

Technical Notes 17A - Reinforced Brick Masonry - Materials and Construction

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Abstract: This Technical Notes provides a discussion of the proper methods of constructing reinforced brick masonry. Materials used in reinforced brick masonry are included Construction of brick masonry, placement of steel reinforcement and grouting are addressed. Recommendations are provided to ensure that the completed masonry will provide adequate performance. Particular emphasis is placed on those aspects of construction that are unique to reinforced brick masonry. Various quality assurance procedures and tests are also explained.

Key Words: bracing, brick ,construction, grouting, inspection, reinforced brick masonry reinforcement, shoring.

INTRODUCTION

Reinforced brick masonry (RBM) is different from more conventional brick veneer in many ways. Key to those differences is the concept of grouting the brick masonry. Ground brick masonry is defined as construction made with clay or shale units in which cavities or pockets in elements of solid units, or cells of hollow units are filled with grout. Common examples of RBM elements are beams, columns, pilasters, multi-wythe brick walls with grouted collar joints and hollow brick walls. This Technical Notes reviews the materials and construction practices used to build RBM elements. The different techniques are discussed with particular emphasis on the concepts of grouting and the placement of reinforcement. Quality assurance and minimum standards of workmanship to ensure a high level of consistency and adequate masonry performance are addressed.

The information in this Technical Notes should be carefully reviewed by the mason contractor prior to constructing reinforced brick masonry. It should also be studied by the masonry inspector. Other Technical Notes in this series provide design theories and design aids for RBM elements such as beams, walls, columns and pilasters.

RBM MATERIALS

The materials used to construct RBM elements should comply with applicable ASTM standards. Brick should meet the requirements of ASTM C 62 Specification for Building Brick, C 216 Specification for Facing Brick, or C 652 Specification for Hollow Brick. Mortar should comply with the requirements of ASTM C 270 Specification for Mortar for Unit Masonry. Grout should comply with ASTM C 476 Specification for Grout for Masonry. Metal wall ties, bar positioners, and reinforcing bars and wires should comply with the applicable ASTM standards as required by the Specification for Masonry Structures (ACI 530.1/ASCE 6/TMS 602)[2], also known as the MSJC Specification. All metal wall ties, positioners and joint reinforcement should be corrosion resistant or protected from corrosion by appropriate coatings. Refer to Technical Notes 3A for a discussion of the material properties of brick, mortar, grout and reinforcement.

The materials in both fine and coarse grout should comply with the requirements of ASTM C 476 Specification for Grout for Masonry. Both fine grout and coarse grout should comply with the volume proportions given in ASTM C 476. Specifying grout by proportions is preferred over specifying a minimum grout strength. Typically, the maximum aggregate size should be 3/8 in. (9.5 mm) for coarse grout. While larger size aggregate can be used when filling large grout spaces, it must be noted that such grout likely cannot be pumped and will require placement by pouring from a hopper.

It must be remembered that grout is different from concrete. Concrete is placed with a minimum of water into nonporous forms. Grout is poured with considerably more water, as the brick masonry creates absorptive forms. Grout should be sufficiently fluid to flow into the space to be filled, and surround the steel reinforcement, leaving no voids. It should be wet enough to flow without separation of the constituents. Whereas good mortar should stick to a trowel, it should be impossible for grout to do so. The water cement ratio as mixed, highly important in concrete work, is less important for grout in brick masonry. Although excessive water is detrimental to the strength and durability of the grout, when introduced into the brick masonry the water cement ratio rapidly changes from a high to a low value. Grout is often mixed too dry and stiff for proper placement.

One concern with the use of a very fluid grout mixture is excessive shrinkage. Shrinkage can create voids in the grout space, which are to be avoided. For this reason, plasticizers and shrinkage-compensating admixtures are recommended for grout in brick masonry. Such admixtures will provide the necessary fluidity while also providing a

hardened grout mixture with minimal voids.

There is a temptation to fill the grout space with the mortar that is used to lay up the brickwork, especially when simultaneously laying brick and grouting. This is not recommended, but may be permitted by local building codes. It is common to find excessive voids in the grout space with this practice. Proper placement and consolidation of grout or grout mixture with a shrinkage-compensating admixture and poured in a continuous process is much more likely to form a solid grout fill.

