SESSION V, Papers 1–16

V–1. Methods of Grouting Masonry Walls

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ABSTRACT

The use of masonry throughout the United States and the world has promulgated a need for improving techniques for grouting masonry walls. Although it is basically the contractors' problems to improve construction methods and techniques, it is also the architects' and engineers' problems to insure that methods of construction are satisfactory and will result in structures that are in accordance with the code and of a quality acceptable to the architects, engineers and owners.

This paper presents the basic methods of grouting walls which have proved very successful in the Western United States. In addition, two new methods are incorporated and described which have been developed within the last few years and have been used to expedite construction, reduce construction costs and still result in satisfactory masonry walls.

GROUT

What is grout? Well, for easy visualization and understanding of grout, consider it to be soupy concrete. Comparison of grout to soupy concrete is to have an understanding that concrete, according to the ACI code, has a maximum slump of six inches while grout is considered satisfactory when the slump is from eight to ten inches; therefore, grout is soupy concrete.

WHY GROUT?

Although grouting masonry walls might be considered to be an exclusive condition for reinforced masonry, it is not necessarily confined to that use. Grout in masonry walls performs multiple functions.

1. It adds mass to the wall thereby increasing its thermal storage capability which is very beneficial in passive solar design. Use of heavy masonry walls provides a fly wheel effect in holding and releasing energy over a long period of time.
2. Grouting walls improves their STC rating (sound transmission classification). With a higher STC number, the wall is more resistant to the transmission of noise.
3. Grouted walls provide more area for load on the wall. It improves the wall's load carrying capacity for vertical loads on the wall.
4. It improves the shear characteristics of the wall by providing a greater cross sectional area to resist shear due to lateral forces either parallel or perpendicular to the wall.
5. It provides the medium by which a reinforced wall will act as a homogeneous element. The grouted reinforcing bars are bonded into the wall and thereby permit it to act as a total reinforced structural system.
   a. For vertical loads, the bars can carry load in compression along with the masonry and grout. When this is considered, as in a column, the reinforcing bars must be tied.
   b. Lateral loads on the walls due to earth, water or wind or seismic forces, will cause the reinforcing bars to act in tension. The reinforcing bars resist the tension forces while the masonry resists the compression forces.
   c. To increase the shear of capacity of the wall, the reinforcing bars are bonded into the system through the grout and significantly increase the shear resistance of the wall for forces parallel to the wall.

TYPES OF GROUT

Where the grout is to be used significantly determines the type of grout. We consider, basically, two types of grout.

1. *Fine Grout.* Fine grout is portland cement, sand and water mixed to a consistency for a slump of nine inches plus or minus one inch. The code specifies the proportions by volume of fine grout as one part portland cement and 2½ to 3 parts sand. Fine grout is required where the grout space is narrow. When the grout space is from ¾" to 2" wide, and for 4" and 6" wide block, fine grout is recommended.
2. *Coarse Grout.* Coarse grout is similar to fine grout but with the addition of pea gravel. The code proportions by volume are one part portland cement, 2 to 3 parts sand, and not more than 2 parts pea gravel. The pea gravel, up to ⅜" in size, is to add bulk to the grout so that there is not as much cement, sand and water, and more volume can be taken up by the coarse aggregate. Coarse grout is used where the grout space is 3 to 4 inches wide or greater and the block units are over 6 inches in width.

Where the grout spaces are significant in width, approximately 8" or more in width, coarse grout may use ¾" aggregate. This larger size aggregate takes up even more volume and thus will reduce the amount of shrinkage in the wall.

COMPRESSIVE STRENGTH OF GROUT

In accordance with the Uniform Building Code, grout shall have a minimum compressive strength of 2,000 psi. This is so the total system of masonry, mortar and grout, will have minimum strengths of 2,000 psi. From this, it is assumed that the strength of the wall for Grade MW brick, moderate weather, will have an f_m of 1500 psi.

