



ANCHOR BOLTS FOR BRICK MASONRY

Abstract: Anchor bolts are used extensively in brick masonry to make structural attachments and connections. To date, a limited amount of information has been available to aid designers in the selection and design of anchor bolts in brick masonry. This *Technical Notes* addresses the types of anchor bolts available, detailing of anchor bolt placement and suggested design procedures. A discussion of current and proposed codes and standards is also presented.

Key Words: anchors, bolts, conventional anchors (bent bar, plate, sleeve, wedge), edge distance, headed bolts, loads, proprietary anchors (adhesive, expansion), shear, tension, through bolts.

INTRODUCTION

Anchor bolts are used in masonry construction with few or no guidelines for the practicing designer to follow. This *Technical Notes* offers basic information covering 1) the types of anchor bolts available for structural applications in brick masonry, 2) typical details of proper anchor bolt installation, 3) suggested allowable anchor bolt design loads and 4) the current and proposed codes and standards governing anchor bolts in brick masonry construction.

In new masonry construction, anchor bolts are commonly embedded in walls and columns to support beams, plates and ledgers. In prefabricated panel construction, anchor bolts are used to facilitate connections to the structural frame. Renovation and rehabilitation of existing masonry structures usually require that anchor bolts be used to attach stair risers, elevator tracks and various frame assemblages for equipment installation. This is only a fraction of the possible uses of anchor bolts in masonry construction and with the increase of new, innovative architectural masonry designs, the uses of anchor bolts in masonry construction are likely to increase.

This *Technical Notes* is the first in a series on masonry anchors, fasteners and ties, and addresses anchor bolts for brick masonry. Other *Technical Notes* in this series will address brick masonry fasteners and ties.

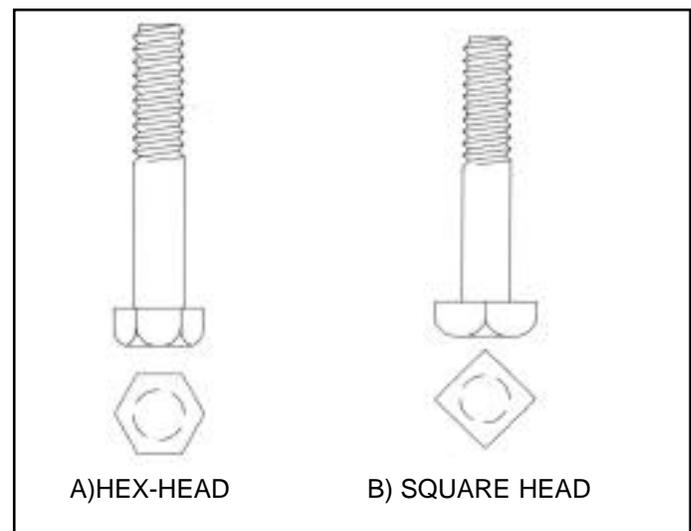
ANCHOR BOLT TYPES

Anchor bolts can be divided into two major groups: conventional (unpatented) anchors and proprietary (patented) anchors. Conventional anchor bolts are usually embedded in the masonry during construction and require careful attention to bolt location and grip length requirements to avoid problems with connection alignment and erection. Proprietary anchors, however, are typically installed after completion of construction and therefore, permit a larger degree of freedom in anchor placement. For this reason, proprietary anchors are becoming popular

in masonry construction and add new concerns in the area of anchor bolt design.

Conventional Anchor Bolts

Conventional bolts are usually made to the specific project requirements by steel fabricators or they may be purchased in standard sizes (diameters and lengths) from steel suppliers. The availability and cost of conventional bolts are generally based on demand and fabrication requirements. The types of conventional anchor bolts most often used are discussed below.



Headed Bolts
FIG. 1

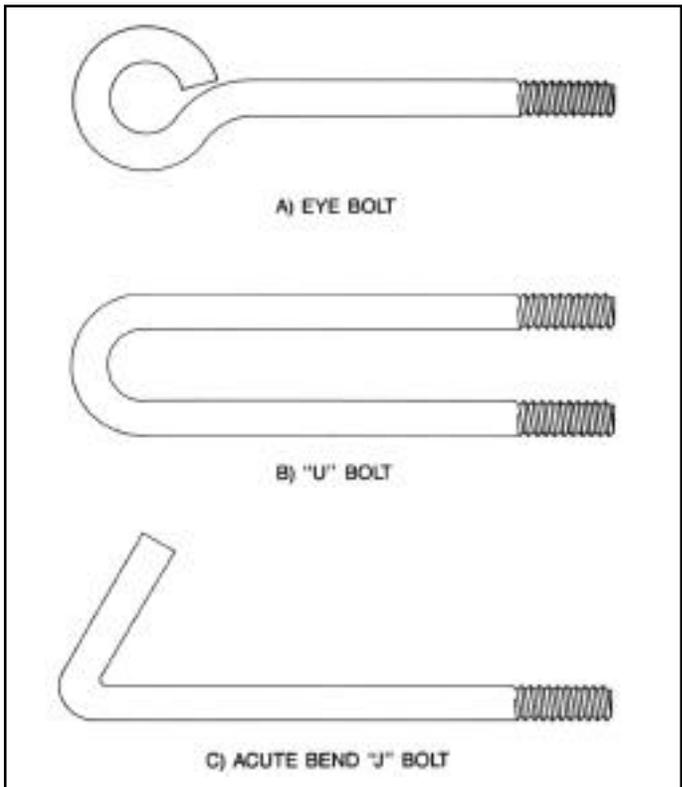
Headed Bolts. Square or hex-headed ASTM A 307 bolts are frequently used as anchor bolts due to their wide availability and relatively low cost (see Figure 1). Higher strength bolts, such as ASTM A 325 bolts, are available and can be used, but are more expensive. A washer placed against the bolt head is often used with the inten-

tion of increasing the bearing area and thus increasing the anchor strength. However, the actual strength increase obtained by adding a washer is small, if any, and under certain conditions (small edge distances), may actually decrease the tensile strength.

Bent Bar Anchors. Bent bar anchors, frequently used in masonry construction, are usually made in "J" or "L" shapes (see Fig. 2). Even though the "J" and "L" shapes are the more popular, a variety of shapes (see Fig. 3) is available since there currently is no standard governing the geometric properties of bent bar anchors. These anchors are usually made from ASTM A 36 bar stock and are shop-threaded.

Plate Anchors. Plate anchors are usually made by welding a square of circular steel plate perpendicular to the axis of a steel bar that is threaded on the opposite end (see Fig. 4). There are no standards governing the dimensions (length, width or diameter) of the plate. The American Institute of Steel Construction does limit the fillet weld size based on the plate thickness (see Table 1). Both the plate and bar are usually made from ASTM A 36 steel.

Through Bolts. As the name implies, through bolts extend completely through the thickness of the masonry and are composed of a threaded rod or bar with a bearing plate located on the surface opposite the attachment (see Fig. 5). In the early 1900's, through bolts were used in loadbearing masonry structures to tie floor and wall systems together. Often decorative cast bearing plates were used since through bolts were visible on the exterior masonry surfaces (see Fig. 6). Today, through bolts are primarily used in industrial construction where aesthetics are not a principal concern, or in retrofitting existing structures. Through bolt rods are usually made from ASTM A 307 threaded rod or threaded ASTM A36 bar stock. Bearing plates are typically made from ASTM A 36 steel plate.



