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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. *Technical Note* 7B discusses placing of mortar and tooling of mortar joints.

SELECTION OF MORTAR

Mortar bonds individual brick units 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 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 not be based solely on the compressive strength of the material. Rather, selection of mortar should be based primarily on other properties, such as durability and workability in combination with 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, TMS 402, *Building Code Requirements for Masonry Structures* (TMS Code) [Ref. 6], does not permit the use of Type N or masonry cement mortars in ungrouted or partially grouted portions of the lateral force-resisting system for structures located in Seismic Design Categories D, E or F.

Other considerations may include durability (especially for masonry 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. Therefore, the properties of the selected mortar should be compatible with the properties of the brick.

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 C270, *Standard Specification for Mortar for Unit Masonry* [Ref. 1], into four Types: M, S, N and O. These four Types of mortar can be made with portland, blended or hydraulic cement combined with lime or masonry or mortar cement, which already contain plasticizing materials.

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 compressive and 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 these descriptions provide basic mortar characteristics, each mortar Type can be used in a variety of applications. No single mortar is best for all purposes. Therefore, it is important to verify that the properties of the mortar are compatible with the application, properties of the masonry units and any adjacent accessory masonry products.

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 anchored brick veneer. Stronger applications are typically needed in high-seismic and high-wind areas.

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. For mortar used in a paving application, refer to the *Technical Note* 14 Series.

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 M	S 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. For instance, using a cement-lime mortar per the proportion specification in ASTM C270 allows the mason to adjust the amount of lime in the mix to better match the IRA of the brick. Type N cement-lime mortar always includes 1 volume of cement, but the volume of lime is permitted to range between ½ and 1¼. A common proportion of cement and lime in this mortar Type is 1:1, but if the brick used has a low IRA, the amount of lime could be reduced to ¾ or ½ to lower water retention of the mortar, yet still qualify as a Type N mortar. Bed joint surface texture also may influence bond strength and extent of bond, but to a lesser degree than IRA. Mortar tends to bond greater to roughened surfaces than to smooth surfaces because rougher surfaces provide more contact area for the mortar [Ref. 7].

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. 4] and *Bond Strength and Water Penetration of High IRA Brick and Mortar* [Ref. 5]. The mortar recommendations in Table 2 are applicable for construction in temperatures from 40° to 100 °F (4° to 37.8 °C). In colder or hotter temperatures, other brick and mortar combinations may be preferable. Refer to *Technical Note* 1 for hot- and cold-weather construction recommendations. Bond strength of particular brick/mortar combinations can be tested using the methods prescribed in ASTM C1072, *Standard Test Methods for Measurement of Masonry Flexural Bond Strength* [Ref. 1].

TABLE 2

Mortar Recommendations Based on Brick Unit IRA[a]

Initial Rate of Absorption	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/mm²)	Type S	Type S	Type S
10 to 30 g/min/30 in.² (0.0005 to 0.0016 g/min/mm²)	Type N or S	Type N or S	Type N or S
Above 30 g/min/30 in.² (Above 0.0016 g/min/mm²) Dry when laid	Type N	—[b]	—[b]
Above 30 g/min/30 in.² (Above 0.0016 g/min/mm²) Wetted prior to laying	Type N	Type N or S	Type S

a. Type S and Type N mortars are typically used interchangeably depending on the preference of the mason. Provided that any requirements for compressive strength in a given application are met, Type S mortar is considered an acceptable alternative to Type N mortar and vice versa.

b. Not recommended unless verified with testing.

Mortars for Special Applications

Certain applications may require special considerations for mortar selection. Several of these applications are as follows.