In many instances, particularly in high rise structures, there is a need for much higher strength materials. The f_m may have to be significantly higher than the assumed values of the code. Accordingly, the 2,000 psi minimum strength grout has to be increased also. It is recommended that the minimum strength grout be at least 25% and as much as 40% more than the desired f_m = 3,000 psi, the grout would have a compressive strength from 3750 psi up to 4200 psi.

CONSTRUCTION PROCEDURE

After the type of grout has been selected, the strength of grout determined and the appropriate mix design obtained so that the grout will fulfill the phsyical characteristics desired, it comes down to the problem of what method of grouting shall be employed in the construction of the wall. There are a number of methods of grouting masonry walls, but basically, they fall into three categories: low lift grouting; medium lift grouting; and high lift grouting. Also, there is consideration in grouting as to whether it is a two-wythe masonry wall or a hollow unit masonry wall. The determination of which method to use may be the decision of the engineer or architect, or may be upon the recommendation of the contractor, depending upon the equipment he has available, his experience, and the benefits that can be derived from any particular method of construction.

Regardless of the method of grouting selected, the end result must be an acceptable masonry wall that is structurally sound.

Grouting Two-Wythe Brick Walls

1. *Low Lift Grouting.* Probably the easiest method of grouting a two-wythe brick wall is by the low lift procedure. Low lift grouting is particularly applicable where the masonry project or where grouting areas are small or there are many interruptions in the construction schedule. Minimum equipment is required and the technique of grouting is simple and results in very satisfactory walls. Either fine grout or coarse grout can be used. The procedure is as follows:
   a. All units in the outer wythes shall be laid up shoved head and bed mortar joints. Masonry headers should not project into the grout space.
   b. The exterior wythe, which is the wythe furthest from the bricklayer, may be carried up to approximately 18 inches before grouting. The interior wythe is then laid up and as each coarse is laid, grout is placed between the inner and outer wythes. The code states that the height of lifts shall not exceed six times the width of the grout space for the maximum of eight inches. This limitation indicates that perhaps two or three courses of masonry could be placed prior to grouting the wall.
   c. The collar joint, grout wythe, or the grout space (all same), should be not less than ¾" in thickness. If the grout space is from ¾" to 2", it is recommended that fine grout be used. If the grout space is 2" or more, coarse grout may be used. If floaters are used to reduce the amount of grout in the wall, fine grout may be used for walls with grout space up to 5" wide.
   d. All grout shall be puddled with a puddling stick immediately after pouring.
   e. If the work is stopped one hour or longer, a horizontal construction joint shall be formed by keeping the grout approximately one inch below the top of the brick.

2. *Medium Lift Grouting*
   a. In the medium lift grouting procedure, as approved by the ICBO Research Committee Report No. 3038, each wythe may be laid up to a maximum of four feet.
   b. The wythes are tied together with wall ties that are minimum #9 gauge wire. These ties are in the form of a rectangle 4" wide by two inches less than the overall wall thickness.
   c. Walls with grout space more than 4" wide, or for walls laid up in stack bond, the ties are spaced 12" vertically and 16" horizontally. For walls with grout space 4" or less in width, the ties may be spaced 16" vertically and 16" horizontally. These dimensions may vary so that an equivalent area is resisted by a tie. The ties may be placed closer than specified at the option of the contractor.
   d. Cleanout holes are not required in this method of grouting. However, special care must be taken to minimize the mortar droppings into the grout space. Mortar droppings in the grout space will form a layer of loose material and create a weakened horizontal joint. This will reduce both the horizontal shear capability of the wall and the vertical load-carrying capacity of the wall.
   e. Mortar fins should not protrude into the grout space more than the thickness of the mortar joint. In some instances, it is recommended that mortar should not protrude into the grout space at all but should be parged against the inside face of the wythe. The protruding mortar should not be cut off where it would drop to the bottom of the grout space. It is better to leave some mortar protrude into the grout space rather than cut it off and have it drop down. This protruding mortar will aid the bonding of the grout to the outside wythes and create shear keys.
   f. It is recommended that in placing mortar on the masonry units, it be held back from the edge and beveled in the form of a wedge to prevent mortar from being squeezed in to the grout space when the next masonry unit is placed upon the mortar bed.