Other Bent Bar Anchors
FIG. 3

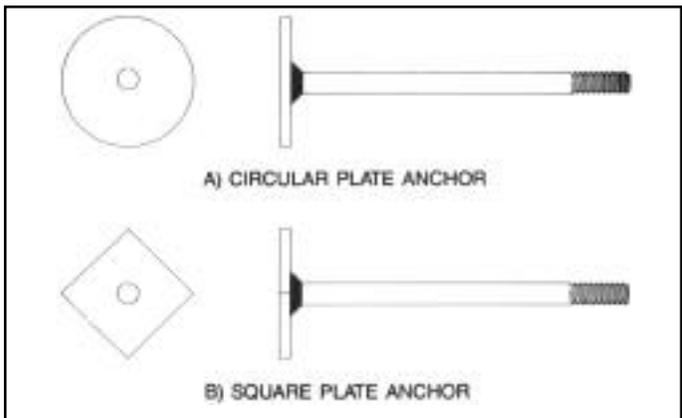
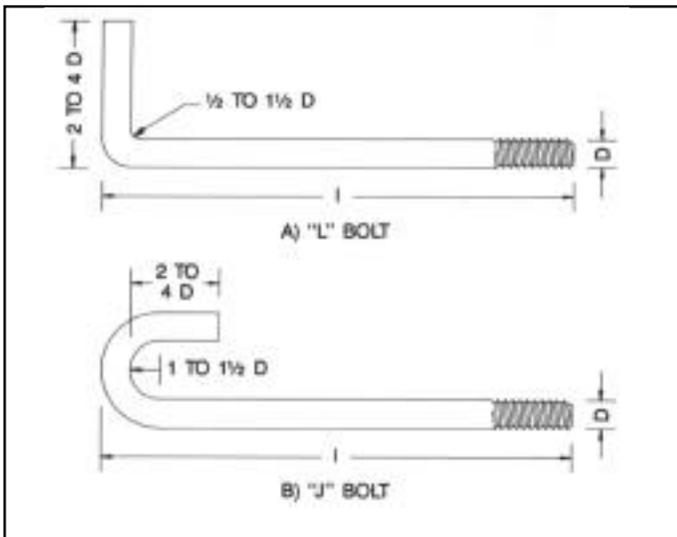
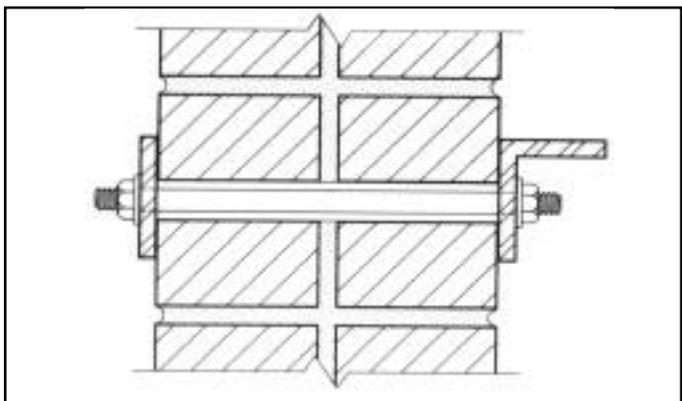


Plate Anchors
FIG. 4



"L" and "J" Bent Bar Anchors
FIG. 2



Through Bolt
FIG. 5

| TABLE 1 AISC* Fillet Weld Size Requirements | |
|---|------------------------|
| Minimum Size | |
| Material Thickness of Thicker Part Joined | Minimum Leg Dimensions |
| <u>In.</u> | <u>In.</u> |
| To 1/4 Inclusive | 1/8 |
| Over 1/4 to 1/2 | 3/16 |
| Over 1/2 to 3/4 | 1/4 |
| Over 3/4 | 5/16 |
| Maximum Size | |
| 1. Along edges of material less than 1/4 in. thick, not greater than the thickness of the material. 2. Along the edges of material 1/4 in. or more in thickness, not greater than the thickness of the material minus 1/16 in., unless the weld is especially designated on the drawing to be built out to obtain full throat thickness. | |
| *American Institute of Steel Construction | |



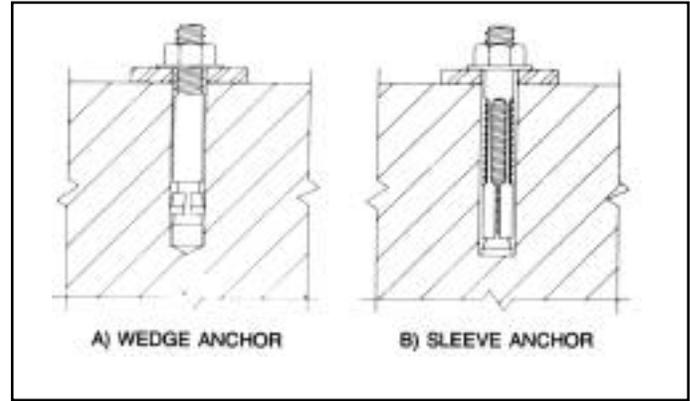
Decorative Through Bolt Bearing Plate
FIG. 6

Proprietary Anchor Bolts

Proprietary anchors are available through a number of manufacturers under numerous brand names. Although the style and physical appearance of the anchors differ between manufacturers, the basic theories behind the anchors are very similar. For this reason, proprietary anchors can be divided into two generic categories: expansion-type anchors and adhesive or chemical-type anchors.

Expansion Anchors. Two different types of expansion anchors are generally recommended by their manufacturers for use in brick masonry: the wedge anchor and the sleeve anchor (see Fig. 7). These anchors develop their strength by means of expansion into the base material. Wedge anchors develop their hold by means of a wedge or wedges that are forced into the base material when the bolt is tightened. The wedges create large point bearing stresses within the hole; therefore, this anchor

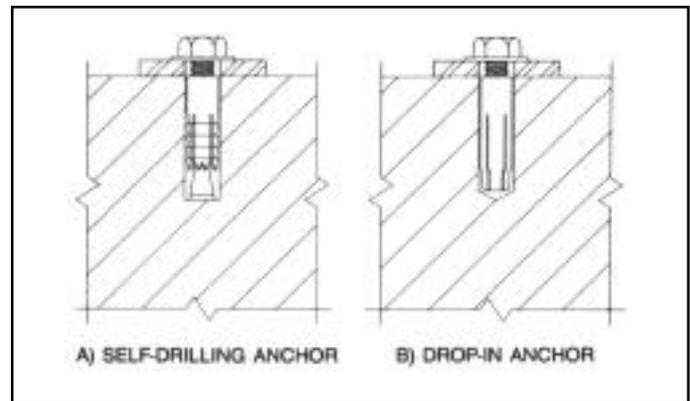
requires a solid base material to develop its full capacity. For this reason, voids formed by brick cores and partially filled mortar joints in some brick masonry may make the construction unsuitable for wedge anchor installation.



Proprietary Expansion Anchors
FIG. 7

Sleeve anchors develop their strength by the expansion of a cylindrical metal sleeve or shield into the base material as the bolt is tightened. The expansion of the sleeve along the length of the anchor provides a larger bearing surface than the wedge anchor, and is less affected by irregularities and voids in the base material than is the wedge anchor. For this reason, sleeve anchors are recommended by their manufacturers for use in brick masonry more often than wedge anchors.