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. Prior to the early 1900s, masonry mortars consisted primarily of lime. Portland cement was not commonly added to mortar mixes until after this time period. Mortars with no or little cement content have lower compressive strength values. Hence, it is likely necessary to use a weaker mortar for repairing older masonry than would be used for new construction. The compressive strength of the repointing mortar should be equal to or less than the existing mortar. Stronger repointing mortar will create stress concentrations on existing historic masonry and result in spalling. If necessary, the existing mortar can be tested to determine proportions of ingredients for the repointing mortar, to duplicate the original mortar composition as closely as possible. To determine the composition of existing mortar, samples should be extracted from the wall and sent to a laboratory for testing. Type O mortar often is used for repointing older brickwork. Type N mortar may be suitable for repointing newer brickwork. ASTM C1713, *Specification for Mortars for the Repair of Historic Masonry* [Ref. 1] can be used in lieu of ASTM C270 for structures that were not constructed with modern mortars.

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 that will retain its shape when formed into a ball. After 1 to 1½ hours, additional water should be added to bring the mortar to the proper consistency for placement, which is still significantly drier than the consistency used to lay brick. The drier consistency of repointing mortar makes it easier to place the mortar into the joint and compact it, and to help minimize shrinkage over time. Refer to *Technical Note* 46 for more information about repointing.

Paving. Although paving applications should be designed with good drainage to minimize saturation, they are still more likely to be in a saturated condition than masonry wall applications. Because of this, the mortar typically must be more durable to resist the harsher exposure. Type M mortar is recommended for most exterior paving applications. Type S mortar is an acceptable alternative to Type M for interior paving applications. Certain exterior applications may be suitable for Type S mortar. Using a mortar with a latex modifier conforming to ANSI A118.4, *Specification for Modified Dry-Set Cement Mortar* [Ref. 2], or ANSI A118.15, *Specification for Improved Modified Dry-Set Cement Mortar* [Ref. 3], is also an option to provide a durable assembly. A Type S mortar with a liquid polymer additive used in place of water is an acceptable alternative to Type M mortar in exterior applications. Flexible brick paving, which uses sand rather than mortar as a bed below pavers and 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* 14 Series for more information about paving materials.

Moisture-Resistant/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. A more accurate description of these additives is that they are dry water-repellent admixtures, used to create a moisture-resistant mortar. As such, they also make for a stain-resistant mortar, since stains typically penetrate a masonry substrate as a liquid. The use of water-repellent admixtures in mortar for brick masonry is not recommended, as bond to the brick unit can be impaired. If water-repellent properties are required for the project, the use of breathable water repellents applied to masonry after construction is preferred to integral water repellents. Refer to *Technical Note* 6A for more information on water repellents.

Chemical-Resistant Mortar. Chemical-resistant masonry often is used in food processing plants, refineries and breweries. Chemical-resistant mortars may include silicate mortars, sulfur mortars, various resin mortars or cementitious mortars. Special consideration should be given to additional procedures for chemical-resistant mortars, as some proprietary manufacturers specify applying acid solutions to the exposed mortar surfaces prior to placing the installation in service. For further information on chemical-resistant mortar, refer to *Corrosion and Chemical Resistant Masonry Materials Handbook* [Ref. 8].

MIXING REQUIREMENTS

Although most mortar is mixed on-site, preblended dry mortar mixes are becoming more common compared with mixing individual ingredients. Preblended mortar mixes are supplied to the job site in consistent proportions without the need for on-site batching and measurement controls. Preblended mortar mixes must conform to the requirements of ASTM C1714, *Standard Specification for Preblended Dry Mortar Mix for Unit Masonry* [Ref. 1]. Preblended mortar mixes that conform to the requirements of ASTM C1714 also comply with the requirements of ASTM C270. While each mortar Type has specified ranges of material quantities, accurate and consistent material quantities are desired throughout the job. Admixtures should be used only when approved by the specifier.

Material measuring and batching should be by volume and checked using weight to ensure that the specified mortar proportions are accurately controlled and maintained. For material weights and recommended proportions, refer to ASTM C270 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 of the mix water is added to the mixer, followed by about half of the sand in a damp, loose condition, and then any and all lime. The cement and the remainder of the sand are then added, followed by the remainder of the water. Cement and lime should be placed in the mixer in whole (preferable) or half bags to avoid the risk of oversanding. If admixtures are approved to be used by the specifier, they should consistently be added at the same point in the mixing process.