g. For medium lift grouting, it is recommended that the grout space be not less than three inches of width when there is vertical and horizontal steel in the grout space. If the grout space contains no horizontal steel, vertical steel only, and the horizontal steel is joint reinforcing in the mortar beds, then the grout space may be as small as two inches.

h. The walls should cure at least 18 hours before pouring grout so that they may gain strength. This is easily achieved by allowing the walls to stand overnight and grouting the following morning.

i. Vertical grout barriers or dams should be built of solid masonry across the grout space for a height of each grout lift to control the horizontal flow of grout. Grout barriers should be spaced at convenient intervals, but not more than 30 feet apart.

3. *High Lift Grouting.* High lift grouting was developed to expedite the construction of two-wythe brick walls. In this method, masonry is continually laid up by the bricklayer until the wall is topped out, and he is not interrupted by any grouting procedures. The wall, in the high lift grouting procedure, is self inspected because it is subjected to severe hydrostatic pressure by the fluid grout perpendicular to the face of the wall. The reinforcing steel can easily be placed and inspected after the wall has been constructed and before it is grouted.

a. The wall may be constructed to its full height or to a height convenient for grouting, which may be between floors, to the ledger line, or some convenient intermediate height if so desired by the contractor or specified by the architect or engineer.

b. The two wythes must be bonded together with wire ties similar to the ties used in medium lift grouting.
Kinks, water drips or deformations are not permitted in the ties. These would reduce the strength of the ties and under lateral pressure may allow the walls to bow out and buldge and thus damage the wall and make it unacceptable.

c. One wythe of the wall should be built up not more than 16″ ahead of the other wythe.

d. For running bond, the ties shoudl be laid not more than 24″ on centers horizontally and 16″ on centers vertically, or one tie for every two square feet of wall.

e. The walls that are built to heights of 10, 15, or 20 feet high can accumulate a lot of mortar droppings at the bottom of the wall in the grout space. To remove these mortar droppings, cleanout holes must be provided at the bottom of each pour by leaving out every other brick at the bottom of the section being poured.

f. During the laying up of the brick, mortar fins should be knocked off the wall and the wall cleaned out twice a day. This will remove all droppings from the grout space and the mortar fins and other foriegn matter will be removed from the grout space.

g. While the wall is being built, horizontal steel can be placed either in the mortar joints or in the grout space resting on the ties. Vertical steel can be now placed in the grout space. The steel can be in one piece, lowered into place and located properly through the cleanout openings at the bottom and wired to the dowels protruding from the foundation or the wall below.

h. The grout space should be not less than three inches in width.

i. The masonry walls should cure at least three days in normal weather and more in cold weather. This is required for the walls to gain sufficient strength so that they will not buldge or blow out during the pouring operation.

j. Vertical grout barriers or dams at about 30 foot intervals should be built of solid masonry across the grout space the entire height of the wall to control the horizontal flow of grout.

k. In high lift grouting, there may be a large amount of grout placed at one time. Accordingly, it is usually ordered from a ready-mix plant and delivered in a ready-mix truck. It is usually placed by pumping and should be placed before any initial set occurs and in no case more than 1½ hours after the water has been added.

l. After the wall has stood a sufficient time (three days minimum), grouting should be done in a continuous pour in lifts not exceeding six feet. Grouting is continued around the wall or building until each wall has six feet of grout in it. The grout is consolidated by mechanical vibrating during placement and reconsolidated after the excess moisture has been absorbed into the masonry but before plasticity is lost. To reduce volume change, provide an admixture that will cause a slight expansion characteristic.

m. The next lift of grout is then poured in the wall and continued around the building. The grouting of any section of wall between control barriers or dams should be completed in one day with no interruptions between lifts greater than one hour. It is very important that all grout lifts are consolidated by vibration.