RBM CONSTRUCTION

The construction of RBM elements can be separated into three parts: brick masonry construction, placement of the steel reinforcement and grouting. Each of these steps is critical to the end result. Following is a review of the three construction procedures in the order of their execution.

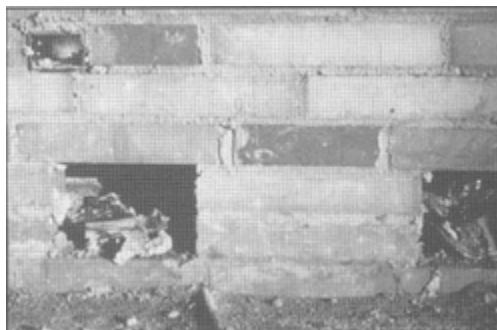
There are two key points to remember when laying the brick. First, the brick masonry is the permanent formwork for the grout. This masonry formwork must be built in a manner that facilitates placement and positioning of the steel reinforcement and installation of grout. Second, the quality of workmanship will have a significant impact on the strength of the RBM. Unfilled mortar joints and elements that are out-of-plumb will not provide the performance assumed by the designer.

All RBM elements constructed of solid brick should be laid with full head and bed joints. The ends of brick should be buttered with sufficient mortar to fill the head joints. Furrowing of bed joints should not be deep enough to result in voids. Years ago, it was believed by some that the head joints in solid brick masonry could be made only half full and that the grout would flow into the remainder of the head joint and fill the voids. It was felt that the grout would form a shear key and make the brick masonry bond more strongly to the grout core. This is not the case. In fact, creation of voids is more likely with this practice, which reduces the masonry's strength and can promote efflorescence due to entrapped water.

Hollow brick are normally laid with face shell bedding. That is, the unit's face shells are filled solidly with mortar and head joints are filled with mortar to a depth equal to the face shell thickness. In some instances, bed joints of cross webs are covered with mortar to confine grout or to increase net area. Head joints may be filled solid for similar reasons.

Cleanouts and Maintaining a Clear Grout Space

Cleanouts are used to remove all mortar droppings and debris from the bottom of a grout space and also to ensure proper placement of reinforcement prior to grouting. Cleanouts should be provided in the bottom course of all spaces to be grouted when the grout pour exceeds 5 ft (1.5 m) in height. In partially grouted masonry, a cleanout is recommended at each vertical bar. In fully grouted masonry, the spacing of cleanouts should not exceed 32 in. (813 mm) on center according to the MSJC Specification. For reinforced brick masonry elements constructed with solid brick, cleanouts should be formed by omitting brick in the bottom course periodically along the base of the element. For hollow brick masonry, cleanouts should be provided in the bottom course of masonry by removing the face shell of the cells to be grouted. Examples of cleanouts in brick masonry walls are shown in Figure 1.



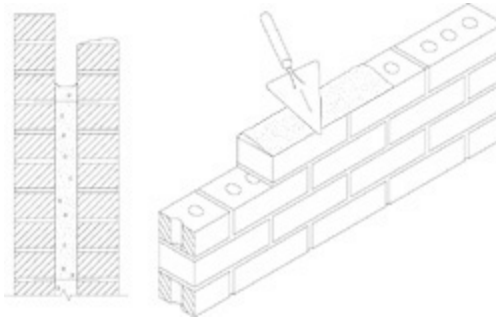
Example of Grout Space Cleanouts
FIG. 1

The minimum cleanout opening dimension should be 3 in. (76 mm). However, smaller spaces can be used if it is shown with a demonstration panel that the spaces can be cleaned.

The grout spaces should be cleaned prior to grouting. It is good practice to clean out grout spaces at the end of each work day so that mortar droppings can be easily removed. A high pressure water spray, compressed air or industrial vacuum cleaner should be used for this purpose. Many contractors have found that cleaning of the grout space is facilitated by placing a layer of sand or sheets of plastic film at the bottom of the cleanout to catch mortar

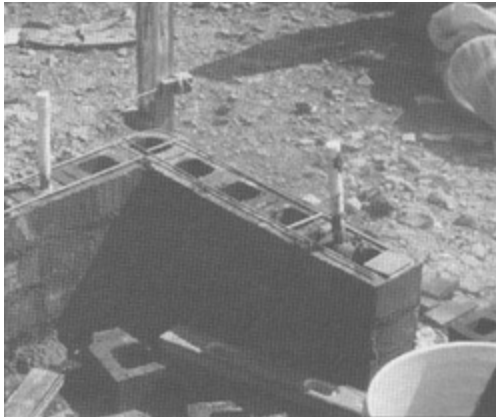
droppings. After cleaning and prior to grouting, cleanouts should be closed with masonry units or sealed with a blocker to resist grout pressure. A minimum curing time of two days is recommended for the cleanout plugs or they should be adequately braced against the grout pressure. Bracing is discussed further in the section on Shoring and Bracing.

