NCMA TEK

National Concrete Masonry Association
an information series from the national authority on concrete masonry technology

CONCRETE MASONRY CONSTRUCTION

TEK 3-8A
Construction (2001)

Keywords: ASTM specifications, bond patterns, cleaning, construction techniques, construction tolerances, grout,

INTRODUCTION

Concrete masonry is a popular building material because of its strength, durability, economy, and its resistance to fire, noise, and insects. To function as designed however, concrete masonry buildings must be constructed properly.

This TEK provides a brief overview of the variety of materials and construction methods currently applicable to concrete masonry. In addition, a typical construction sequence is described in detail.

MATERIALS

The constituent masonry materials: concrete block, mortar, grout, and steel, each contribute to the performance of a masonry structure. Concrete masonry units provide strength, durability, fire resistance, energy efficiency, and sound attenuation to a wall system. In addition, concrete masonry units are manufactured in a wide variety of sizes, shapes, colors, and architectural finishes to achieve any number of appearances and functions. The *Concrete Masonry Shapes and Sizes Manual* (ref. 4) illustrates a broad sampling of available units.

While mortar constitutes approximately 7% of a typical masonry wall area, its influence on the performance of a wall is significant. Mortar bonds the individual masonry units together, allowing them to act as a composite structural assembly. In addition, mortar seals joints against moisture and air leakage and bonds to joint reinforcement, anchors, and ties to help ensure all elements perform as a unit.

Grout is used to fill masonry cores or wall cavities to improve the structural performance and/or fire resistance of masonry. Grout is most commonly used in reinforced construction, to structurally bond the steel reinforcing bars to the masonry, allowing the two elements to act as one unit in resisting loads.

Reinforcement incorporated into concrete masonry structures increases strength and ductility, providing increased resistance to applied loads and, in the case of horizontal reinforcement, to shrinkage cracking.

Specifications governing material requirements are listed in Table 1.

CONSTRUCTION METHODS

Mortared Construction

Most concrete masonry construction is mortared construction, i.e., units are bonded together with mortar. Varying the bond or joint pattern of a concrete masonry wall can create a wide variety of interesting and attractive appearances. In ad-

Placement of Concrete Masonry Units

Table 1—Masonry Material Specifications

Units
Loadbearing Concrete Masonry Units, ASTM C 90
Concrete Building Brick, ASTM C 55
Calcium Silicate Face Brick (Sand-Lime Brick), ASTM C 73
Nonloadbearing Concrete Masonry Units, ASTM C 129
Prefaced Concrete and Calcium Silicate Masonry Units, ASTM C 744

Mortar
Mortar for Unit Masonry, ASTM C 270

Grout
Grout for Masonry, ASTM C 476

Reinforcement
Axle-Steel Deformed and Plain Bars for Concrete Reinforcement, ASTM A 617
Deformed and Plain Billet-Steel Bars for Concrete Reinforcement, ASTM A 615
Epoxy-Coated Reinforcing Steel Bars, ASTM A 775
Low-Alloy Steel Deformed Bars for Concrete Reinforcement, ASTM A 706
Rail-Steel Deformed and Plain Bars for Concrete Reinforcement, ASTM A 616
Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement, ASTM A 767
Masonry Joint Reinforcement, ASTM A 951

Ties & Anchors

dition, the strength of the masonry can be influenced by the bond pattern. The most traditional bond pattern for concrete masonry is running bond, where vertical head joints are offset by half the unit length.

Excluding running bond construction, the most popular bond pattern with concrete masonry units is stack bond. Although stack bond typically refers to masonry constructed so that the head joints are vertically aligned, it is defined as masonry laid such that the head joints in successive courses are horizontally offset less than one quarter the unit length (ref. 2). *Concrete Masonry Bond Patterns* (ref. 3) shows a variety of bond patterns and describes their characteristics.

Dry-Stacked Construction

The alternative to mortared construction is dry-stacked (also called surface bonded) construction, where units are placed without any mortar, then both surfaces of the wall are coated with surface bonding material. Shims or ground units are used to maintain elevations. This construction method results in faster construction, and is less dependent on the skill of the laborer than mortared construction. In addition, the surface bonding coating provides excellent rain penetration resistance. *Surface Bonded Concrete Masonry Construction* (ref. 9) contains further information on this method of construction.