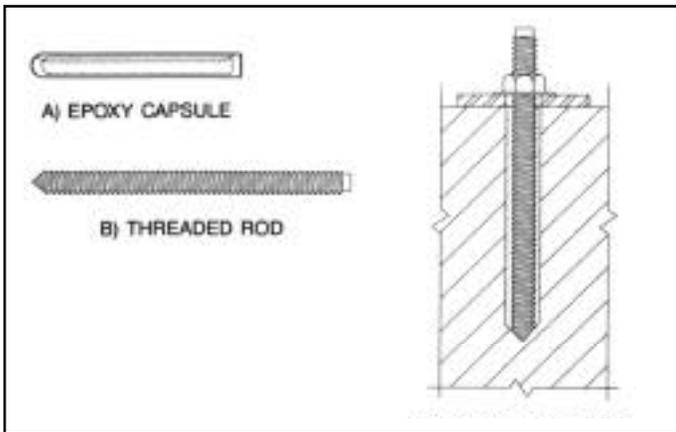
Drop-in and self-drilling anchors (see Fig. 8) are two other types of expansion anchors available, but are typically not recommended by their manufacturers for use in masonry. The reason for this is due to the embedment and setting characteristics of the two anchors. Both anchors are produced to allow shallow embedment depths and are expanded or set by an impact setting tool. The combination of shallow embedment and high stresses imparted by the expansion tend to cause cracking or splitting in masonry. Depending on the extent of cracking or splitting, the anchor could experience a reduction in load-carrying capacity or undergo complete failure during installation.



Other Proprietary Expansion Anchors
FIG. 8

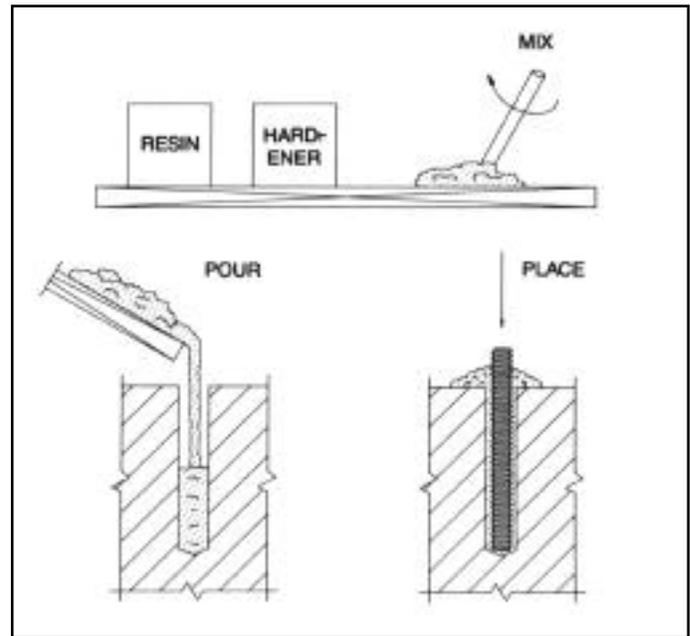
There are several considerations that should be examined when contemplating the use of expansion-type anchors in brick masonry. These are: 1) Expansion anchors should not be used to resist vibratory loads. Vibratory loads tend to loosen expansion anchors. 2) Specific torques are required to set expansion anchors. Excessive torque can reduce anchor strength or may lead to failure as excessive torque is applied. 3) Expansion anchors require solid, hard embedment material to develop their maximum capacities. Some brick construction may not provide a good embedment material due to voids formed by brick cores and partially filled mortar joints.

Adhesive Anchors. Two basic types of adhesive anchors are currently available. The major difference between the two is that one anchor is manufactured as a pre-mixed, self-contained system, whereas the second type requires measurement and mixing of the epoxy materials at the time of installation. The more popular self-contained types use a double glass vial system (see Fig. 9) to contain the epoxy. The outer vial contains a resin and the inner vial contains a hardener and aggregate. The glass vial is placed in a pre-drilled hole and a threaded rod or bar is driven into the hole with a rotary hammer drill, breaking the vials and mixing the adhesive components. The other type of adhesive anchor requires that the epoxy components be hand-measured and mixed before the epoxy is placed into a pre-drilled hole. A threaded rod or bar is then set into the epoxy mixture, as shown in Fig. 10. Adhesive epoxies usually vary slightly between manufacturers, but the steel rods or bars are typically ASTM A 307 or ASTM A 325 threaded rod, or ASTM A 36 shop-threaded bar.



**Self-Contained Adhesive Anchor
FIG. 9**

There are special requirements and limitations that should be considered when contemplating the use of adhesive anchors in brick masonry. They are: 1) Specially designed mixing and/or setting equipment may be required. 2) Dust and debris *must* be removed from the pre-drilled holes to insure proper bond between the adhesive and base material. 3) The adhesive mixture tends to fill small voids and irregularities in the base material. 4) Large voids (due to brick cores, intentional air spaces and partially filled joints) may cause reductions in anchor capacities. This is especially true with the self-

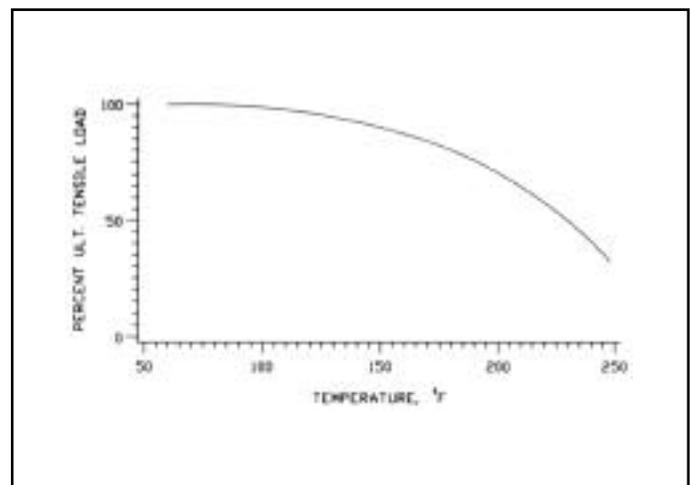


**Site-Mixed Adhesive Anchor
FIG. 10**

**TABLE 2
Some Chemicals That May Affect
Adhesive Anchor Epoxies^a**

| | |
|---------------------------|---------------------|
| Acetic Acid | Hydrogen Peroxide |
| Acetone | Lactic Acid |
| Ammonia | Machine Oil |
| Calcium Chloride Solution | Methanol |
| Carbon Tetrachloride | Nitric Acid |
| Caustic Soda | Phenol Solution |
| Citric Acid | Phosphoric Acid |
| Diesel Oil | Saline Solution |
| Ethyl Alcohol | Sea Water |
| Formaline | Soda Solution |
| Formic Acid | Sodium Hypochloride |
| Hydrochloric Acid | Sulphuric Acid |

^aThe manufacturer should always be consulted when adhesive anchors are to be used in areas where contact with chemicals is likely.



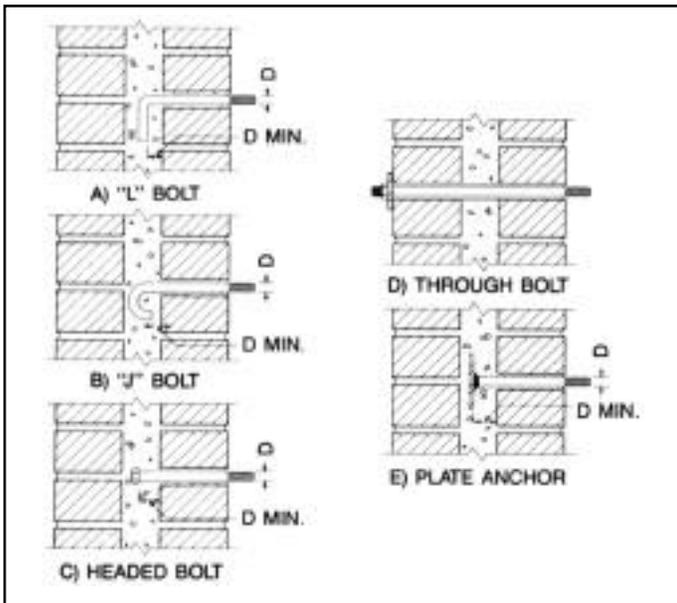
**Effect of Temperature on Ultimate Tensile Capacity
FIG. 11**

contained adhesive anchors since a limited volume of epoxy is available to fill the voids and provide a bond to the anchor. 5) The adhesive bond strength is reduced at elevated temperatures and may also be adversely affected by some chemicals (see Table 2 and Fig. 11).