For solid brick masonry, the top of the mortar bed joint should be beveled outward from the center of the grout space to minimize the amount of mortar extruded into the grout space when the brick are laid, as illustrated in Fig. 2.



Beveling Mortar Bed Joints
FIG. 2

Mortar protruding from bed or head joints into the grout space should be struck flush with the surface or removed prior to grouting. The maximum protrusion of a mortar fin should be 1/2 in. (13 mm). The spaces to be grouted should also be kept free of mortar droppings. One method of keeping collar joints clear consists of laying wood strips on the metal ties as the two wythes of brick masonry are built. The strips catch mortar droppings during construction and are removed by means of attached heavy strings or wires as the wall is built. To keep the cells of hollow brick clear for grouting, sponges are typically used, as shown in Fig. 3.



Sponges to Keep Cell Clear of Mortar Droppings
FIG. 3

Erection Tolerances

All RBM elements should be laid within the permitted dimensional tolerances found in the MSJC Specifications. Masonry elements that are not constructed within these limits are not as strong in compression as those that are. The thickness of mortar joints will also influence the masonry's strength. Excessively thin or thick mortar joints will reduce brick masonry's tensile and compressive strength. The erection tolerances stated in the MSJC Specification are given in Table 1.

TABLE 1
Erection Tolerances for RBM Elements

Elements		Tolerance from Specified Dimension, in. (mm)
Dimension of assembly, in cross-section or elevation		- $\frac{1}{8}$ (6.4) + $\frac{1}{8}$ (13)
Grout space or cavity width		- $\frac{1}{8}$ (6.4) + $\frac{1}{8}$ (9.5)
Mortar joint thickness	Bed joints	$\pm\frac{1}{8}$ (3.2)
	Head joints	- $\frac{1}{8}$ (6.4) + $\frac{1}{8}$ (9.5)
	Collar joints	- $\frac{1}{8}$ (6.4) + $\frac{1}{8}$ (9.5)
Variation from level ¹	In 10 ft (3.1 m)	$\pm\frac{1}{8}$ (6.4)
	Maximum	$\pm\frac{1}{8}$ (13)
Variation from plumb and true to a line	In 10 ft (3.1 m)	$\pm\frac{1}{8}$ (6.4)
	In 20 ft (6.1 m)	$\pm\frac{1}{8}$ (9.5)
	Maximum	$\pm\frac{1}{8}$ (13)
Alignment of columns and walls ²	Bearing member	$\pm\frac{1}{8}$ (13)
	Non-bearing member	$\pm\frac{1}{8}$ (19)

¹Bed joints and top surface of bearing members.
²Bottom versus top.

This specification and its accompanying Building Code Requirements for Masonry Structures (ACI 530/ASCE 5/TMS 402) [1] [also known as the MSJC Code] stipulate minimum size of grout spaces that are dependent on the height of grout pour and the grout type. The limits given in Table 2 are to ensure adequate access of grout to the space.

TABLE 2
Grout Space Requirements

Grout Type	Maximum Grout Pour Height, ft (m)	Minimum Width of Grout Space Between Masonry Wythes, in. (mm) ¹	Minimum Grout Space Dimensions for Grouting Cells of Hollow Units ^{1,2} in. \times in. (mm \times mm)
Fine	1 (0.3)	$\frac{1}{8}$ (19)	$1\frac{1}{2} \times 2$ (38 \times 51)
	5 (1.5)	2 (51)	2×3 (51 \times 76)
	12 (3.7)	$2\frac{1}{2}$ (64)	$2\frac{1}{2} \times 3$ (64 \times 76)
	24 (7.3)	3 (76)	3×3 (76 \times 76)
Coarse	1 (0.3)	$1\frac{1}{2}$ (38)	$1\frac{1}{2} \times 3$ (38 \times 76)
	5 (1.5)	2 (51)	$2\frac{1}{2} \times 3$ (64 \times 76)
	12 (3.7)	$2\frac{1}{2}$ (64)	3×3 (76 \times 76)
	24 (7.3)	3 (76)	3×4 (76 \times 102)

¹Grout space dimension is the clear dimension between any masonry protrusion and shall be increased by the diameters of the horizontal bars within the cross section of the grout space.