The mixer should be sized accordingly, depending upon the project requirements and the size of the masonry crew. The mortar materials should be mixed for 3 to 5 minutes. The same quantities of materials should be added in the same order from batch to batch to help ensure uniform results throughout the job. Every effort should be made to keep the materials agitated by the paddles. If ingredients are added too fast or 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.

Photo 1 shows an example of batching and measurement controls that are both economical and accurate. Sand can be measured with a 1 ft^3 (0.028 m^3) box or a 5-gallon bucket equal to ⅔ ft^3 (0.019 m^3). Sand should be in a damp, loose condition when added to the mixer, as the moisture content of the sand affects its volume. While not as accurate, the number of shovels of sand required to fill the box or bucket can be calibrated. To maximize accuracy, the shovel count calibration should be done every morning, every afternoon, and whenever the shovel size or individual shoveling sand is changed.

Photo 1
Obtaining Accurate Sand Quantities

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. TMS Code [Ref. 6] assumes that all masonry is constructed under a quality assurance program.

For mortar specified by ASTM C270, the key to quality assurance is adherence to the material proportions added to the mixer. ASTM C270 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 C1586, *Standard Guide for Quality Assurance for Mortars* [Ref. 1], explains how to use ASTM C270 and ASTM C780 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 properly proportioned when mixed. Inspection also may include verifying proper mix time, retempering, mortar placement and tooling.

Testing

Field testing of mortar is not necessary on most projects. However, when the ASTM C270 property specification is used, preconstruction laboratory testing per ASTM C780 is necessary to establish proper mortar mix proportions, which are then used to prepare field-mixed mortar. The proportions established for the field-mixed mortar can be verified during construction by inspection. If inspection of mortar mixing is not possible, then a quality assurance program as described in ASTM C780 is appropriate. If the preconstruction laboratory testing per ASTM C780 is not conducted, then it is not recommended to conduct the field testing per ASTM C780, as the results are often erroneously compared with the values in ASTM C270. For guidance on the proper use of ASTM C270 and ASTM C780 in evaluating masonry mortar produced in the laboratory and at the construction site, refer to ASTM C1586.

ASTM C780, *Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry* [Ref. 1], provides methods for sampling and testing mortar in the laboratory and in the field to determine if the proper proportions are being used. It defines procedures for measuring properties of plastic mortar, such as consistency, mortar 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.

Interpreting Test Results

If ASTM C780 field test methods are used, then the results must be properly interpreted and compared only with preconstruction test results. ASTM C780 compressive strength test results obtained from field-sampled mortar cannot be compared with the minimum requirements of the ASTM C270 property specification. The different sampling and mixing requirements of ASTM C780 will yield different results from those determined according to ASTM C270. ASTM C270 is for laboratory-prepared and -tested mortars, while ASTM C780 is for field sampling and testing. Compressive strength results obtained according to ASTM C780 can be expected to be lower and more variable than ASTM C270 laboratory test results; the two are not comparable.

Be aware that the compressive strength of the mortar laid with the masonry will be much higher than that measured in the field-sampled mortar tested per ASTM C780 because of the reduced water–cement ratio in the wall mortar compared to the field-sampled mortar. This is because the brick adjacent to the wall mortar will absorb the mix water into the masonry units, thereby effectively lowering the water–cement ratio of the wall mortar.

Observations should be made throughout each phase of testing to ensure consistent results are achieved. Such observations 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 the preconstruction and field results of testing in accordance with ASTM C780, then 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, then 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 and the project requirements when specifying mortar Type, as well as implementing a good quality assurance plan, will contribute to a properly performing brick structure.

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.

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ASTM C1072	Standard Test Methods for Measurement of Masonry Flexural Bond Strength
ASTM C1586	Standard Guide for Quality Assurance for Mortars

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