GROUT...
THE THIRD INGREDIENT

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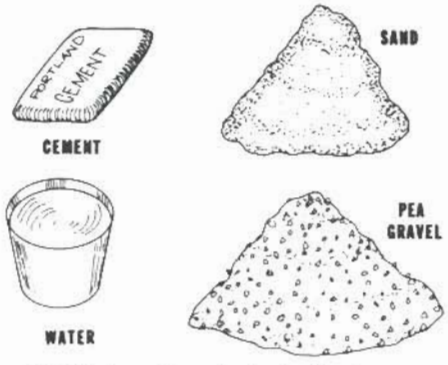

FIGURE 1 — Ingredients in Grout.

Reinforced masonry! Reinforced masonry is the only type of masonry that should be built in "earthquake country." Reinforced masonry is made up of four constituents: the masonry unit, either brick or block; mortar which binds the masonry unit together, provides a level ing bed between units and also architectural appearance; grout, which is the ingredient with which this article is concerned; and reinforcing steel.

Grout is a material used in reinforced masonry that is quite misunderstood.

Grout is not mortar and grout is not concrete. It is somewhere in between. For a rapid visual concept of what grout is, let's call it "soupy concrete." Soupy concrete may give the proper connotation and understanding because it is made up of a cement/water combination which is the paste that binds together the aggregate, which may be sand only or sand and gravel. These are the same ingredients that make up concrete: cement, water, sand and gravel. This is even similar to mortar, which is cement, water, sand and, instead of gravel, lime. All these materials harden into a stone-like mass.

The big difference between concrete, mortar and grout is in their plasticity or fluidity in the initial stage. Mortar is relatively stiff, and if a slump test were made it would have a slump of five to eight inches. Concrete is also relatively stiff with a slump varying from two inches to six inches maximum. The slump of concrete is a controlled requirement for it reflects directly to the water/cement ratio of the concrete mix. This is one major point of variance between concrete and grout. Concrete, with a tightly controlled water/cement ratio, has a relatively low slump, relatively slight plasticity and very low fluidity, for all the water in the concrete will stay within the concrete for it is placed in water-tight forms. All the water in the concrete mix is part of the calculation of the water|cement ratio. Also, in concrete, the forms are spread relatively far apart, and the size of member is relatively large compared to the aggregate material, which allows for easy placement.

Mortar is a plastic material with a low water/cement ratio and high in cement content. Mortar must be relatively stiff in order to be handled on a trowel, to be spread on the masonry unit and to evenly support the masonry units placed on it. This stiffness is required for the masonry wall to be built above without the mortar squashing or squeezing out and deforming. Although mortar has a low water/cement ratio, this ratio is further decreased after the mortar is spread on the bed and the masonry units are placed on it. Any excess water in the mortar is absorbed both down into the masonry unit on which the

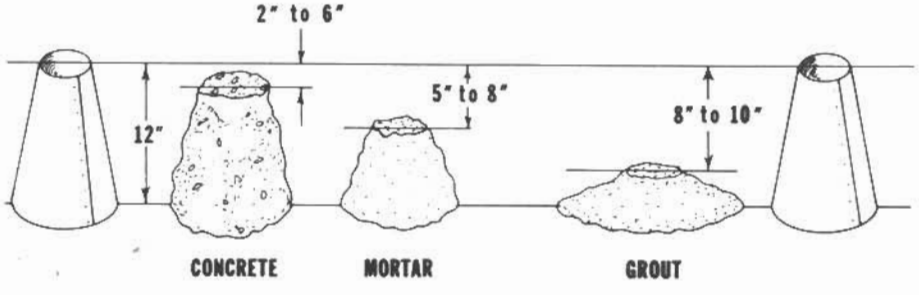

FIGURE 2 — Slump Tests of Concrete, Mortar and Grout.

