PARAMETERS INFLUENCING THE QUALITY OF GROUT IN HOLLOW CLAY MASONRY

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ABSTRACT Even though grout is an essential component of reinforced hollow masonry, little systematic research has been performed to assess the influence of grout placement procedures, grout constituents, or masonry unit absorption properties on the quality of grout. Good quality grout is defined here to be that which is well bonded to masonry units and free of internal flaws, e.g., arches and voids. The objective of this project was to define how various parameters influence grout quality in grouted masonry. Parameters considered were consolidation type, consolidation time, admixture type, initial water-cement ratio, and masonry absorption properties. In addition, an evaluation of the UBC Standard No. 24-22 "Field Compressive Test Specimen for Grout" will be presented.

1. INTRODUCTION

A number of factors may affect the quality of grout in reinforced masonry construction (1,3,4,5,6). Some of these, such as unit absorption properties, vary randomly from job to job. Others, such as water-cement ratio and consolidation technique, vary as a result of poor definition in the codes. It was the objective of this work to determine how these various parameters influence the strength and integrity of grout in hollow clay masonry structures.

In order to accomplish this task, an experimental program was carried out in two phases. In Phase 1, the procedure for mixing, pouring and consolidating grout was varied until a grout placement procedure was developed that resulted in grout free of flaws and shrinkage cracks. In this phase, grout quality was evaluated visually by cutting vertically through grouted cells of hollow bricks. In Phase 2, the grout placement procedure was held constant, and the effect of varying grout water-cement ratio and masonry absorption properties on grout compressive strength and brick/grout bond strength was observed.

This paper will be concerned primarily with the results of Phase 1, with the exception of a discussion of results from compression tests on grout specimens constructed according to UBC Standard No. 24-22 (7).

2. PROGRAM SCOPE

Each series of tests in this investigation involved the variation of grout constituents, masonry unit properties, or construction procedures. The grout constituents varied were aggregate type, water content, and admixture. Unit property variables were absorption and size, and construction procedures were varied by altering the method and time of consolidation. Each of these variables will be discussed briefly below.

2.1 Masonry Absorption Properties

Due to the porous nature of clay, bricks have a tendency to absorb water from the mortar or grout in contact with them. The magnitude of this effect depends on the absorption properties of the particular unit, and the properties of the mortar or grout. The result of this migration of water from grout is a reduction in the water-cement ratio of the grout, as well as significant reduction of grout volume. The units in this study were chosen to represent a wide range of absorption properties in order to determine the effect of absorption on grout properties. The absorption characteristics of each brick used are listed in Table 1.

TABLE 1 BRICK ABSORPTION PROPERTIES

Brick Type	Width		IRA	
	mm	in	$\frac{kgm}{m^2(min)}$	$\frac{gm}{30in^2(min)}$
Buckskin	92	3 5/8	0.258	5
Buckskin	143	5 5/8	1.137	22
Copper Nugget	92	3 5/8	1.292	25
Copper Nugget	143	5 5/8	1.602	31
Copper Nugget	194	7 5/8	1.963	38
Mission Autumn Gold	194	7 5/8	1.137	22
Walnut	92	3 5/8	0.620	12
Buff	194	7 5/8	0.413	8

2.2 Unit Size

Hollow clay units with nominal widths of 102, 152, and 203 mm were chosen to represent the range of brick sizes used in construction.

2.3 Grout Water Content

The compressive strength of concrete and cement mortars depends on the quantity of water available for hydration of the cement. It is fairly easy to control this quantity in concrete. In grouted masonry, however, the absorbent units decrease the water

content of the grout, leaving an unknown quantity of water for hydration. Since different bricks absorb differing amounts of water, the grout water content at the time the cement takes its initial set remains unknown even if the initial water content is tightly controlled. One of the primary objectives of this project was to determine the effect of varying initial water content on the properties of grout.

The initial water content of grout controls its pourability. In general, water is added to grout to attain a pourable consistency. A slump of 203 mm, (8 inches), represents a reasonable lower bound for the desired consistency. The upper bound cannot be measured adequately by the slump test, but is recognized as the point just before the constituents begin to segregate. For the purposes of this study the initial water contents for the grout were chosen to represent these upper and lower bounds plus an additional intermediate point. The amount of water required for each batch was varied as required by the presence of admixture and coarse aggregate.

2.4 Aggregate

Both fine and coarse aggregates were used in this investigation in order to determine the influence of coarse aggregate on grout shrinkage and strength.