Grouting of Hollow Unit or Clay Block Walls

1. *Low Lift Grouting Procedure for Block Walls.* The technique of low lift grouting of hollow unit or block walls is similar to the medium lift grouting for two-wythe walls; however, wire ties need not be used because the cross webs serve the same function.

a. All hollow unit masonry walls should be built to provide an unobstructed vertical continuity of at least 2″ by 3″ of the cells to be grouted. The face shells should be bedded with mortar, and if the wall is to be grouted only where there is reinforcing steel, the cross webs around the steel should be also bedded with mortar. This will pre-

vent the leakage of grout from the cells with steel that are grouted. When the wall is solidly grouted, cross webs need not be mortared. The grout will flow into the cells and through the joint between the block at the mortar line.

b. The head joints need only be the thickness of the face shells.
c. The wall is laid up to a height of four feet. Cleanouts need not be provided.
d. There are two methods to place the steel in hollow unit walls:

(1) The steel is in six foot lengths and placed into the cell and the wall grouted; the steel extends out two feet. The next four foot height of wall is placed with the units being lifted over the projecting two feet of steel. This is the lap for the succeeding six foot length of steel.

The steel may also be placed after the four foot height of wall is grouted by pushing it down into the grout in its proper position in the cell, either in the center or to one side of the wall as required. The six foot length of steel then would extend two feet beyond the grouted position for the next four feet of wall to be constructed.

(2) The wall may be constructed with single or double open end units so that the steel may be full length without splices in it. The masonry units are laid around the projecting steel. Open end units are required for this type of construction because it is impossible to lift the masonry units over high steel.

e. Grout the cells, stopping one to two inches below the top of the unit or over the horizontal steel which should be fully imbedded in the grout. Make sure that the vertical bar is in proper location.
f. When the wall is to be grouted only where the reinforcing is located, expanded metal mesh or other material that will not interfere with the mortar bond should be laid on top of the units that are not to receive grout. This will permit the units above the expanded metal mesh to receive grout and prevent grout from flowing into the cells below the mesh.
g. It is the general practice to grout the vertical cell and the horizontal bond beam in one operation. Therefore, for a four foot height of wall, the vertical cells are grouted and the bond beam is grouted at the top.

2. *High Lift Grouting of Hollow Unit Walls*

The procedure for high lift grouting hollow unit walls is similar to grouting two-wythe brick walls except the wire ties need not be provided for the cross webs serve that function; however, cleanout holes are required.

a. All hollow unit masonry should be built so that there is vertical continuity of the cells that are to be filled. If the wall is to be partially grouted, the cross webs surrounding the cells that are to be grouted shall be mortared. Also, expanded metal mesh should be used under and over all horizontal members that are to receive grout.
b. Mortar thickness for the head joints should be at least the thickness of the face shells. Cross webs need not be mortared unless the wall is to be partially grouted and then the cross webs should be mortared only at the cells to be grouted. For a solid grouted wall, the grout will flow through the cells and through the space between units at the cross webs.
c. When the walls are built to the required height of 10, 15 or 20 feet or more, there may be a significant amount of mortar droppings that will occur during construction.
Accordingly, cleanout openings shall be provided at the bottom of all cells to be filled for each pour of grout. The overhanging mortar or obstructions or debris shall be removed from the cleanout holes so that there is intimate contact between the grout pours.
d. Horizontal reinforcement shall be placed as the wall is constructed. It may be joint reinforcing in the mortar joints or it may be steel bar reinforcing in the grout space.
e. Vertical reinforcement may be placed before the wall is constructed, in which case the bars without splices must be held in position at top and bottom and at intervals not to exceed 192 bar diameters. Under these circumstances, open end units would be required to fit around the vertical steel.
If the steel is to be placed after the wall is to be constructed, closed end units can be used. The bars are lowered down through the cells in their proper position and tied to projecting dowels or properly located at the bottom of the cells through the cleanout openings.
f. All cells containing reinforcement shall be filled solidly with grout. Grout should be placed in lifts of four to six feet.
g. All grout should be consolidated at the time of placing with a mechanical vibrator. It should then be reconsolidated again after excess water has been absorbed into the masonry but before plasticity is lost.
h. In order to prevent excess volume change due to the loss of water into the grout, it is necessary to (1) sufficiently vibrate and revibrate to consolidate the grout and to reconsolidate it to make up for any loss of volume due to water loss, or (2) to provide an admixture that will compensate for volume loss through the expansion characteristics of the admixture. This technique of using admix, such as Grout Aid, will compensate for the volume due to water loss and thus maintain integrity of the grout with the masonry unit.