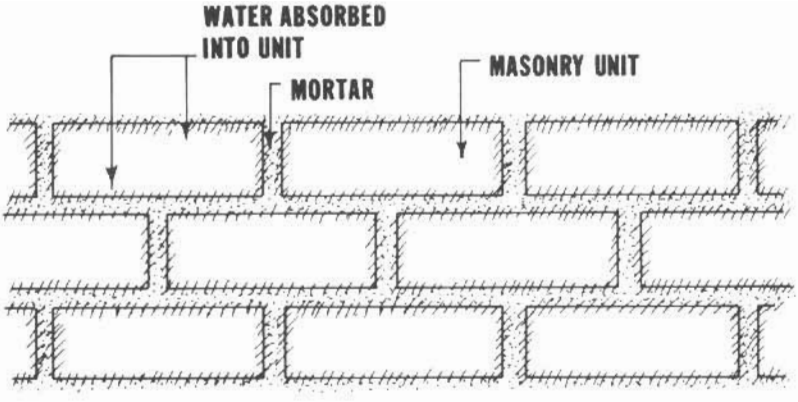

FIGURE 3 — Masonry Units Absorbing Excess Water from Mortar.

mortar is spread and up into the masonry unit that is placed on the mortar bed. This absorption helps create bond between the mortar and the masonry unit.

Grout, although having the same ingredients of concrete, has a fluidity or a plasticity far greater than normal concrete as mentioned above. Grout is placed in the cells of hollow masonry units and in relatively narrow grout spaces in brick walls in heights of anywhere from just a few inches to as high as 25 feet, as in the case of high lift grouting. Accordingly, grout must be fluid, it must completely fill the cells, the grout space and the joints between masonry units in order to provide a solid, homogeneous grouted masonry wall.

If the grout is stiff, it will not flow into the cells or grout space, but will hang up and leave large voids within the wall. Grout must have fluidity with a slump of eight to ten inches. This fluidity allows the grout to flow through the grout space, around the reinforcing bars and completely surround and bond to the steel and masonry unit.

Now what about the water/cement ratio? After all, the grout must have a minimum or specified strength, as will be discussed later. This is taken into account in the design of the grout mix. The excess water, which is a placement vehicle for the grout and helps it flow throughout the wall, is absorbed by the masonry units, whether brick or block, and thus the final water/cement ratio of the grout is reduced to a point where the strength of the hardened grout is in accordance with the specification or code requirements.

The high water content is important. To quote the Office of the State Architect, Structural Safety Section, Circular Number 9, "Filled Cell Concrete Masonry, High Lift Grouting Method," paragraph 4(b), Grout, states, "Sufficient water shall be added to make a workable mix that will flow into all joints of the masonry without separation or segregation. When grout is to be placed in masonry units with typical rates of absorption, the slump of the grout should be approximately five to ten inches, depending upon temperature and humidity conditions."

The Office of the State Architect, Structural Safety Section, Circular Number 10, "Clay Brick Masonry, High Lift Grouting Method," section 4(b) states, "Sufficient water shall be added to make a workable mix that will flow into all joints in the masonry tiers without separation or segration. The slump of the grout should be varied depending upon the rate of absorption of the masonry units and temperature and humidity conditions. The range should be from eight inches for units with a low rate of absorption (30 to 40 grams per minute) up to 10 inches for units with a high rate of absorption (80 to 90 grams per minute)."

These structural circulars by the California Office of the State Architect, in addition to the recommendations of the Masonry Institute of America and other masonry organizations, provide the basis for allowing and needing grout of this fluidity so that it can be properly placed in walls. After all, if a very stiff grout were used, say similar to concrete with a slump of four inches and it hung up in the wall, there could be large void spaces in the wall. This would be unsatisfactory and the wall would not be a solid grouted masonry wall.

Grout, as required by the Uniform Building Code, must have a minimum 28-day compressive strength of 2,000 psi. Grout specimens for compression tests must be taken in accordance with the Uniform Building Code Standard No. 24-22 in which masonry units are placed together to form a square with side dimensions of the square one-half the height of the prism it forms. The mold is lined with paper towels or blotting paper to prevent bonding of the grout to the masonry units and to allow the excess water from the grout to be absorbed through the blotting paper or paper towels into the masonry units. This simulates the same conditions that would occur in placing the grout in the masonry wall and compression test results should be representative of the strength of grout in the wall.