²Area of vertical reinforcement shall not exceed 6 percent of the area of the grout space.

Shoring and Bracing

RBM elements typically require temporary support during construction provided by shoring and bracing. These supporting members are typically of wood or steel construction. Temporary support is required for two reasons. First, grout is very fluid when placed and exerts considerable pressure on the surrounding brick masonry. Second, RBM elements gain strength over time as the mortar and grout cure and harden. RBM walls, columns and pilasters are often braced along their height. RBM beams and arches may require both shoring for vertical support and bracing for lateral load resistance and grout pressure resistance.

Shoring and bracing should be left in place until it is certain that the masonry has gained sufficient strength to carry its own weight and all other imposed loads including temporary loads that occur during construction. The most common problem related to temporary supports for masonry elements is inadequate lateral bracing to resist wind pressures during construction until the masonry has gained sufficient strength to resist these loads. This is especially true when the roof and floor diaphragms have not been installed and anchored to the top of the masonry wall. Without proper bracing, the wall is a free-standing cantilever element and is more vulnerable to collapse.

Appropriate time for removal of shoring and bracing depends on many factors. For example, proper curing of the mortar and grout may take considerably longer under cold weather conditions. The results of suitable compression tests of prisms or grout may be necessary as evidence that the masonry has attained sufficient strength to permit removal of shoring or bracing. Rules-of-thumb for the minimum time which should elapse before removal of shoring or bracing that have been recommended for many years include the following:

1. For RBM beams, 10 days after completion of the element
2. For RBM arches, 7 days after completion

3. Lateral bracing for walls, columns and pilasters, 7 days after placement of the grout.

Longer time periods will be necessary with inadequate curing conditions. It is always a good idea to consult the project engineer for a recommended bracing scheme and the length of time required for bracing to remain in place.

Curing Time Prior to Grouting. If grouting is performed too rapidly after construction the hydrostatic pressure of the grout can cause "blowout" of mortar joints or even entire sections of brickwork. This is especially true when the grout pour is high. Blowout of the grout can be avoided by a combination of proper curing time, adequate wall ties or joint reinforcement across the grout space and bracing.

Recommended duration of curing prior to grouting depends upon the method of grouting and the extent of bracing to resist the grout pressure. If no bracing against grout pressure is provided, the masonry should be permitted to cure for at least 3 days to gain strength before placement of grout in lifts greater than 5 ft (1.5 m) in height. For shorter grout lift heights, grout may be poured relatively soon after the brick are laid. Since grout lift heights are very short, the mason contractor should adjust the speed of construction as needed to avoid blowout of the wall.

Wall Ties Across Grout Spaces. Freshly placed grout exerts a hydrostatic pressure on the surrounding masonry formwork. This pressure increases with increasing pour height. To resist the grout pressure, wall ties are used across the grout space to tie the brick wythes together. For multi-wythe masonry walls, a minimum number of wall ties will already be provided to tie the wythes together in accordance with the building code. The wall ties resist the grout pressure by their tensile capacity. The ties provide the additional benefit of a positive mechanical anchorage between the grout core and the surrounding masonry. Ties may not be required across small grout spaces such as in columns or pilasters.

Wall ties across grout spaces should be at least W 1.7 (9 gage) wire. For masonry elements laid in running bond, ties should be spaced not more than 24 in (610 mm) o.c. horizontally and not more than 16 in. (406 mm) o.c. vertically. If stack bond is used, the vertical spacing should be reduced to 12 in. (305 mm) o.c. All ties should be placed in the same line vertically to facilitate the grout consolidation process. Ties should be embedded at least one-half the thickness of the masonry wythe.

