Mortars for Brickwork - Selection and Quality Assurance

Abstract: This *Technical Note* discusses the selection and specification of mortar Type.

Key Words: bond strength, extent of bond, lime, masonry cement, mortar, mortar cement, portland cement, quality assurance, sand, testing, workability.

SUMMARY OF RECOMMENDATIONS:

- Select a mortar Type with the lowest compressive strength meeting project requirements
- Select mortar appropriate for application, project conditions and workability
- Type N mortar is recommended for normal use, including most veneer applications
- Create a quality assurance program, where appropriate, to obtain consistent mortar
- Follow recommended procedure and sequence for mixing mortar
- Measure mortar materials by volume

INTRODUCTION

Selection of an appropriate mortar helps to ensure durable brickwork that meets performance expectations. Mortar Type and mortar material selection should consider multiple aspects of a project, including design, brick or masonry materials, exposure and required level of workmanship. Improper mortar selection may lead to lower performance of the finished project.

This *Technical Note* provides guidance for selecting the appropriate mortar Type. It also describes a quality assurance program to ensure the desired results. *Technical Note* 8 addresses specific properties of mortar, mortar materials and their selection as well as the specification of mortar.

SELECTION OF MORTAR

Mortar bonds individual brick together to function as a single element. In its hardened state, mortar must be durable and must help resist moisture penetration. Mortar also must have certain properties in its plastic state so that it is both economical and easy to place.

One property of mortar that is often overemphasized is compressive strength. Stronger is not necessarily better when specifying mortar. In fact, the opposite is often true. Mortar selection should be based on properties such as durability and workability in addition to compressive strength.

Mortar for each project should be selected to balance the construction requirements with the performance of the completed masonry. High lateral loads from wind or seismic activity may require a mortar that develops high flexural tensile strength. Allowable flexural tensile and compressive stresses for unreinforced structural masonry are given in the building code. Building code requirements may limit the use of some mortar Types under certain conditions. For example, *Building Code Requirements for Masonry Structures* (ACI 530/ASCE 5/TMS 402) [Ref. 8] does not permit the use of Type N or masonry cement mortars in any part of the lateral force-resisting system for structures located in Seismic Design Categories D, E or F.

Other considerations may include durability (below grade or in retaining walls), color uniformity, flexibility, workability or other desired properties. The combination of the mortar and brick properties may dictate the selection of a certain mortar.

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These are the fundamental guidelines of mortar selection:

- No single mortar is best for all purposes.
- Select a mortar Type with the lowest compressive strength meeting the project requirements.

Of course, these guidelines must be used with good judgment. For example, it could be uneconomical and unwise to use different mortars for various portions of the same structure.

Mortar Type Characteristics

Mortars are classified by ASTM C 270, *Standard Specification for Mortar for Unit Masonry* [Ref. 2], into four Types: M, S, N and O. These four Types of mortar can be made with portland cement, masonry cement, mortar cement or blended cements some of which are combined with hydrated lime.

Each mortar Type has some basic characteristics:

- Type N mortar - General all-purpose mortar with good bonding capabilities and workability
- Type S mortar - General all-purpose mortar with higher flexural bond strength
- Type M mortar - High compressive-strength mortar, but not very workable
- Type O mortar - Low-strength mortar, used mostly for interior applications and restoration

Although the descriptions above provide basic mortar characteristics, each mortar Type can be used in a variety of applications. No single mortar is best for all purposes.

Simplistic Mortar Selection

The easiest method to select mortar is to remember the following mnemonic:

- Type N for normal brickwork applications
- Type S for stronger brickwork applications

Normal applications include most veneer. Stronger applications are needed in high seismic and high wind areas and in reinforced brickwork.

Mortar Selection Based on Use

More explicit guidance on mortar selection based on the location and use of the building segment is given in Table 1. More durable mortar Types are recommended for more severe exposures.

TABLE 1

Mortar Recommendations Based on Use

Location	Building Segment	Mortar Type	
		Recommended	Alternate
Exterior, above grade	Reinforced or Loadbearing walls Veneer or Non-loadbearing walls Parapets, Chimneys	S N N	N S S
Exterior, at or below grade	Foundation walls, Retaining walls Sewers, Manholes	M	S
Interior	Loadbearing walls Partitions	N N	S O or S

Brick Properties Influencing Mortar Selection

In general, the bond between brick and mortar is the most important property to consider when selecting mortar Type. Bond actually has two components: extent of bond and bond strength. Extent of bond refers to the amount of intimate contact between the mortar and brick, which is enhanced by good mortar workability. Good extent of bond provides durability and resistance to water penetration. Bond strength refers to the force required to separate the mortar from the brick. Good bond strength provides resistance to cracking.

Brick properties, particularly the initial rate of absorption (IRA), also can affect bond. Brick with a high IRA should be used with mortar that has a greater ability to retain mixing water. Conversely, brick with a low IRA should be used with mortar that does not retain water as easily. Bed joint surface texture also may influence bond strength and extent of bond, but to a lesser degree than IRA.