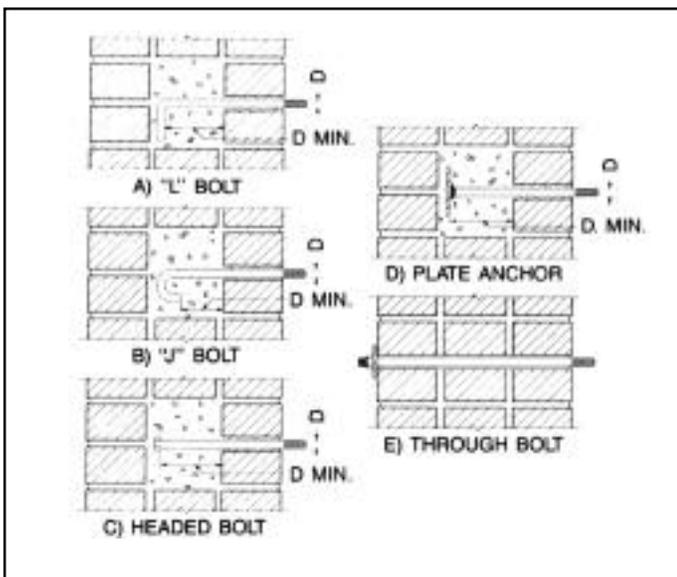
INSTALLATION DETAILS

Conventional Anchor Bolts

Typical embedment details for each type of conventional anchor used in grouted collar joint construction are shown in Fig. 12. The conventional embedded anchors (headed bolts, bent bar and plate anchors) are usually placed at the intersection of a head joint and bed joint. By using this location, the brick units adjacent to the anchor can be chipped or cut to accept the anchor without altering the joint thickness.



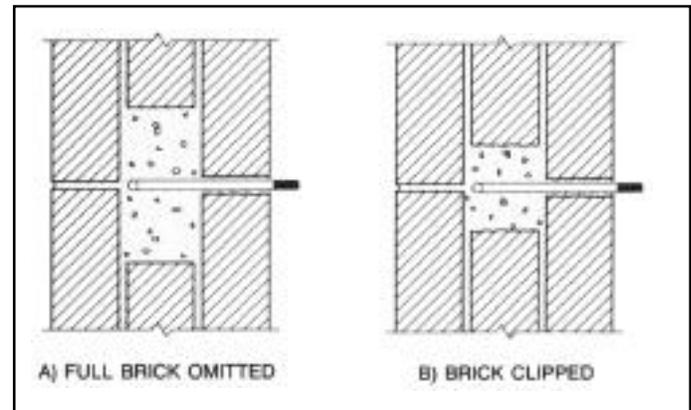
Conventional Anchors in Grouted Collar Joints
FIG. 12



Conventional Anchors in Multi-Wythe Brick Masonry
FIG. 13

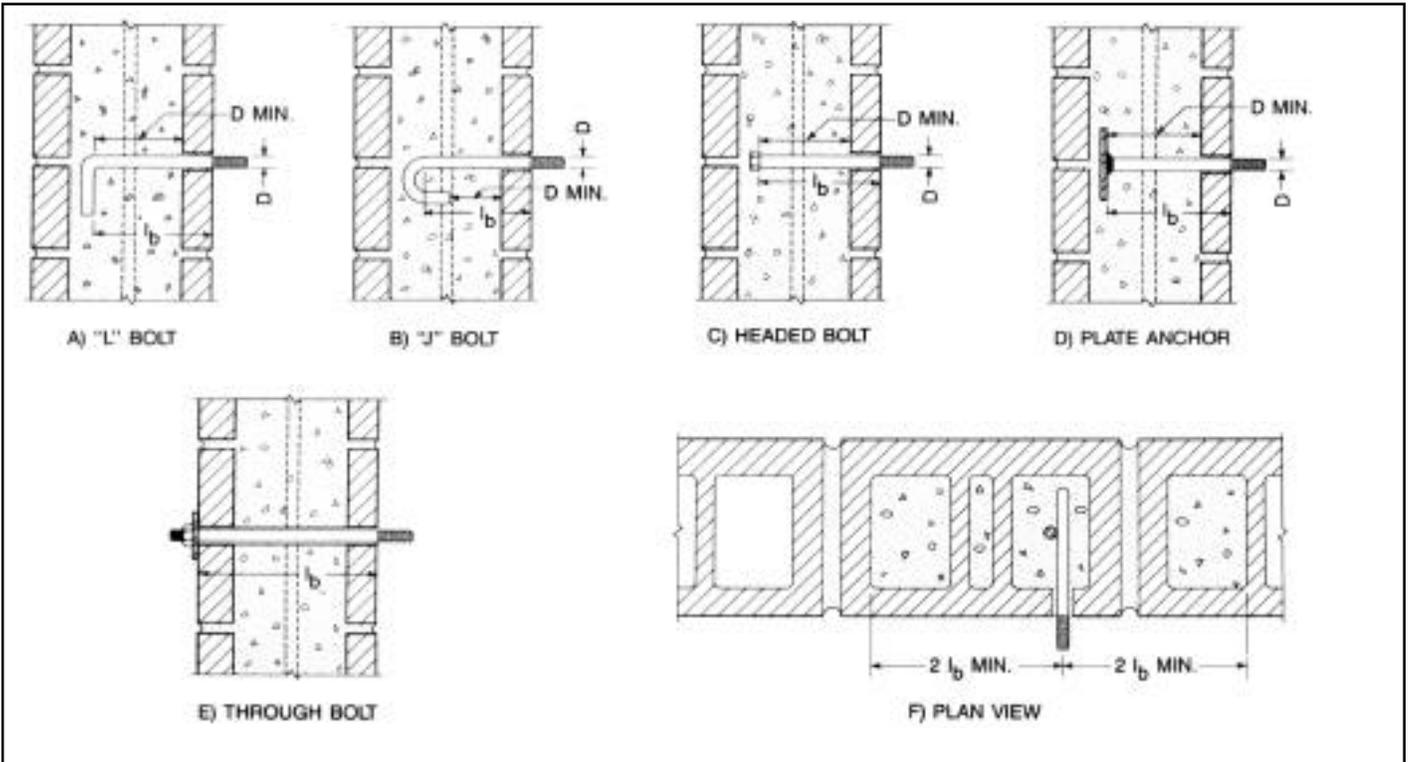
Typical embedment details of conventional anchors in multi-wythe brick construction are shown in Fig. 13. A brick, or portion of a brick, is left out of the inner wythe to form a cell for the embedded anchor (Fig. 14). After the anchor is placed, the cell is filled with mortar or grout prior to placement of the next course.