Another sampling technique for hollow block construction is to place the

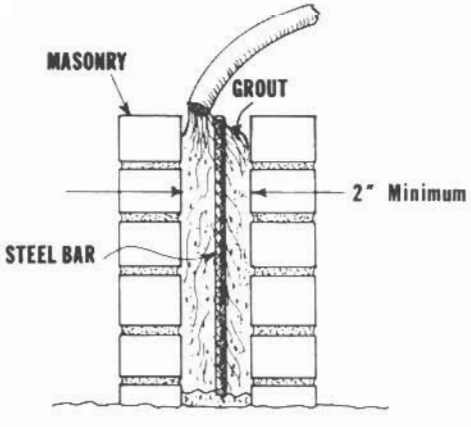

FIGURE 4 — Grout Being Pumped into Two-Wythe Brick Wall.

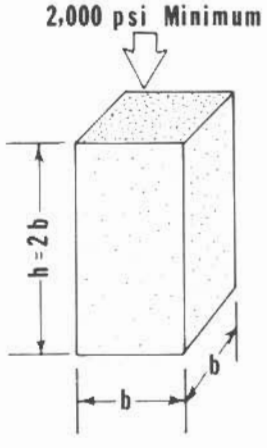

FIGURE 5 — Grout Prism.

grout in the clay or concrete block cell, allowing the excess water to be absorbed by the block, and after a period of time of several days, the block is broken away from the grout. The grout then is sawed into a prism with a height-to-width ratio of two. These grout prisms are cured in a moist room in accordance with curing concrete specimens and tested in compression at the end of 28 days. The grout must have a minimum strength of 2,000 psi in compression in accordance with the Uniform Building Code, Sec. 2403(c)3, or 1,500 psi in accordance with Title 21 of the State of California.

Many times, higher strength grouts than required by code are needed due to the design requirements for the masonry system. Accordingly, if an f_m' of 3,000 psi is required for the wall, grout strengths should be specified of approximately 3,750 psi, or 25 per cent more than the desired f_m'. To attain grout of this strength, a laboratory designed mix should be made. This designed mix should have sufficient cement, sand, gravel and water to have a slump of eight to 10 inches. The test specimen should be made as previously described in the absorbent molds and tested after 28 days. The absorption of the excess water into the masonry units reduces the water/cement ratio to a satisfactory level so that the strength of the grout prism will be as required.

Depending upon the size of grout space, the area of the cell or the width of the grout space, either fine grout or coarse grout can be used. Fine grout is cement, sand and water; and for the grout specified by the Uniform Building Code, which required a minimum strength of 2,000 psi, the proportions by volume are one part portland cement and two-and-one-quarter to three parts sand. The usual proportions are 1 : 3 Fine grout is used where the grout spaces are narrow, two inches or less, or in hollow block that is four inches or less in width.

Coarse grout contains pea gravel or *even larger coarse aggregate, and in* accordance with the Uniform Building Code, the proportions for coarse grout by volume could be one part portland cement, two to three parts sand, and not more than two parts gravel.

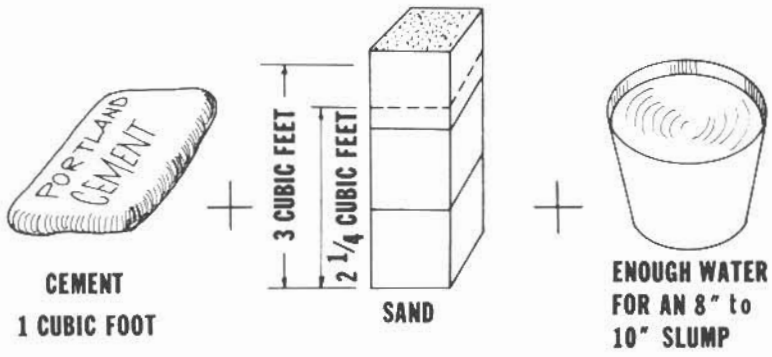

FIGURE 8 — Volumetric Proportions of Fine Grout.