Table 2 can be used to select a mortar based on IRA. These recommendations are based on *Bond Strength and Water Penetration of Low IRA Brick and Mortar* [Ref. 6] and *Bond Strength and Water Penetration of High IRA Brick and Mortar* [Ref. 7]. The mortar recommendations in Table 2 are applicable for construction in temperatures from 40° to 100 °F (4° to 37.8 °C). Under colder or hotter temperatures, other brick and mortar combinations may be preferable. Refer to *Technical Note* 1 for hot and cold weather construction recommendations. In addition, there may be other brick/mortar combinations that perform as well. Bond strength of particular combinations can be tested using ASTM C 1357, *Standard Test Methods for Evaluating Masonry Bond Strength* [Ref. 4].

TABLE 2

Mortar Recommendations Based on Brick Unit IRA[1]

Initial Rate of Absorption Range of Brick	Portland or Blended Cement: Lime Mortar	Mortar Cement Mortar	Masonry Cement Mortar
Up to 10 g/min/30 in.^{2} (Up to 0.0005 g/min/mm^2)	Type S (Type N)	Type S (Type N)	Type S (Type N)
10 to 30 g/min/30 in.^{2} (0.0005 to 0.0016 g/min/mm^2)	Type N or S	Type N or S	Type N or S
Above 30 g/min/30 in.^{2} (Above 0.0016 g/min/mm^2) Dry when laid	Type N (Type S)	—[2]	—[2]
Above 30 g/min/30 in.^{2} (Above 0.0016 g/min/mm^2) Wetted prior to laying	Type N (Type S)	Type N (Type S)	Type S (Type N)

[1] Alternate Types listed in parentheses

[2] Not recommended unless verified with testing

Mortars for Special Applications

Certain applications may require special considerations for mortar selection. Several of these follow:

Repointing Mortars. Repointing mortars are used in maintenance and restoration projects. Compatibility between existing brick and mortar is the most important consideration in selecting a repointing mortar. Hence, it may be necessary to use a weaker mortar for older masonry than would be used for new construction. In general, the compressive strength of a repointing mortar should not exceed that of the existing mortar. If necessary, the existing mortar can be tested to determine proportions of ingredients for the repointing mortar. Type O mortar often is used for repointing older brickwork. Type N mortar may be suitable for repointing newer brickwork.

Repointing mortars should be pre-hydrated. In this process the mortar materials are mixed dry, and then just enough water is added to produce a damp mix which will retain its shape when formed into a ball. After one to one and half hours, additional water should be added to bring the mortar to the proper consistency for placement. Refer to *Technical Note* 46 for more information about repointing.

Paving. Paving applications are more likely to be in a saturated condition than walls. Because of this, the mortar typically must be more durable to resist the harsher exposure. Type M mortar is recommended with Type S as the alternate. A mortar with a latex modifier conforming to ANSI A118.4, *Specification for Latex-Portland Cement Mortar* [Ref. 1], may provide a more durable assembly. Flexible brick paving, which uses sand rather than mortar to fill joints between pavers, is less susceptible to damage from exposure and should be considered as an alternative to mortared paving. Refer to *Technical Note* 14A for more information about paving materials.

Stain-Resistant Mortar. Where resistance to staining is desired, aluminum tristearate, calcium stearate or ammonium stearate may be added to the mortar. Where maximum stain resistance is desired, use mortar consisting of one part portland cement, one-eighth part lime and two parts graded fine (80 mesh) sand, proportioned by volume. To this, add aluminum tristearate, calcium stearate or ammonium stearate equal to 2 percent of the portland cement by weight.

Chemical-Resistant Mortar. Chemical-resistant masonry often is used in food processing plants, refineries or breweries. Chemical-resistant mortars may include silicate mortars, sulfur mortars, various resin mortars or cementitious mortars. For further information on chemical-resistant mortar, refer to *Corrosion & Chemical Resistant Masonry Materials Handbook* [Ref. 9].

MIXING REQUIREMENTS

Although most mortar is mixed on-site, preblended mortar also is available. Preblended mortar is supplied in consistent proportions without the need for on-site batching and measurement controls. While each mortar Type has specified ranges of material quantities, accurate and consistent material quantities are desired throughout the job.

Material measuring and batching should be by volume or by weight to ensure that the specified mortar proportions are accurately controlled and maintained. For material weights and recommended proportions, refer to ASTM C 270 or *Technical Note* 8. When using a mechanical mixer, the ingredients should be added in such a manner that the mix remains damp. Typically, about half the mix water is added to the mixer, followed by about half of the sand, then any and all lime. The cement and the remainder of the sand are then added, followed by the remainder of the water. These materials should be mixed for three to five minutes. If admixtures are to be used, they should consistently be added at the same stage in the mixing process. The same quantities of materials should be added in the same order from batch to batch to help ensure uniform results throughout the job.

Photo 1
Obtaining Accurate Sand Quantities

Every effort should be made to keep the materials agitated by the paddles. This may require changing the sequence in which water is added. If ingredients are added too fast or if not enough water is added to the mixer before the dry ingredients, the mixer may not be able to combine them, and the dry materials will stick around the bowl.