In hollow brick construction, the units are laid so that the cells are aligned and provide continuous channels for reinforcing steel placement and for grouting. Depending on the design, every cell or intermittent cells may be reinforced and grouted (see *Technical Notes 41 Revised*). The anchor embedment detail will depend on the reinforcing pattern used in the construction. Figure 15 shows typical embedment details for conventional anchors embedded between reinforcing cells. The anchor should be solidly surrounded vertically and horizontally by grout for a minimum distance of twice the embedment depth (1_b) (Figs. 14 and 15) for full tension cone development. The tension cone theory is discussed in following sections. This may require that some cells be partially grouted. A wire mesh screen can be placed in the bed joint across cells that are to be partially grouted to restrict the grout flow beyond a certain point. Figure 16 shows typical embedment details for conventional anchors embedded in reinforced cells. In this detail, the anchor may be tied with wire to the reinforcing to secure the anchor during the grouting process. Again, the anchor should be solidly surrounded by grout to a minimum distance of twice the actual anchor embedment depth, both vertically and horizontally.

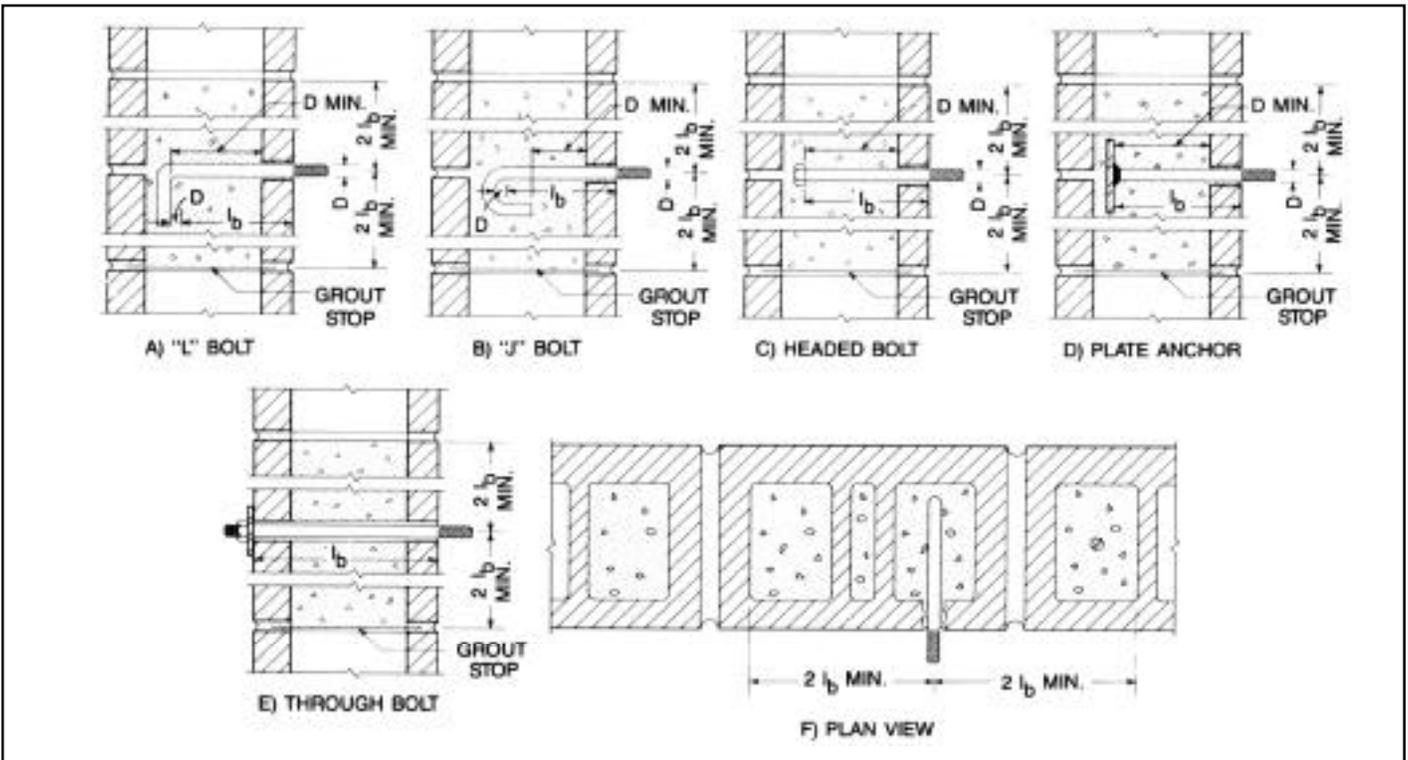


Plan View of Grout Cell in Multi-Wythe Brick Masonry
FIG. 14

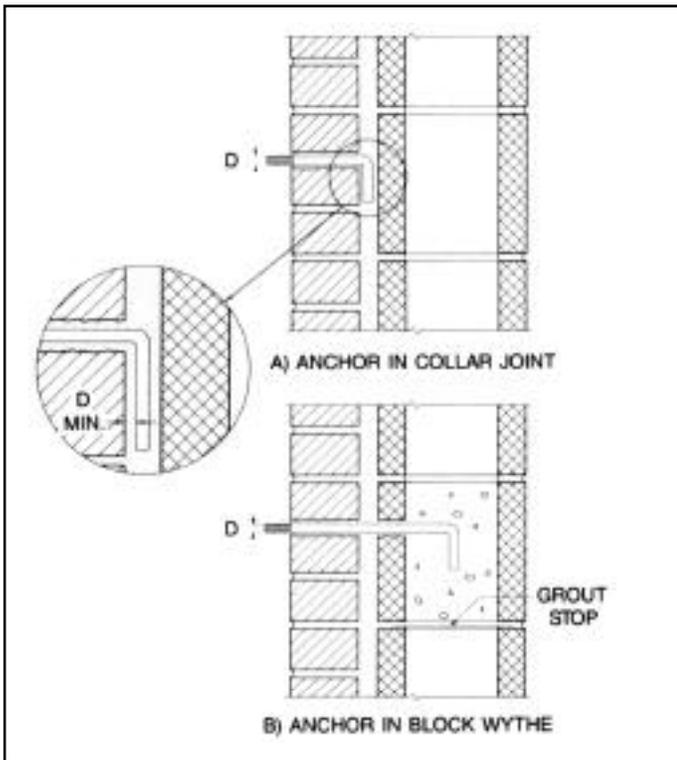
Two typical embedment details for conventionally embedded anchor bolts installed in composite brick and concrete block construction are shown in Fig. 17. As shown, anchor bolts may be placed in the collar joint between the brick and block wythes or placed into cells in the concrete block wythe and grouted into place. In details similar to Fig. 17(a), the anchor bolt type and diameter may be controlled by the width of the collar joint. Collar joints should be a minimum of 1 in. (25 mm) wide when fine grout is used, or a minimum of 2 in. (50 mm) wide when coarse grout is used (see *Technical Notes 7A Revised*). When the collar joint dimension is in the 1 in. (25 mm) range, it may become difficult to position anchor bolts in the collar joint and maintain the recommended



Conventional Anchors in Reinforced Hollow Brick
 FIG. 15



Conventional Anchors in Partially Grouted Hollow Brick
 FIG. 16



Conventional Anchors in Composite Brick/Block Masonry
FIG. 17

clear distance between the masonry and the anchor (Fig. 17). The practice of using soaps to accommodate anchors larger than the collar joint is not recommended because the reduction in the brick masonry thickness around the anchor could lead to strength reductions. If the anchor dimensions required are larger than the collar joint, a detail similar to that shown in Fig. 17(b) should be considered.

Through bolts are typically installed after construction and grouting by drilling through the completed masonry work. When through bolts are to be installed after construction in reinforced brick masonry, care should be taken during installation to avoid cutting or damaging reinforcement while drilling the through bolt holes. Reinforcing bar locations can be identified by specially tooled joints or other marks made during construction.

Proprietary Anchors

Proprietary expansion and adhesive anchors typically require special installation procedures and equipment. The manufacturer should be contacted to determine the appropriate anchor for a particular application, the correct installation procedure and if any special installation equipment is required. Improper application and installation of proprietary anchors may lead to less than satisfactory structural performance.