CONSTRUCTION SEQUENCE

Mixing Mortar

To achieve consistent mortar from batch to batch, the same quantities of materials should be added to the mixer, and they should be added in the same order. Mortar mixing times, placement methods, and tooling must also be consistent to achieve uniform mortar for the entire job.

In concrete masonry construction, site-mixing of mortar should ideally be performed in a mechanical mixer to ensure proper uniformity throughout the batch. Mortar materials should be placed in the mixer in a similar manner from batch to batch to maintain consistent mortar properties. Typically, about half the mixing water is added first into a mixer. Approximately half the sand is then added, followed by any lime. The cement and the remainder of the sand are then added. As the mortar is mixed and begins to stiffen, the rest of the water is added. *Specification for Masonry Structures* (ref. 7) requires that these materials be mixed for 3 to 5 minutes. If the mortar is not mixed long enough, the mortar mixture may not attain the uniformity necessary for the desired performance. A longer mixing time can increase workability, water retention, and board life.

The mortar should stick to the trowel when it is picked up, and slide off the trowel easily as it is spread. Mortar should also hold enough water so that the mortar on the board will not lose workability too quickly, and to allow the mason to spread mortar bed joints ahead of the masonry construction. The mortar must also be stiff enough to initially support the weight of the concrete masonry units.

To help keep mortar moist, the mortarboard should be moistened when a fresh batch is loaded. When mortar on the board does start to dry out due to evaporation, it should be retempered. To retemper, the mortar is mixed with a small amount of additional water to improve the workability. After a significant amount of the cement has hydrated, retempering will no longer be effective. For this reason, mortar can be retempered for only $1^1/_2$ to $2^1/_2$ hours after initial mixing, depending on the site conditions. For example, dry, hot, and windy conditions will shorten the board life, and damp, cool, calm conditions will increase the board life of the mortar. Mortar should be discarded if it shows signs of hardening or if $2^1/_2$ hours have passed since the original mixing.

Placing Mortar

Head and bed joints are typically $^3/_8$ in. (10 mm) thick, except at foundations. Mortar should extend fully across bedding surfaces of hollow units for the thickness of the face shell, so that joints will be completely filled. Solid units are required to be fully bedded in mortar.

Although it is important to provide sufficient mortar to properly bed concrete masonry units, excessive mortar should not extend into drainage cavities or into cores to be grouted. For grouted masonry, mortar protrusions extending more than $^1/_2$ in. (13 mm) into cells or cavities to be grouted should be removed (ref. 7).

The Importance of Laying to the Line

Experienced masons state that they can lay about five times as many masonry units when working to a mason line than when using just their straightedge. The mason line gives the mason a guide to lay the block straight, plumb, at the right height, and level. The line is attached so that it gives a guide in aligning the top of the course.

If a long course is to be laid, a trig may be placed at one or more points along the line to keep the line from sagging. Before work begins, the mason should check to see that the line is level, tight, and will not pull out.

Each mason working to the same line needs to be careful not to lay a unit so it touches the line. This will throw the line off slightly and cause the rest of the course to be laid out of alignment. The line should be checked from time to time to be certain it has remained in position.

PLACING UNITS

The Foundation

Before building the block wall, the foundation must be level, and clean so that mortar will properly adhere. It must also be reasonably level. The foundation should be free of ice, dirt, oil, mud, and other substances that would reduce bond.

Laying Out the Wall

Taking measurements from the foundation or floor plan and transferring those measurements to the foundation, footing, or floor slab is the first step in laying out the wall.

Once two points of a measurement are established, corner to corner, a chalk line is marked on the surface of the foundation to establish the line to which the face of the block will be laid. Since a chalk line can be washed away by rain, a grease crayon, line paint, nail or screwdriver can mark the surface for key points along the chalk line, and a chalk line re-snapped along these key points. After the entire surface is marked for locations of walls, openings, and control joints, a final check of all measurements should be made.

The Dry Run—Stringing Out The First Course

Starting with the corners, the mason lays the first course without any mortar so a visual check can be made between the dimensions on the floor or foundation plan and how the first course actually fits the plan. During this dry layout, concrete blocks will be strung along the entire width and length of the foundation, floor slab, and even across openings. This will show the mason how bond will be maintained above the opening. It is helpful to have $^3/_8$ in. (10 mm) wide pieces of wood to place between block as they are laid dry, to simulate the mortar joints.

At this dry run the mason can check how the block will space for openings which are above the first course—windows, etc., by taking away block from the first course and checking the spacing for the block at the higher level. These checks will show whether or not units will need to be cut. Window and door openings should be double checked with the window shop drawings prior to construction.