CONCLUSION

When grout is placed in two-wythe brick walls, in hollow clay unit walls, in low lift, medium lift or high lift grouting, whether the wall is solid grouted or partially grouted, the

final result must be a wall that will perform structurally as required and have the appearance conceived by the architect and the owner.

Following the procedures outlined in this paper and providing either periodic or continuous inspection will result in strong homogeneous walls.

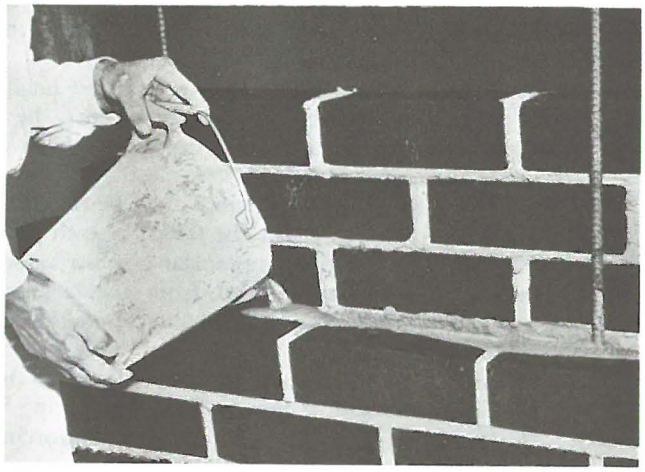

Figure 1. Pouring grout in low lift grouting

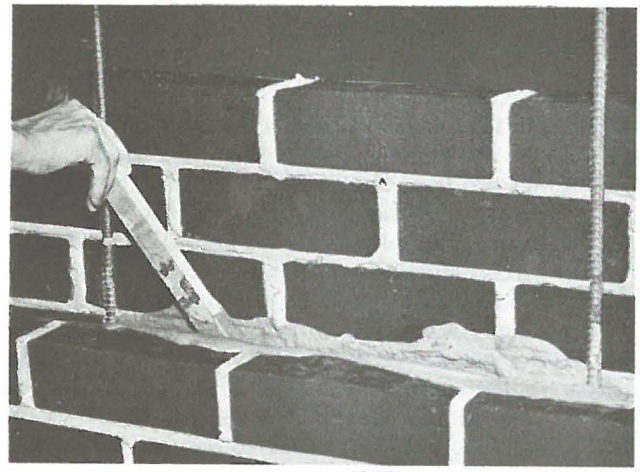

Figure 2. Puddling grout with puddle stick using swishing rather than tamping procedure.