Typical proprietary anchor details are shown in Fig. 18. It is suggested that proprietary anchors be embedded in head joints when facing or building brick are used. This reduces the possibility of placing anchors in brick cores that occur within the thickness of the brick and adjacent to the bed joint surfaces. Anchors set in grouted hollow brick should be placed in holes drilled in the bed joints so that they

intersect grouted cells, or should be placed in holes drilled through the faces of the units into the grouted cells. As with conventional anchors, proprietary anchors should be solidly surrounded vertically and horizontally by grout for a minimum distance of twice their embedment depth.

ANCHOR BOLT DESIGN

Anchor bolts are used as a means of tying structural elements together in construction and therefore, provide continuity in the overall structure. In virtually all applications, anchor bolts are required to resist a combination of tension and shear loads acting simultaneously due to combinations of imposed dead loads, live loads, wind loads, seismic loads, thermal loads and impact loads. For this reason, and also to insure safety, anchor bolt details should receive the same design considerations as would any other structural connection. However, due to a lack of available research and design guides, anchor bolt designs are based largely on past experience with very little engineering backup. This situation may lead to conservative, uneconomical designs at one extreme, or nonconservative designs at the other.

Recently, however, research investigating the strength of conventional and proprietary anchors in masonry has been completed. Reports have been issued that evaluate anchor performance and suggest equations to predict ultimate anchor strengths. By combining the research findings with design practices currently used in concrete design, equations for allowable tension, shear and combined tension/shear loads for plate anchors, headed bolts and bent bar anchors are under consideration for adoption in the proposed "Building Code Requirements for Masonry Structures" (ACI/ASCE 530). These equations are outlined below.

Tension

The tensile capacity of an anchor is governed either by the strength of the masonry or by the strength of the anchor material. For example, if the embedded depth of an anchor is small relative to its diameter, a tension cone failure of the masonry is likely to occur. However, if the embedded depth of the anchor is large relative to its diameter, failure of the anchor material is likely. For these reasons, the allowable tensile load is based on the smaller of the two loads calculated for the masonry and anchor material. Thus, the allowable load in tension is the lesser of:

$$T_A = 1/2 A_p \sqrt{f'_m} \quad (\text{Eq. 1})$$

or

$$T_A = 0.2 A_B f_y \quad (\text{Eq. 2})$$

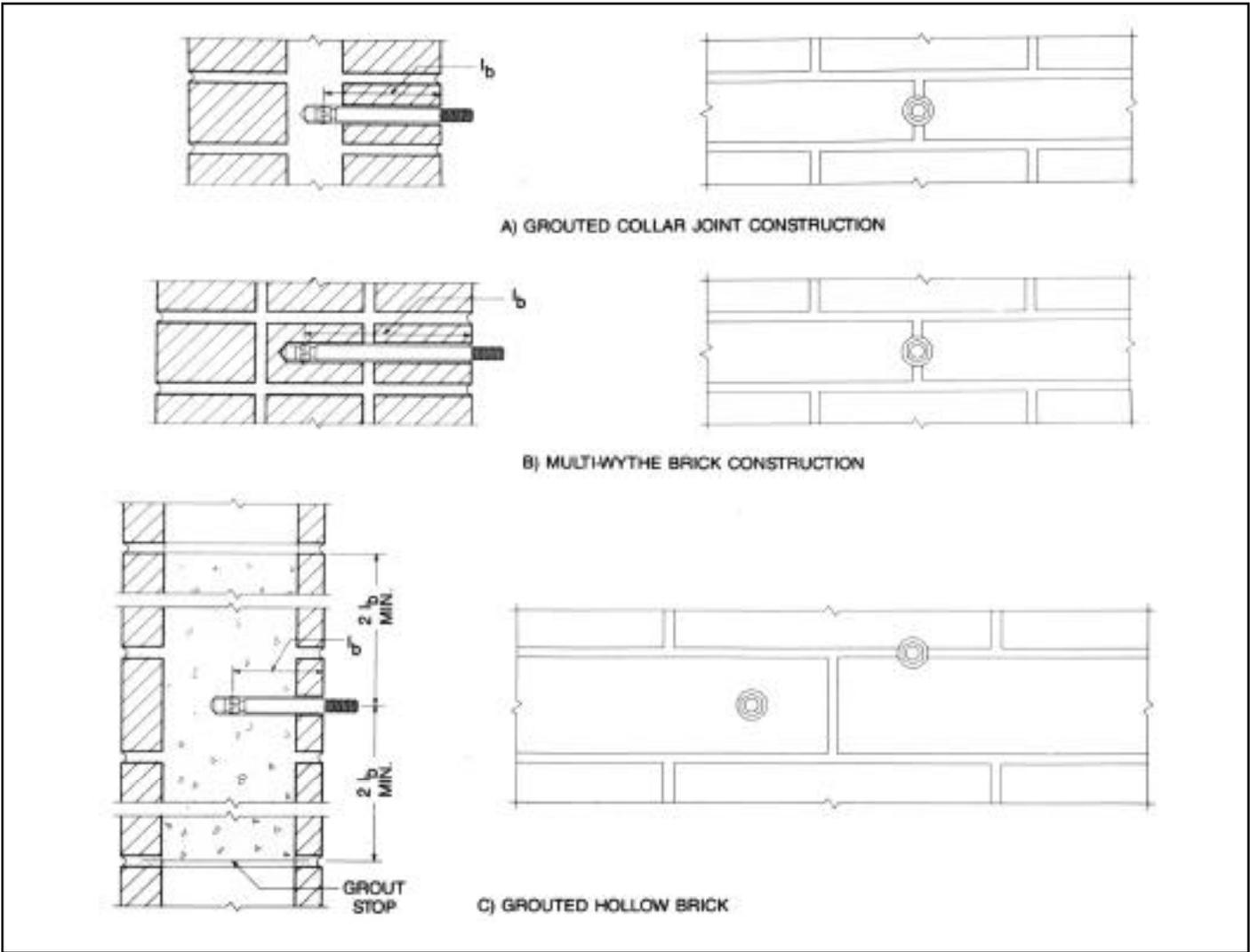
where:

T_A = Allowable tensile load, lb,

A_p = Projected area of the masonry tension cone, in.²,

f'_m = Masonry prism compression strength (In composite construction, when the masonry cone intersects different materials, f'_m should be based on the weaker material), psi,

A_B = Anchor gross cross-sectional area, in.²,



Typical Proprietary Anchor Details
FIG. 18

f_y = Anchor steel yield strength, psi.