When this is done, the mason marks the exact location and angle of the corners. It is essential that the corner be built as shown on the foundation or floor plan, to maintain modular dimensions.

Laying the Corner Units

Building the corners is the most precise job facing the mason as corners will guide the construction of the rest of the wall. A corner pole can make this job easier. A corner pole is any type of post which can be braced into a true vertical position and which will hold a taut mason's line without bending. Corner poles for concrete block walls should be marked every 4 or 8 in. (102 to 203 mm), depending on the course height, and the marks on both poles must be aligned such that the mason's line is level between them.

Once the corner poles are properly aligned, the first course of masonry is laid in mortar. Typically, a mortar joint between $^1/_4$ and $^3/_4$ in. (6.4 to 19 mm) is needed to make up for irregularities of the footing surface. The initial bed joint should be a full bed joint on the foundation, footing, or slab. In some areas, it is common practice to wet set the initial course of masonry directly in the still damp concrete foundation.

Where reinforcing bars are projecting from the foundation footing or slab, the first course is not laid in a full mortar bed. In this case, the mason leaves a space around the reinforcing bars so that the block will be seated in mortar but the mortar will not cover the area adjacent to the dowels. This permits the grout to bond directly to the foundation in these locations.

After spreading the mortar on the marked foundation, the first block of the corner is carefully positioned. It is essential that this first course be plumb and level.

Once the corner block is in place, the lead blocks are set—three or four blocks leading out from each side of the corner. The head joints are buttered in advance and each block is lightly shoved against the block in place. This shove will help make a tighter fit of the head joint, but should not be so strong as to move the block already in place. Care should be taken to spread mortar for the full height of the head joint so voids and gaps do not occur.

If the mason is not working with a corner pole, the first course leads are checked for level, plumb, and alignment with a level.

Corners and leads are usually built to scaffold height, with each course being stepped back one half block from the course below. The second course will be laid in either a full mortar bed or with face shell bedding, as specified.

Laying the Wall

Each course between the corners can now be laid easily by stretching a line between. It should be noted that a block has thicker webs and face shells on top than it has on the bottom. The thicker part of the webs should be laid facing up. This provides a hand hold for the mason and more surface area for mortar to be spread. The first course of block is thereafter laid from corner to corner, allowing for openings, with a closure block to complete the course. It is important that the mortar for the closure block be spread so all edges of the opening between blocks and all edges of the closure block are buttered before the closure block is carefully set in place. Also, the location of the closure block should be varied from course to course so as not to build a weak spot into the wall.

The units are leveled and plumbed while the mortar is still soft and pliable, to prevent a loss of mortar bond if the units need to be adjusted.

As each block is put in place, the mortar which is squeezed out should be cut off with the edge of the trowel and care should be taken that the mortar doesn't fall off the trowel onto the wall or smear the block as it is being taken off. Should some mortar get on the wall, it is best to let it dry before taking it off.

All squeezed out mortar which is cut from the mortar joints can either be thrown back onto the mortar board or used to butter the head joints of block in place. Mortar which has fallen onto the ground or scaffold should never be reused.

At this point, the mason should:

- Use a straightedge to assure the wall is level, plumb and aligned.
- Be sure all mortar joints are cut flush with the wall, awaiting tooling, if necessary.
- Check the bond pattern to ensure it is correct and that the spacing of the head joints is right. For running bond, this is done by placing the straightedge diagonally across the wall. If the spacing of head joints is correct, all the edges of the block will be touched by the straightedge.
- Check to see that there are no pinholes or gaps in the mortar joints. If there are, and if the mortar has not yet taken its first set, these mortar joint defects should be repaired with fresh mortar. If the mortar has set, the only way they can be repaired is to dig out the mortar joint where it needs repairing, and tuckpoint fresh mortar in its place.

Tooling Joints

When the mortar is thumbprint hard, the head joints are tooled, then the horizontal joints are finished with a sled runner and any burrs which develop are flicked off with the blade of the trowel. When finishing joints, it is important to press firmly, without digging into the joints. This compresses the surface of the joint, increasing water resistance, and also promotes bond between the mortar and the block. Unless otherwise required, joints should be tooled with a rounded jointer, producing a concave joint. Once the joints are tooled, the wall is ready for cleaning.

