortar Cylinders	Provides information on the tensile strength development characteristics of the mortar.	Elapsed time between mixing, sampling, and molding; consistency when molded, air content, water content, aggregate ratio, mixing time, sand properties, and properties of cementitious materials.

as it provides a check list to assure that adequate information accompanies the compressive strength test report. In addition, it should be verified that:

- Cube molds, when used, meet the requirements of ASTM C109 - particularly the dimensional tolerance limits.
- Cylinder molds, when used, comply with requirements of ASTM C470. (Note that cylinder specimens yield lower results than cubes, due to shape alone. ASTM C780 indicates that the cylinder specimen strengths are about 85% of cube compressive strengths.)
- Proper molding, handling, and curing techniques are used in preparing test specimens.

Often test results are lower than expected simply as a result of careless application of test procedures.

Significance of Test Results

In addition to the related variables noted in Table 1, test results are affected by inherent variations in the procedures and the technique used by the person performing those procedures. Clearly, methods that have fewer contributing variables are generally more desirable for quality control testing. Test methods that are affected by a complex combination of factors (such as compressive strength)



In-place performance of masonry can better be evaluated from results of masonry assembly tests than from test results of component masonry materials.

require companion information from preconstruction testing, laboratory testing, other field test procedures, along with a detailed record of test conditions for a meaningful interpretation of results. The purpose of field testing and the potential problem of interpreting results should be carefully considered when selecting which tests to conduct. For example, if control of batching is the purpose of specifying ASTM C780 testing, the aggregate ratio test offers a more direct measure of mortar proportions than does the compressive strength method. For the designer seeking data representative of in-place masonry, the most effective procedures are masonry assembly tests such as ASTM C1314, the Standard Method for Constructing and Testing Masonry Prisms Used to Determine Compliance with Specified Compressive Strength of Masonry. These assembly tests indicate the interaction between mortar and unit, quality of workmanship, mortar consistency, and numerous other characteristics of the masonry.

When examining mortar field compressive strength test results, the responsible authority should remember that: while these results can be used to evaluate uniformity of mortar production, **they are not required to meet the minimum compressive strengths of the property specifications of ASTM C270.** Such field test results can be expected to be lower and more variable than laboratory test results. Furthermore, field determined compressive strength test results of mortar do not correlate well with the structural properties of the in-place masonry.

If compressive strength test results vary significantly during construction from the values established during preconstruction testing, the cause(s) of that variance must be established before any corrective action can be taken. The quality of mortar materials can be verified by repeating laboratory tests of mortar materials. Batching control may be investigated by running aggregate ratio tests or inspec-

tion of batching procedures. Information on the consistency of mortar and other test conditions can be evaluated from the test report. Only a proper identification of the cause(s) can lead to a determination as to which corrective measures, if any, may be appropriate.

Related Publications

Readers of this publication may also be interested in the following publications available for purchase from the Portland Cement Association. A complete listing of PCA publications is given in the free **PCA Catalog** (MS254G). To order, write or call Order Processing, Portland Cement Association, 5420 Old Orchard Road, Skokie, Illinois 60077-1083, phone 847/966-6200.

A Homeowner's Guide to Building with Concrete, Brick, and Stone, SP038H

Water Penetration Tests of Masonry Walls, IS219M
Building Weather-Resistant Masonry Walls, IS220M

Concrete Masonry Handbook, EB008M

Mortars for Masonry Walls, IS040M

Masonry Cement Mortars, IS181M

SpecData: Masonry Cement, IS238M

Masonry Cement: Beauty to Last a Lifetime, PA163M

Recommended Practices for Laying Concrete Block, PA043M

Masonry Cement Mortars - A Laboratory Investigation, RD095T

Air Content and Water Penetration of Masonry Walls, IS191M

Selecting and Specifying Mortar and Grout for Unit Masonry, IS275M

Trowel Tips: Efflorescence, IS239M

Trowel Tips: Tuckpointing, IS240M

Trowel Tips: Mortar Sand, IS 241M

CAUTION: Contact with wet (unhardened) concrete, mortar, cement, or cement mixtures can cause SKIN IRRITATION, SEVERE CHEMICAL BURNS, or SERIOUS EYE DAMAGE. Wear waterproof gloves, a long-sleeved shirt, full-length trousers, and proper eye protection when working with these materials. If you have to stand in wet concrete, use waterproof boots that are high enough to keep concrete from flowing into them. Wash wet concrete, mortar, cement, or cement mixtures from your skin immediately after contact. Indirect contact through clothing can be as serious as direct contact, so promptly rinse out wet concrete, mortar, cement, or cement mixtures from clothing. Seek immediate medical attention if you have persistent or severe discomfort.

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