The value of A_p in Eq. 1 is the area of a circle formed by a failure surface (masonry cone) assumed to radiate at an angle of 45° (see Fig. 19) from the anchor base. When an anchor is embedded close to a free edge, as shown in Fig. 20, a full masonry cone cannot be developed and the area A_p must be reduced so as not to overestimate the masonry capacity. Thus, the area A_p , in Eq. 1 will be the lesser of:

$$A_p = 1_b^2 \quad (\text{Eq. 3})$$

or

$$A_p = 1_{be}^2 \quad (\text{Eq. 4})$$

where:

A_p = Projected area of the masonry tension cone, in.²,

1_b = Effective embedded anchor length, in.,

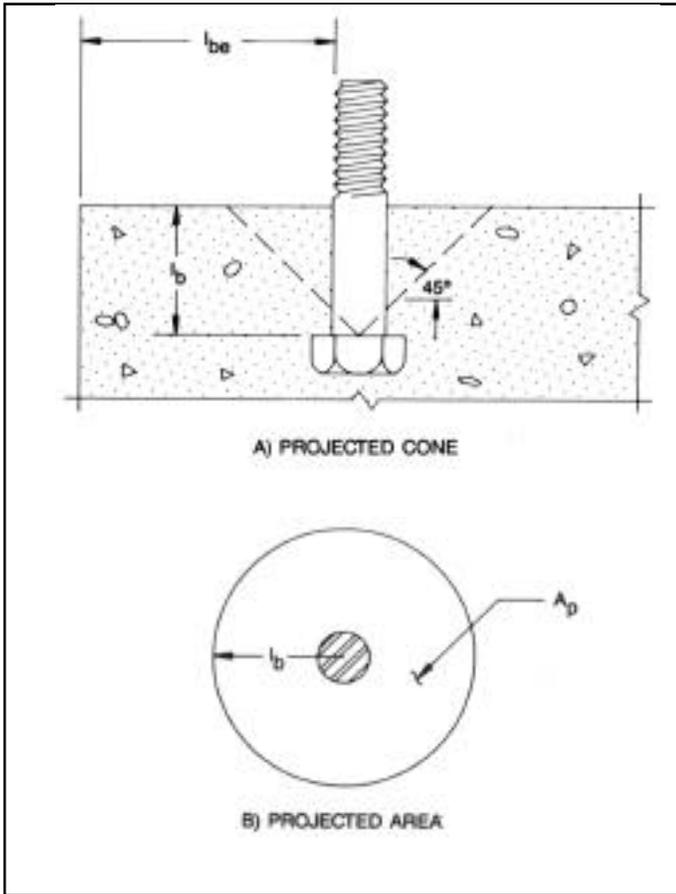
1_{be} = Distance to a free edge, in.

The effective anchor embedded length (1_b) is the

length of embedment measured perpendicular from the surface of the masonry to the plate or head for plate anchors or headed bolts. The effective embedded length of bent bar bolts (1_b) is the length of embedment measured perpendicular from the surface of the masonry to the bearing surface of the bent end minus one bolt diameter. Where the projected areas of adjacent anchors overlap, A_p of each bolt is reduced by one-half of the overlap area. Also, any portion of the projected cone falling across an opening in the masonry (i.e., holes for pipes or conduits) should be deducted from the value of A_p calculated in Eqs. 3 or 4.

Shear

The allowable shear load is based on the same logic as the allowable tension load. That is, the anchor capacity is governed by either the masonry strength or the anchor material strength. The distance between an anchor and a free masonry edge has an effect on the masonry shear capacity. Calculations have shown that for edge distances less than twelve times the anchor diameter, the masonry shear strength controls the anchor



Full Masonry Tension Cone
FIG. 19

capacity. (Calculations based on masonry with $f'_m = 1000$ psi and anchor steel yield strength with $f_y = 60$ ksi.

Therefore, where the edge distance equals or exceeds 12 anchor diameters, the allowable shear load is the lesser of:

$$V_A = 350 \sqrt{f'_m A_B} \quad (\text{Eq. 5})$$

or

$$V_A = 0.12 A_s f_y \quad (\text{Eq. 6})$$

where:

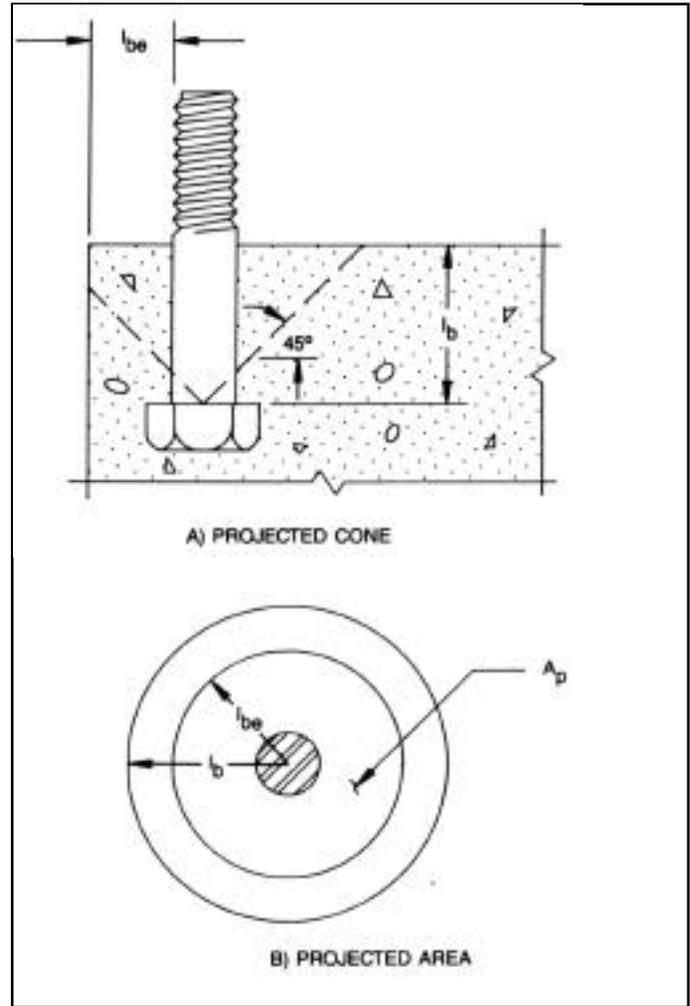
$$V_A = \text{Allowable shear load, lb.}$$

When anchors are located less than 12 anchor diameters from a free edge, the allowable shear load is determined by linear interpolation from a value of V_A obtained in Eq. 5 at an edge distance of 12 anchor diameters to an assumed value of zero at an edge distance of 1 in. (25 mm). This takes into consideration the reduction in the masonry shear capacity due to the edge distance.

Combined Tension and Shear

Allowable combinations of tensile and shear loads are based on a linear interaction equation between the allowable pure tension and pure shear loads calculated in Eqs. 1, 2, 5 and 6. Anchors subjected to combinations of tension and shear are designed to satisfy the following equation:

$$T / T_A + V / V_A \leq 1.0 \quad (\text{Eq. 7})$$



Reduced Masonry Tension Cone
FIG. 20

where:

T = Applied tensile load, lb.,

V = Applied shear load, lb.

TABLE 3
Allowable Shear on Bolts and Anchors¹

| Bolt or Anchor Diameter, In. | Minimum ² Embedment, In. | Allowable Shear Load, Lb | |
|------------------------------|-------------------------------------|---------------------------------|------------------------------|
| | | Without ³ Inspection | With ⁴ Inspection |
| 1/4 | 4 | 180 | 270 |
| 3/8 | 4 | 270 | 410 |
| 1/2 | 4 | 370 | 550 |
| 5/8 | 4 | 500 | 750 |
| 3/4 | 5 | 730 | 1,100 |
| 7/8 | 6 | 1,000 | 1,500 |
| 1 | 7 | 1,230 | 1,850 |
| 1 1/8 | 8 | 1,500 | 2,250 |

^{*} From *Building Code Requirements for Engineered Brick Masonry*, Brick Institute of America, August 1969.

¹ In determining the stresses on brick masonry, the eccentricity due to loaded bolts and anchors shall be considered.

² Bolts and anchors shall be solidly embedded in mortar or grout.

³ No engineering or architectural inspection of construction and workmanship.

⁴ Construction and workmanship inspected by engineer, architect or competent representative.