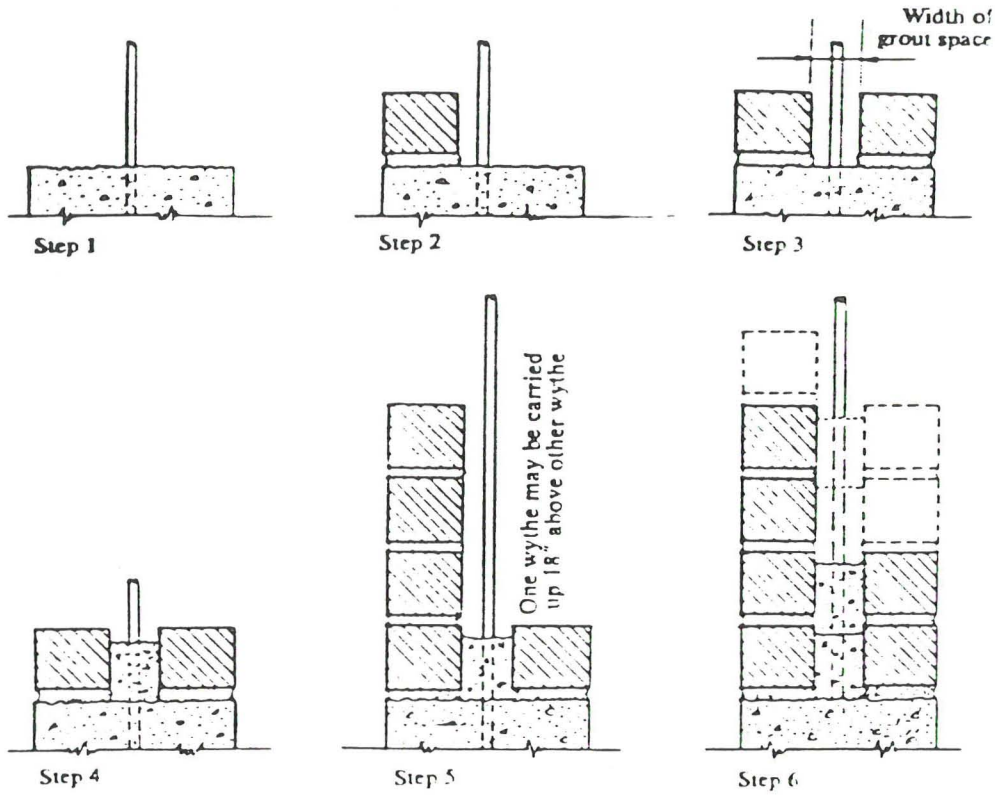

Figure 3. Low lift grouting procedure

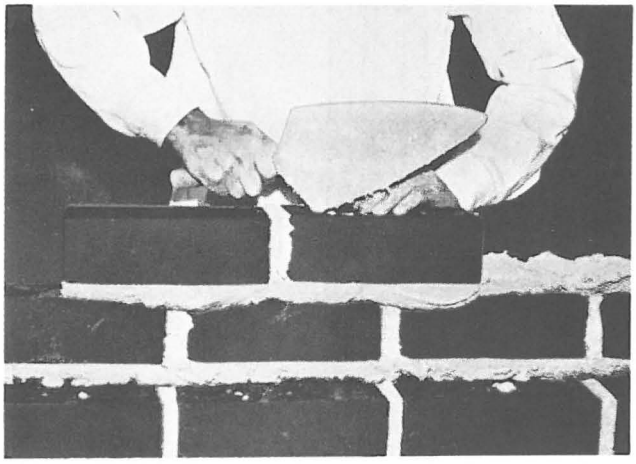

Figure 4. Minimum mortar fins should only protrude into the grout space

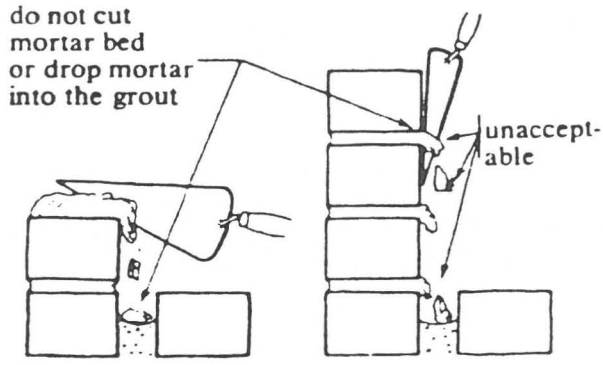

Figure 5. Improper method of evening and trimming mortar.