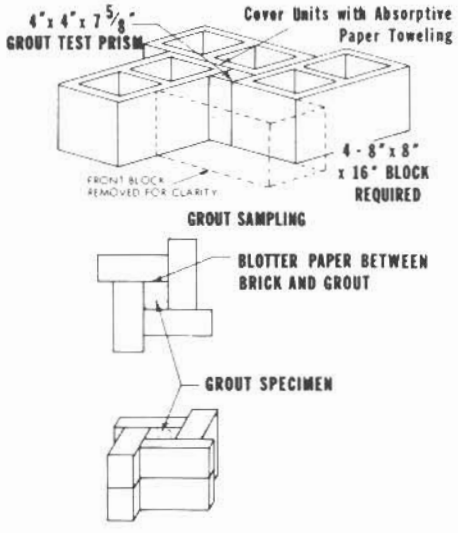

FIGURE 6 — Making Grout Prisms.

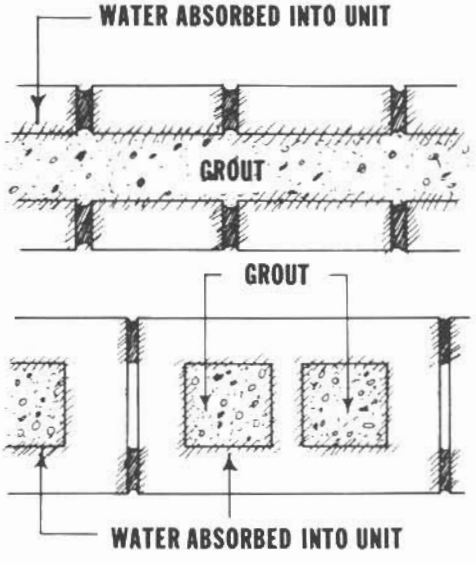

FIGURE 9 — Grout Spaces and Absorption of Excess Water by Masonry.

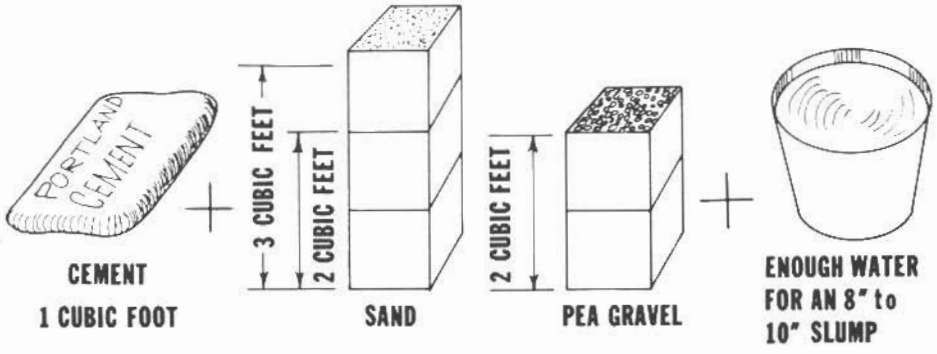

FIGURE 7 — Volumetric Proportions of Coarse Grout.

Coarse grout that is to be placed by means of a grout pump should have proportions of approximately 70% to 80% sand and 20% to 30% pea gravel.

Coarse grout may be used in grout spaces in brick masonry, two inches or more in horizontal dimensions and the cells in block construction should be four inches or more in both horizontal dimensions.

If the grout space is wide, say eight or more inches, in horizontal dimensions between the brick wythes, a coarse grout

using ¾ inch aggregate might be used. This larger size aggregate takes up more volume, reduces shrinkage of the grout and requires less cement for high strength. Also, the slump can be reduced to seven or eight inches because of easier placement.