Cement and lime should be placed in the mixer in whole (preferable) or half bags. The mixer should be sized accordingly, also depending upon the project requirements and the size of the masonry crew.

Photo 1 shows an example of batching and measurement controls that are both economical and accurate. Sand can be measured with a 1-cubic foot (0.028 m^3) box or a 5-gallon bucket equal to 2/3-cubic-feet (0.019 m^3). Alternatively, the number of shovels of sand required to fill the box or bucket can be calibrated. Shovel count calibration should be done every morning and afternoon or whenever the shovel size or individual shovelling sand is changed.

QUALITY ASSURANCE

A quality assurance program provides policies, procedures and requirements intended to ensure compliance with the contract documents. Quality assurance requirements may be set by the owner, designer or governing building code. Quality control is a part of the quality assurance program that may involve testing, inspection, or both. Some quality assurance programs require the contractor to submit documentation showing conformance to the contract documents. *Building Code Requirements for Masonry Structures* [Ref. 8] assumes that all masonry is constructed under a quality assurance program.

For mortar specified by ASTM C 270, the key to quality assurance is adherence to the material proportions added to the mixer. ASTM C 270 prescribes the volumes of the materials in each mortar Type when the proportion specification is used. When the property specification is used, laboratory testing establishes the material proportions that will be used in the field. Observation during measuring and mixing is thus an essential component of the quality assurance program. Testing may be included as a second component. ASTM C 1586, *Standard Guide for Quality Assurance for Mortars* [Ref. 5], explains how to use ASTM C 270 and ASTM C 780 for evaluating laboratory-prepared and field-prepared mortars.

Inspection

Inspection is often a part of the quality assurance programs required by the contract documents or building code. Mortar inspection typically entails verifying that the specified materials are used and that they are in the proper proportions. Inspection also may include verifying proper mix time, retempering, mortar placement and tooling.

Testing

Field testing of mortar is not necessary on most projects. When the ASTM C 270 property specification is used, however, laboratory testing is necessary to establish mortar mix proportions, which are then used to prepare mortar in the field. If inspection during mixing is not possible, some physical testing of the mortar may be appropriate.

ASTM C 780, *Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry* [Ref. 3], provides methods for sampling and testing mortar in the laboratory and in the field. It defines procedures for measuring properties of plastic mortar such as consistency, the aggregate ratio, air content and water content. Finally, it defines procedures for measuring properties of hardened mortar, such as compressive strength. These test results are used to verify mortar consistency from batch to batch.

For test results to be useful there must be a basis of comparison. Preconstruction testing with the materials to be used during the actual construction provides the benchmark for field testing results. Proper interpretation of mortar test results requires a thorough knowledge of mortar specifications and test methods.

For example, compressive strength test results from field-sampled mortar cannot be compared with the minimum requirements of the ASTM C 270 property specification. The different sampling and mixing requirements of ASTM C 780 will yield different results from those determined according to ASTM C 270. ASTM C 270 is for laboratory-prepared and tested mortars, while ASTM C 780 is mainly for field sampling and testing. Compressive strength results obtained according to ASTM C 780 can be expected to be lower and more variable than ASTM C 270 laboratory test results; the two are not comparable.

ASTM C 780 can be used to determine whether the proper proportions are being used in the field. Freshly sampled mortar is placed in a jar with isopropyl or methyl alcohol to prevent hydration. The sand used in the mortar also is sampled to determine its gradation. After weighing the materials, the fine material is filtered out of the mortar using a sieve. The remaining material is assumed to be sand, from which the sand to cement ratio can be determined. This can be compared with the specified proportions.

Interpreting Test Results

If ASTM C 780 field test methods are used, the results must be properly interpreted and compared with preconstruction test results. Observations should include mortar sampling, test specimen preparation, specimen handling during transportation, storage at the test facility and test procedures. If there is a substantial difference between preconstruction and field results, the following should be investigated:

- Change of mortar materials or proportions
- Change in brick properties (different brick or wet brick) resulting in a change to the amount of water added to the mortar
- Change in time between mortar mixing and sampling
- Proper construction of specimens
- Unusual curing conditions
- Damage to specimens during transit or storage
- Proper adherence to test procedures
- Accuracy of calculations

This information can be used to help identify the possible cause(s) of inconsistent test results. If questions about mortar quality remain, additional masonry testing may be required. In some cases, prism tests of masonry specimens from the project can be conducted to determine the structural capacity of the masonry.

SUMMARY

Mortar, although it comprises a relatively small portion of brickwork, has a significant impact on overall performance. A range of mortars is available to suit the needs of all brick projects. Taking into consideration the brick unit properties as well as the project requirements when specifying mortar Type will contribute to a properly performing brick structure, as will implementing a good quality assurance plan.

> *The information and suggestions contained in this* Technical Note *are based on the available data and the combined experience of engineering staff and members of the Brick Industry Association. The information contained herein must be used in conjunction with good technical judgment and a basic understanding of the properties of brick masonry. Final decisions on the use of the information contained in this* Technical Note *are not within the purview of the Brick Industry Association and must rest with the project architect, engineer and owner.*

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