Cleanup

Masonry surfaces should be cleaned of imperfections that may detract from the final appearance of the masonry structure including stains, efflorescence, mortar droppings, grout droppings, and general debris.

Cleaning is most effective when performed during the wall construction. Procedures such as skillfully cutting off excess mortar and brushing the wall clean before scaffolding is raised, help reduce the amount of cleaning required.

When mortar does fall on the block surface, it can often be removed more effectively by letting it dry and then knocking it off the surface. If there is some staining on the face of the block, it can be rubbed off with a piece of broken block, or brushed off with a stiff brush.

Masons will sometimes purposefully not spend extra time to keep the surface of the masonry clean during construction because more aggressive cleaning methods may have been specified once the wall is completed. This is often the case for grouted masonry construction where grout smears can be common and overall cleaning may be necessary.

The method of cleaning should be chosen carefully as aggressive cleaning methods may alter the appearance of the masonry. The method of cleaning can be tested on the sample panel or in an inconspicuous location to verify that it is acceptable.

Specification for Masonry Structures (ref. 7) states that all uncompleted masonry work should be covered at the top for protection from the weather.

DIMENSIONAL TOLERANCES

While maintaining tight construction tolerances is desirable to the appearance, and potentially to the structural integrity of a building, it must be recognized that factors such as the condition of previous construction and non-modularity of the project may require the mason to vary the masonry construction slightly from the intended plans or specifications. An example of this is when a mason must vary head or bed joint thicknesses to fit within a frame or other preexisting construction. The ease and flexibility with which masonry construction accommodates such change is one advantage to using masonry. However, masonry should still be constructed within certain tolerances to ensure the strength and appearance of the masonry is not compromised.

Specification for Masonry Structures (ref. 7) contains site tolerances for masonry construction which allow for deviations in the construction that do not significantly alter the structural integrity of the structure. Tighter tolerances may be required by the project documents to ensure the final overall appearance of the masonry is acceptable. If site tolerances are not being met or cannot be met due to previous construction, the Architect/Engineer should be notified.

Mortar Joint Tolerances

Mortar joint tolerances are illustrated in Figure 1. Although bed joints should be constructed level, they are permitted to vary by $\pm\,^1/_2$ in. (13 mm) maximum from level provided the joint does not slope more than $\pm\,^1/_4$ in. (6.4 mm) in 10 ft (3.1 m).

Collar joints, grout spaces, and cavity widths are permitted to vary by $-^1/_4$ in. to $+\,^3/_8$ in. (6.4 to 9.5 mm). Provisions for cavity width are for the space between wythes of non-composite masonry. The provisions do not apply to situations where the masonry extends past floor slabs or spandrel beams.

Dimensions of Masonry Elements

Figure 2 shows tolerances that apply to walls, columns, and other masonry building elements. It is important to note that the specified dimensions of concrete masonry units are

3/8 in. (9.5 mm) less than the nominal dimensions. Thus a wall specified to be constructed of 8 in. (203 mm) concrete masonry units should not be rejected because it is 7 5/8 in. (194 mm) thick, less than the apparent minimum of 7 3/4 in. (197 mm) (8 in. (203 mm) minus the 1/4 in. (6.4 mm) tolerance). Instead the tolerance should be applied to the 7 5/8 in. (194 mm) specified dimension.

Plumb, Alignment, and Levelness of Masonry Elements

Tolerances for plumbness of masonry walls, columns, and other building elements are shown in Figure 3. Masonry building elements should also maintain true to a line within the same tolerances as variations from plumb.

Columns and walls continuing from one story to another may vary in alignment by ± 3/4 in. (19 mm) for nonloadbearing walls or columns and by ± 1/2 in. (13 mm) for bearing walls or columns.

The top surface of bearing walls should remain level within a slope of ± 1/4 in. (6.4 mm) in 10 ft (3.1 m), but no more than ± 1/2 in. (13 mm).