In order to insure that the grout flows into all crevices, around all reinforcing bars and completely fills the grout space, it must be consolidated by puddling or vibrating. Much of the water that functions as the transporting or placement vehicle for the grout is absorbed into the masonry units and, accordingly, there is a volume reduction of the grout.

The use of shrinkage-compensating admixture is recommended on all high lift grouted construction. Expanding admixtures, such as Grout Aide, cause a slight expansion, about 8 per cent, which counteracts the volume change due to water loss.

Proper and adequate use of a mechanical vibrator can also counteract the effects of water loss and shrinkage.

The water not only acts as the transporting vehicle for the cement, sand and pea gravel, it also acts as the curing agent for the hydration of the portland cement as it is absorbed into the masonry unit. Portland cement, a hydraulic cement, hydrates or hardens in the presence of water. Therefore, the moisture contained in the masonry units cures the portland cement, and thus the grout gains strength. Accordingly, masonry walls need not be wetted down after the grout is placed.

What is the function of grout and why is grout used in reinforced masonry walls? Grout in brick or block walls (1) increases the cross-sectional area to the wall for vertical load support and for lateral shear both parallel and perpendicular to the wall, (2) it bonds the wythes together, and (3) it transfers stress to the reinforcing bars when the wall is subjected to lateral forces due to wind, earthquakes or earth pressure. The masonry element is stressed in compression and through the grout; the reinforcing steel is stressed in tension when the wall is subjected to forces perpendicular to the plane of the wall.

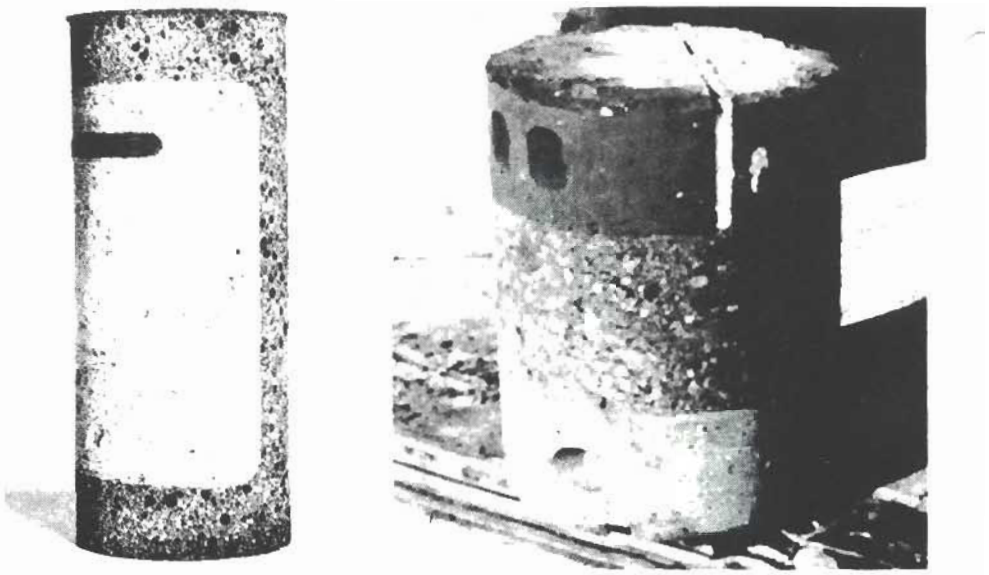

FIGURE 10 — Cores from Brick and Block Walls Showing Monolithic Construction of the Various Constituents.

Grout is not mortar, grout is not concrete; grout is a material unique to reinforced masonry systems, and the rules governing concrete placement should not be imposed upon grout. Grout should have a slump from eight to 10 inches, depending upon the size of the grout space, the height of the grout lift, height of the grout pour, the absorption of the masonry units and the weather conditions. Following good practice for grouted masonry construction will result in a strong and reliable structure.

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