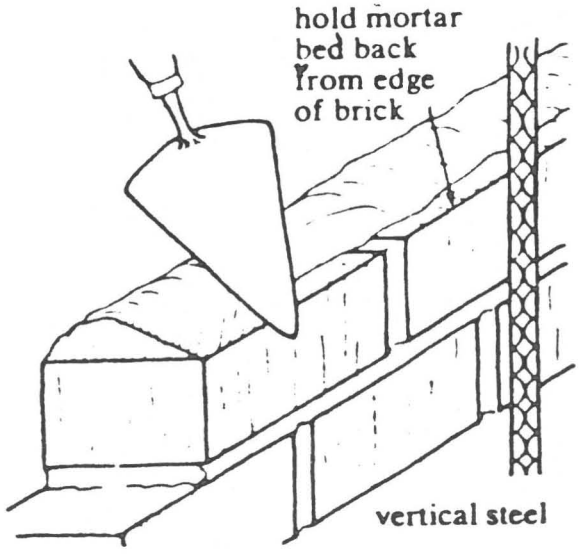

Figure 6. Proper method of evening and trimming mortar

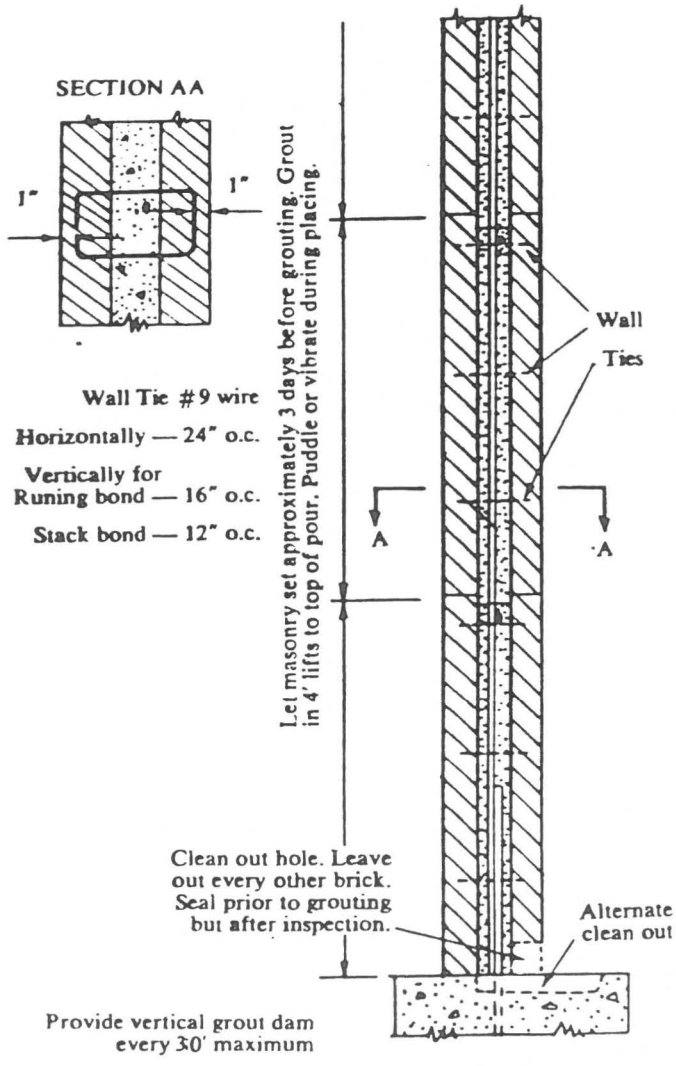

Figure 7. High lift grouting two-wythe wall