Bracing Against Grout Pressure. For grout pour heights less than approximately 5 ft (1.5 m), bracing of the brick masonry may not be necessary. If the grout pour height is greater, consideration should be given to bracing the masonry. This is especially true when a longer curing time for the brick masonry prior to grouting is not feasible. Bracing members are typically externally applied wood construction. The bracing members should be designed by an engineer, based on the grout pour height.

PLACEMENT OF STEEL REINFORCEMENT

Steel reinforcement should be placed in accordance with the size, type and location indicated on the project drawings, and as specified. Dissimilar metals should not be placed in contact with each other because this can promote corrosion of the reinforcement. Nonmetallic flashing should be used when the flashing will come in contact with the reinforcement. If it is possible, all vertical steel reinforcement should be placed after completion of the masonry surrounding the grout space. This keeps the reinforcement out of the mason's way during construction and makes cleaning of the grout space easier. It also prevents contamination of the reinforcement by mortar droppings or protrusions that can adversely affect grout bond to the reinforcement.

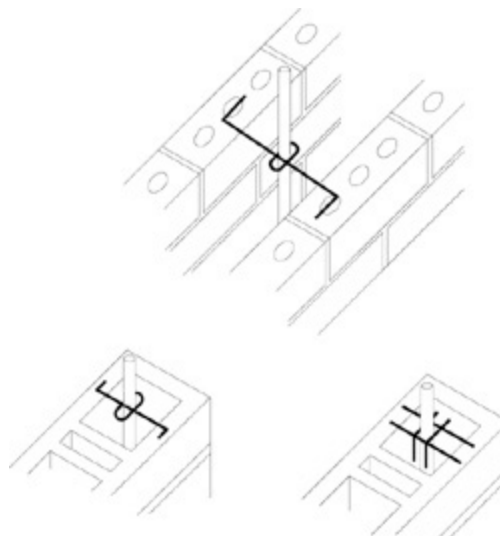
Applicable building codes should be consulted regarding placement requirements for reinforcement in masonry elements. A summary of the placement requirements for reinforcement in masonry stated in the MSJC Code is given in Table 3.

TABLE 3
Reinforcement Placement Requirements

Spacing Requirements				
Minimum clear distance between parallel bars and between a contact lap splice and adjacent splices or bars			Diameter of larger bar, but at least 1 in. (25 mm)	
Minimum clear distance between vertical bars and between a contact lap splice and adjacent splices or bars in columns and pilasters			1½ times the diameter of the larger bar, but at least 1½ in. (38 mm)	
Minimum grout thickness between reinforcement and surrounding masonry		Fine grout	¼ in. (6.4 mm)	
		Coarse grout	½ in. (13 mm)	
Minimum masonry cover	Bars	Masonry face exposed to earth or weather	No. 6 or larger	2 in. (51 mm)
			No. 5 or smaller	1½ in. (38 mm)
	Masonry face not exposed to earth or weather		1½ in. (38 mm)	
	Joint reinforcement wires	Masonry face exposed to earth or weather		½ in. (16 mm)
		Masonry face not exposed to earth or weather		¼ in. (13 mm)
	Erection Tolerances			
Maximum variation of vertical bar position along wall length from location indicated on project drawings			2 in. (51 mm)	
Tolerance from "d" dimension indicated on project drawings or as specified ¹		d ≤ 8 in. (203 mm)	±½ in. (13 mm)	
		8 in. (203 mm) < d ≤ 24 in. (610 mm)	±1 in. (25 mm)	
		d > 24 in. (610 mm)	±1½ in. (32mm)	

¹ In Flexural members, the "d" dimension is the distance from the extreme compression face to the centroid of the tensile reinforcement.

These requirements are to ensure proper bond to the grout, corrosion protection and fire resistance of the reinforcement. Table 3 also identifies the tolerance limits on positioning reinforcement in masonry elements. Reinforcement should only be spliced where indicated on the project drawings. Reinforcement should not be bent or disturbed after placement of the grout. Vertical reinforcement should be accurately placed and secured prior to the grouting process. Reinforcement can be secured by wire ties or other spacing devices. Some examples of common bar spacing devices are shown in Fig. 4.