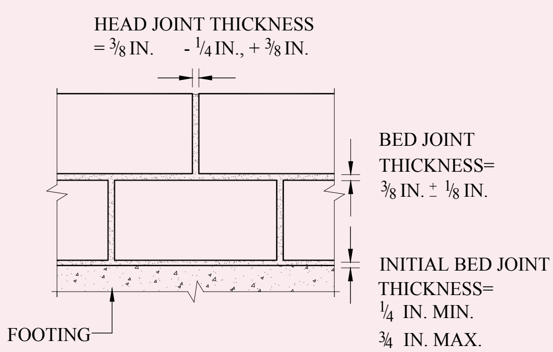

Figure 1—Mortar Joint Tolerances

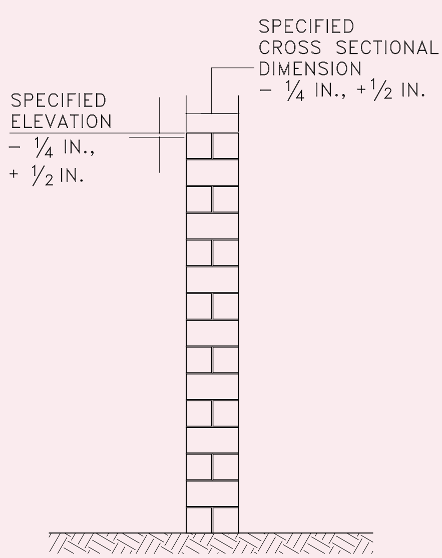

Figure 2—Element Cross Section and Elevation Tolerances

Location of Elements

Requirements for location of elements are shown in Figures 4 and 5.

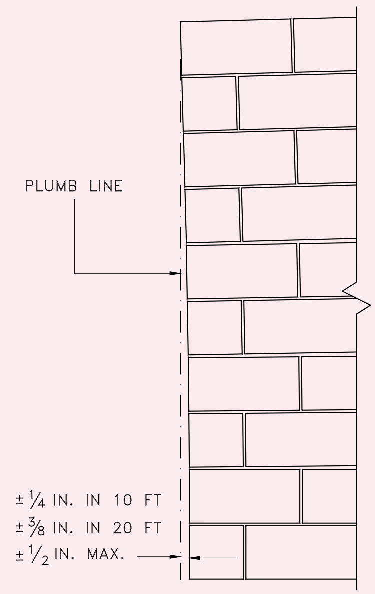

Figure 3—Permissible Variations From Plumb

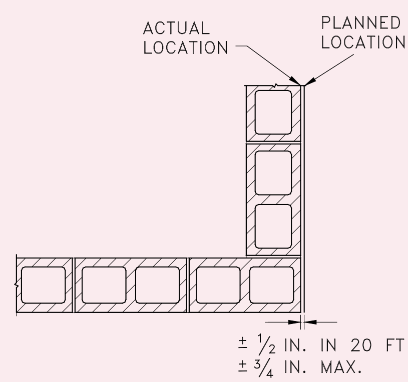

Figure 4—Location Tolerances in Plan

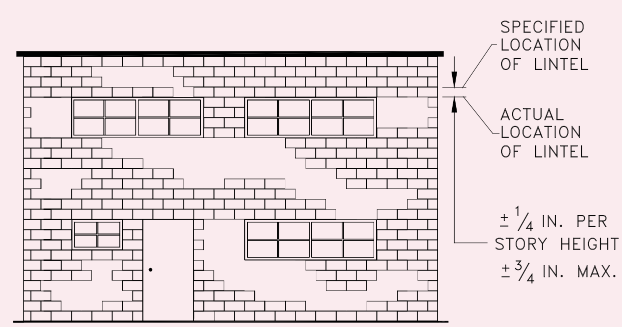

Figure 5—Location Tolerances in Story Height

REFERENCES

1. *Building Block Walls*, VO 6. National Concrete Masonry Association, 1988.
2. *Building Code Requirements for Masonry Structures*, ACI 530-99/ASCE 5-99/TMS 402-99. Reported by the Masonry Standards Joint Committee, 1999.
3. *Concrete Masonry Bond Patterns,* TEK 14-6. National Concrete Masonry Association, 1999.
4. *Concrete Masonry Shapes and Sizes Manual*, CM 260A. National Concrete Masonry Association, 1997.
5. *Inspection of Concrete Masonry Construction*, TR 156. National Concrete Masonry Association, 1996.
6. Nolan, K. J. *Masonry & Concrete Construction*. Craftsman Book Company, 1982.
7. *Specification for Masonry Structures*, ACI 530.1-99/ASCE 6-99/TMS 602-99. Reported by the Masonry Standards Joint Committee, 1999.
8. *Standard Specification for Loadbearing Concrete Masonry Units*, ASTM C 90-00. American Society for Testing and Materials, 2000.
9. *Surface Bonded Concrete Masonry Construction,* TEK 3-5A. National Concrete Masonry Association, 1998.