Table 4
Allowable Shear on Anchor Bolts - From UBC
1985 Edition*

(a) ALLOWABLE SHEAR ON ANCHOR BOLTS¹ FOR
CLAY AND CONCRETE MASONRY

| Diameter (inches) | Total Embedment ² (inches) | Allowable Shear ³ (lbs) |
|-------------------|---------------------------------------|------------------------------------|
| 1/4 | 4 | 270 |
| 3/8 | 4 | 410 |
| 1/2 | 4 | 550 |
| 5/8 | 4 | 750 |
| 3/4 | 5 | 1100 |
| 7/8 | 6 | 1500 |
| 1 | 7 | 1850 ⁴ |
| 1 1/8 | 8 | 2250 ⁴ |

¹An anchor bolt is a bolt that has a right angle extension of at least three diameters. A standard machine bolt is acceptable.

²Of the total required embedment, a minimum of five bolt diameters must be perpendicular to the masonry surface.

³No reduction in values required for uninspected masonry.

⁴Applicable for units having a net area strength of 2500 psi or more.

(b) ALLOWABLE SHEAR ON BOLTS FOR
EMPIRICALLY DESIGNED MASONRY EXCEPT
UNBURNED CLAY UNITS

| Diameter Bolt (inches) | Embedment ² (inches) | Solid Masonry (Shear in lbs) | Grouted Masonry (Shear in lbs) |
|------------------------|---------------------------------|------------------------------|--------------------------------|
| 1/2 | 4 | 350 | 550 |
| 5/8 | 4 | 500 | 750 |
| 3/4 | 5 | 750 | 1100 |
| 7/8 | 6 | 1000 | 1500 |
| 1 | 7 | 1250 | 1850 ² |
| 1 1/8 | 8 | 1500 | 2250 ² |

¹An additional 2 inches of embedment shall be provided for anchor bolts located in the top of columns for buildings located in Seismic Zones Nos. 2, 3, and 4.

²Permitted only with not less than 2,500 pounds per sq. units.

³Reproduced from the Uniform Building Code, 1985 Edition, Copyright 1985 with permission of the publisher, The International Conference of Building Officials."

Proprietary Anchor Bolts

The allowable load equations previously presented are intended for use with plate anchors, headed bolts and bent bar anchors and have been proposed to the ACI/ASCE 530 Committee on Masonry Structures. However, when the allowables from these equations are

compared to test results for proprietary anchors, they appear to produce acceptable safety factors.

Allowable Loads. Average factors of safety are 4.0 for tensile tests and 5.0 for shear tests on proprietary anchors. The combined tension/shear interaction equation produced an average safety factor of 7.0 when compared to test results on proprietary anchors. Therefore, based on comparison to test results, the allowable load equations proposed in this *Technical Notes* are suggested for use in the design of proprietary anchors in brick masonry. The embedment depth used to calculate the allowable load values should be equal to the embedded depth of the proprietary anchor.

Edge Distance. Edge distance is of particular concern when expansion anchors are used in brick masonry, due to lateral expansion forces produced when the anchors are tightened. These forces are often large enough to cause cracking or spalling of the brick when edge distances become small. To date, no research has been conducted in this area. Therefore, due to the lack of information, it is suggested that a minimum edge distance of 12 in. (300 mm) be maintained when expansion anchors are installed in brick masonry.

Through Bolts

There are no known published reports available addressing the strength characteristics of through bolts in brick masonry. However, based on the conservatism in the allowables for bent bar anchors and proprietary anchors, the allowable load equations should provide acceptable allowable load values for through bolts used in brick masonry. The embedment depth used to calculate the allowable load values should be taken as equal to the actual thickness of the masonry.

Current Codes and Standards

At the present time, one model code and one design standard contain provisions for anchor bolt design in brick masonry. The BIA Standard, *Building Code Requirements for Engineered Brick Masonry*, and the *Uniform Building Code* cover design allowables and embedment depths for anchors loaded in shear. There are no provisions for axial tensile loads or combined tension/shear loads in these documents. Tables 3 and 4 show the allowable shear loads and minimum embedment depths from the two documents. The values in Table 4(a) are based on rational analysis and in Table 4(b) on empirical analysis. As can be seen, the tables are very similar and are generally more conservative than the allowable shear loads obtained from Eqs. 5 and 6 for the same embedment depths (Table 5).

SUMMARY

This *Technical Notes* is the first in a series on brick masonry anchors, fasteners and ties. It covers anchor bolt types, detailing and allowable loads for anchor bolts in brick masonry. Other *Technical Notes* in this series will address brick masonry fasteners and ties.

| TABLE 5 | | | |
|---|--|-----------------------------|---|
| Example Calculation of Allowable Shear on Anchors - From ACI/ASCE 530* | | | |
| Anchor Diameter (in.) | Anchor Gross Cross-Sectional Area (in.²) | Embedded Depth (in.) | Allowable¹ Shear Load (lbs) |
| 1/4 | 0.049 | 4 | 210 |
| 3/8 | 0.110 | 4 | 470 |
| 1/2 | 0.196 | 4 | 840 |
| 5/8 | 0.307 | 4 | 1,320 |
| 3/4 | 0.442 | 5 | 1,910 |
| 7/8 | 0.601 | 6 | 2,060 |
| 1 | 0.785 | 7 | 2,200 |
| 1 1/8 | 0.994 | 8 | 2,340 |

*American Concrete Institute/American Society of Civil Engineers Committee 530 on Masonry Structures.
¹Assuming: $f'_m = 2,000$ psi
 ASTM A36 steel $f_y = 36$ ksi
 Edge Distance = 12 Bolt Diameters

8. *Technical Notes on Brick Construction 41 Revised*, "Hollow Brick Masonry-Introduction", Brick Institute of America, McLean, Virginia, 1983.
9. *Specification for the Design and Construction of Load-Bearing Concrete Masonry*, National Concrete Masonry Association, McLean, Virginia, April 1971.
10. *The BOCA Basic/National Building Code*, 9th Edition, Building Officials and Code Administrators, International, Country Club Hills, Illinois, 1984.
11. *Standard Building Code*, Southern Building Code Congress, International, Inc., Birmingham, Alabama, 1985.
12. *Technical Notes on Brick Construction 7A Revised*, "Water Resistance of Brick Masonry-Materials, Part II of III", Brick Institute of America, Reston, Virginia, 1985.

The information and suggestions contained in this *Technical Notes* are based on the available data and the experience of the technical staff of the Brick Institute of America. The information and recommendations contained herein should be used along with good technical judgment and an understanding of the properties of brick masonry. Final decisions on the use of the information discussed in this *Technical Notes* are not within the purview of the Brick Institute of America and must rest with the project designer, owner or both.

REFERENCES

1. *Manual of Steel Construction*, 8th Edition, American Institute of Steel Construction, Inc., Chicago, Illinois, 1980.
2. Whitlock, A.R. and Brown, R.H., *Strength of Anchor Bolts in Masonry*, NSF Award No. PRF-7806095, "Cyclic Response of Masonry Anchor Bolts", August 1983.
3. Brown, R.H. and Dalrymple, G.A., *Performance of Retrofit Embedments in Brick Masonry*, NSF Award No. CEE-8217638, "Static and Cyclic Behavior of Masonry Retrofit Embedments (Earthquake Engineering)", Report No. 1, April 1985.
4. Hatzinikolas, M.; Lee, R.; Longworth, J. and Warwaruk, J., "Drilled-In Inserts in Masonry Construction", Alberta Masonry Institute, Edmonton, Alberta, Canada, October 1983.
5. *Building Code Requirements for Engineered Brick Masonry*, Brick Institute of America, McLean, Virginia, August 1969.
6. *Uniform Building Code*, International Conference of Building Officials, Whittier, California, 1985.
7. *Technical Notes on Brick Construction 17 Revised*, "Reinforced Brick Masonry, Part I of IV", Brick Institute of America, McLean, Virginia, October 1981.