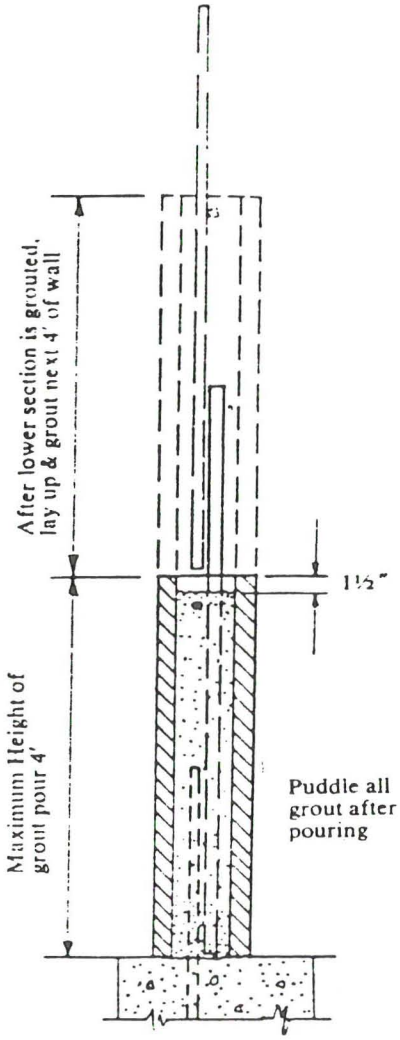

Figure 8. Low lift method of grouting hollow unit masonry

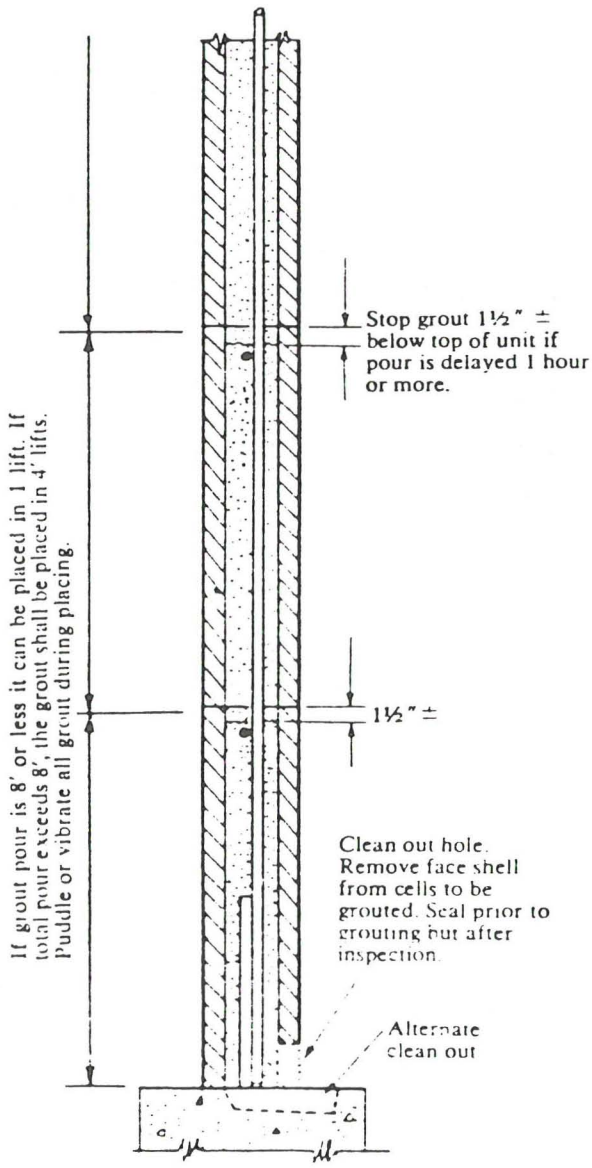

Figure 9. High lift method of grouting block