Bar Spacing Devices
FIG. 4

Vertical reinforcement should be braced at the top and bottom of the element. Additional positioners may be necessary to facilitate proper placement of the bars. When reinforcement is spliced in a grout space between wythes or within an individual cell of hollow brick masonry, the two bars should be placed in contact and wired together. Vertical reinforcement in hollow brick masonry may be spliced by placing the bars in adjacent cells, provided the distance between the bars does not exceed 8 in. (204 mm).

Horizontal reinforcement is usually placed in the mortar joints as the work progresses or in bond beams at the completion of the bond beam course. In partially grouted walls, the bond beam should be grouted prior to further construction of brick masonry on top of the bond beam. For two-wythe, solid brick masonry walls, the horizontal reinforcement may be placed in the grouted collar joint. All horizontal bars should be on the same side of the vertical reinforcement to facilitate consolidation of the grout.

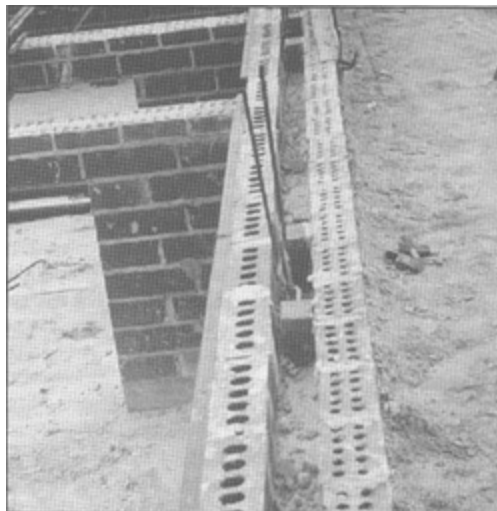
GROUTING

The most crucial aspect of constructing RBM elements is the grouting process. While grouting may seem a simple matter of filling cavities or cells of masonry, it is the one aspect of RBM construction that can cause the most problems. The most common problem is the creation of voids in the grout space due to stiff grout, excessive pour height, grout shrinkage, or blocked grout spaces. To ensure proper grouting, four sequential steps should be properly executed: preparation of the grout space, grout batching, grout placement and consolidation, and curing and protection.

Preparation of the Grout Space

The configuration and condition of the grout space can vary considerably. Common grout spaces for RBM elements are the cells of hollow brick, the collar joint between multi-wythe brick walls, the core of columns or pilasters and the depth of a beam.

For a multi-wythe brick wall with a grouted collar joint, vertical grout barriers, or dams, should be built across the grout space for the entire height of the wall at intervals of not more than 25 ft (7.6 m). Grout barriers control the horizontal flow of grout and reduce segregation. With hollow brick, mortar is placed on the cross webs to confine grout to certain vertical cells. Wire mesh is installed beneath a bond beam to prevent the flow of grout into the masonry below the bond beam. Examples of common grout barrier techniques are shown in Fig. 5.



Vertical Grout Barriers
FIG. 5

Grout spaces should be checked to see that all foreign materials and debris have been removed prior to grouting. The reinforcement should be clean and properly positioned in the grout space. If cleanouts are used, they should be sealed and braced if needed. All grout barriers should be secured and braced, if necessary.

The absorption rate of brick masonry will vary considerably with different units and weather conditions. To make the absorption more consistent, the grout space may be wetted prior to grouting. No free water should be on the units when the grout is placed.

Grout Batching

The quantities of solid materials in the grout mix should be determined by accurate volume measurement at the time of placing in the mixer. All materials for grout should be mixed in a mechanical mixer. Grout is most often supplied in bulk by ready-mix trucks and pumped into place because of the volume and speed of placement required. Batching on site is more common for smaller projects. When prepared on site, the grout mix should be batched in multiples of a bag of portland cement as a quality control measure. If less than a single bag of portland cement is used, extreme care should be used to accurately measure all parts.

Water, sand, aggregate and portland cement should be mixed for a minimum of 2 minutes, then the hydrated lime (if any) and additional water should be added and mixed for an additional 5 to 10 minutes. Make and maintain as high a flow as possible, consistent with good workability. This means that the grout should be wet enough to pour without segregation of the constituent materials or excessive bleeding. Grout should be a plastic mix that is suitable for pumping. The grout slump should be tested in accordance with ASTM C 143 Test Method for Slump of Hydraulic Cement Concrete and should be between 8 and 11 in. (203 and 279 mm).

Grout Placement and Consolidation

Grout should be placed within 1 1/2 hours after the water is first added to the mix and prior to the initial set. Grout slump should be maintained during placement. The grout pour should be done in one or more lifts and the total height of each pour should be from the center of one course to the center of another course of brick masonry. When grouting is stopped for 1 hour or longer, the grout pour should be stopped approximately 1 1/2 in. (38 mm) below the top of the masonry to create a shear key.

Whenever possible, grouting should be done from the unexposed face of the masonry element. Extreme care should be expanded to avoid grout staining on the exposed face or faces of the masonry. If grout does contact the face, it should be cleaned off immediately with water and a bristle brush. Waiting until after curing has occurred will make removal difficult.

Grout in contact with brick solidifies more rapidly than that in the center of the grout space. It is, therefore, important to consolidate the grout immediately after pouring to completely fill all voids. The best procedure is to have two people performing the operation jointly; one to pour the grout and the other to consolidate it. A mechanical vibrator or pudding stick is used for this purpose, depending on the construction method used.

There are two methods of RBM construction: simultaneous brick construction and grouting, and grouting after brick construction. These are sometimes referred to as "low lift" and "high lift" grouted masonry. In the first method, grout is placed in the masonry as the courses are laid. The grout is consolidated with a pudding stick or a mechanical vibrator. This method is typically used with narrow grout spaces. In the second method, the masonry is built to the story height or its full height, after which grout is poured from a hopper or pumped by mechanical means. The grout is consolidated with a low velocity vibrator with a 3/4 in. (19 mm) head. When grouting between wythes, the vibrator should be placed in the grout at points spaced 12 to 16 in. (305 to 406 mm) apart. The grout pour height restrictions given in Table 2 will limit the method of grout placement permitted in some instances. The mason contractor should give consideration to the advantages and disadvantages of each method.

Simultaneous Brick Construction and Grouting. The main benefits of simultaneous construction and grouting are elimination of cleanouts, reduction of grout pressures, and simplicity of construction. With this method of grouting, the entire grout space can be kept entirely clear of blockage and can be easily inspected prior to grouting. Consolidation of the entire grout pour is also easier and bracing may be lessened or eliminated.

For a multi-wythe brick wall with grouted collar joint, one wythe should be built up not more than 16 in. (406 mm) ahead of the other wythe. Typically, the grout pour height will not exceed 12 in. (305 mm) for such walls and a pudding stick may be used for consolidation purposes. If the grout is carried up too rapidly, there is a chance blowout will occur. If a wythe does move, even as little as 1/8 in. (3 mm) out-of-plumb, the work should be torn down rebuilt. This is because the bed joint bond has been broken and cannot be repaired merely by shoving the wall back into plumb.

The grout should be placed to a uniform height between grout barriers and should be consolidated with a mechanical vibrator or pudding stick immediately after placement. Extreme care should be exercised during grout placement and consolidation to avoid displacement of the brick masonry.

Grouting After Brick Construction. Grouting after construction of the masonry has become the industry standard due to its speed and the fact that grout is often supplied by ready-mix trucks. These trucks deliver large quantities of grout, but cannot remain on site indefinitely during construction. Grout delivery must be coordinated with brick construction and preparation of grout spaces. The grout spaces in RBM elements can be very small and become crowded with reinforcing bars and wall ties. In addition, some contractors have commented that the highly absorptive nature of some brick masonry causes the grout to dry out and not flow properly to the bottom of grout spaces if the lift height is too great.

The first lift of grout should be placed to a uniform height between the grout barriers or the surrounding brick masonry, and should be mechanically vibrated to fill all voids. This first vibration should be done within 10 minutes after pouring the grout, while the grout is still plastic and before it has set. Grout pours in excess of 12 in. (305 mm) should be reconsolidated by mechanical vibration after initial water loss and settlement has occurred. The succeeding lift should be poured, vibrated and reconsolidated in a similar manner. In the first vibraton, the vibrator

should extend 6 to 12 in. (152 to 305 mm) into the preceding lift. This further reconsolidates the first lift and closes any shrinkage cracks or separations that may have formed. The work should be planned for a single, continuous grout pour to the top of the wall in 5 ft (1.5 m) lifts. Under normal weather conditions, in the range of 40 to 90 degrees F of (4 to 32 degrees C), the waiting period between lifts should be between 30 and 60 minutes.

Curing and Protection

The masonry work, particularly the top of the grout pour, should be kept covered and damp to prevent excessive drying. The newly grouted masonry should be fog sprayed three times each day for a period of three days following construction when the ambient temperature exceeds 100 degrees F (38 degrees C) or 90 degrees F (32 degrees C) with a wind speed in excess of 8 mph (13 km/hr). The exposed faces of brickwork should be cleaned prior to the fog spraying. Cleaning will be much more difficult if it is postponed until after this curing. The water from cleaning will also aid in the curing process. Refer to the information in Technical Notes 1 Revised for proper construction and protection methods during excessive cold or hot weather conditions.

For walls, columns and pilasters, at least 12 hours should elapse after construction before application of floor or roof members, except that 72 hours should elapse prior to application of heavy, concentrated loads such as truss, girder or beam members.

QUALITY ASSURANCE MEASURES

Not all masonry projects will involve testing or inspection. However, the MSJC Code states that, "A quality assurance program shall be used to ensure that the constructed masonry is in conformance with the Contract Documents." A quality assurance program typically includes inspection of the work by an owner's representative and periodic sampling and testing of masonry materials.

Inspection

The masonry inspector's job is to obtain good quality masonry construction and workmanship according to plans and specifications. The inspector should be able to explain the reasons for the specified procedures and know the important aspects of quality workmanship that will produce RBM elements with the properties assumed in the structural design. The inspector should verify clean grout spaces prior to grouting. Type and positioning of wall ties, bar positioners, joint reinforcement, and reinforcement should be verified against the project drawings and specifications. During the grouting process, the inspector should verify that: the grout is proportioned properly, the proper grouting technique is used, and all grout spaces are completely filled with grout. The inspector should look for darkening of the masonry due to water absorption from the grout as evidence of proper grout placement. Bracing and shoring should be inspected for proper installation. Protection measures such as covering the tops of uncompleted work, heated enclosures, and insulation blankets should be verified

Testing

On some RBM projects, it may be necessary to conduct various quality control tests to ensure that the masonry has been constructed properly. The frequency of testing should be stated in the project specifications. Testing may be conducted prior to or during construction on the individual materials, e.g. brick, mortar, and grout. This is the most common form of quality control testing. Brick are typically tested for compressive strength prior to construction. Mortar may be tested in compression prior to construction in order to establish proportions of ingredients to be measured at the jobsite. The same is true for grout, which should also be tested to verify the slump. Prism compression tests are one example of such testing. The MSJC Specification stipulates the type, method and frequency of material and assemblage quality control tests required for masonry elements. This document states that prisms and grout will be tested for each 5000 sq.ft. (465 m²) of wall area or portion thereof when testing is required. Finally, tests of samples extracted from the constructed masonry may be necessary to verify the strength of elements when this is in question. A prism cut out of a masonry element to be used for compression testing is an example of such a test. For a review of the common quality control tests for brick masonry, refer to the Technical Notes 39 Series.

Quality control tests can seem an onerous and unwanted expense, but they are provided for two very important reasons. First and foremost, tests can indicate consistency during construction. Dramatic changes in strength properties of elements as the work progresses can indicate a problem and should be explained. The second reason for testing is to monitor the strength gain of the masonry elements upon curing. The strength gain is monitored to indicate when shores or bracing can be removed, when loads can be applied to an element, and to verify that the strength assumed in the design has been achieved by the constructed masonry.

SUMMARY

Reinforced brick masonry is constructed in a manner that is different in many ways from conventional brick veneer construction. Proper materials and construction practices as discussed in this Technical Notes should be followed to

ensure that RBM elements achieve adequate strength and meet the applicable building code requirements.

The information and suggestions contained in this Technical Notes are based on the available data and the experience of the engineering staff of the Brick Institute of America. 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 Notes are not within the purview of the Brick Institute of America and must rest with the project architect, engineer and owner.

REFERENCES

1. Building Code Requirements for Masonry Structures (ACI 530/ASCE 5/TMS 402-95), American Society of Civil Engineers, New York, NY, 1996
2. Specification for Masonry Structures (ACI 530.1/ASCE 6/TMS 602-95), American Society of Civil Engineers, New York, NY, 1996