2.5 Admixtures

Grout admixtures were considered as a possible means to eliminate flaws and shrinkage cracks (4). Several admixtures were investigated and judged purely qualitatively by visual examination of the grouted cavities. Since water loss is the source of grout shrinkage, each admixture had some effect on the water in the grout. The admixtures chosen for investigation were lime, bentonite, super-plasticizer, fly ash, and a combination of aluminum powder, plasticizer, and a water retention agent called grout aid.

2.6 Consolidation

A great deal of emphasis is placed on the importance of proper consolidation in the field, with particular attention paid to the practice of "reconsolidation", (i.e. a second consolidation performed after absorption has ceased but before workability is lost). Since the purpose of reconsolidation is to eliminate shrinkage cracks (4), consolidation technique was an important parameter during Phase 1. Consolidation methods tried were rodding and mechanical vibration. Also varied was the time of the second consolidation, (from 30 seconds to 60 minutes after pouring), and the total number of consolidations, (from 0 to 5 times in a 30 minute period).

3. TEST PROCEDURE

Specimens for visual evaluation of grout were obtained by grouting four-unit high stacks of hollow clay units, and then sawcutting vertically through the grouted cells. Specimens for uniaxial compression tests of grout were removed from identical

four-unit stacks with a 53.97 mm (2 1/8 inch), diameter core drill. In addition, compression test specimens were constructed in accordance with UBC standard 24-22 "Field Compressive Test Specimens for Grout".

4. TEST RESULTS

The results were recorded in the form of photographs and descriptive notes indicating the effect of each variable on the quality of the grout cores (i.e. freedom from flaws and shrinkage cracks). Figure 1 shows example specimens. Unfortunately, in no combination of brick-type, grout initial water content, and consolidation technique was it possible to eliminate shrinkage cracks consistently. However, some important observations were made concerning the effect of reconsolidation on grout.

Specimens that were reconsolidated soon after pouring, while grout was still fluid, invariably developed shrinkage cracks.

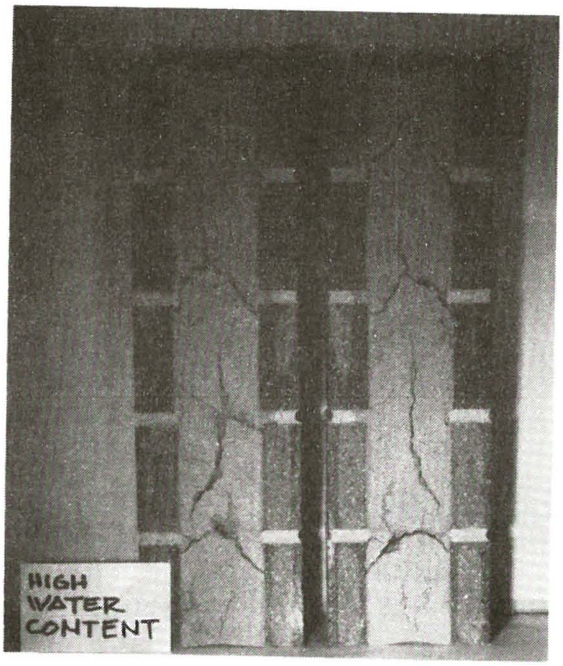

Figure 1

Early consolidation did eliminate air bubbles, and yielded a noticeably denser grout than in unconsolidated specimens, but continuing migration of water after vibration caused significant grout shrinkage.

Specimens that were reconsolidated at later times showed a variety of results depending on the absorption characteristics of the brick and the initial water content of the grout. For bricks with low IRA's or grouts with high initial water contents, reconsolidation at any time up to about fifteen minutes had no more beneficial effect than initial consolidation. After this time, consolidation of the continually stiffening mix served only to disrupt the body of the grout, leaving voids where the vibrator had been. In the case of high IRA bricks or grouts with low initial water contents, the grout became too stiff to consolidate as early as two minutes after pouring. In many cases, shrinkage cracks still appeared when grout was vibrated in a stiff condition.

The use of grout admixtures to eliminate shrinkage cracks was more encouraging. While lime and fly ash improved the workability of the wet mix, they did not help to decrease shrinkage. Bentonite caused an undesirable stiffening of the grout, and as a result of the additional water required, caused an increase in the amount of shrinkage. The addition of super-plasticizer permitted a dramatic decrease in the initial water content of the grout, and resulted in grout cores that contained fewer

shrinkage cracks than in standard grout. Grout aid consistently reduced shrinkage cracks to a minimum, usually eliminating them entirely.

Based on the results of Phase 1, grout for Phase 2 always contained Grout aid, and was consolidated only once by mechanical vibration.

An interesting result of the compression tests done in Phase 2 was a comparison of grout strength as shown by the UBC Standard grout specimens and specimens drilled from an actual grout cavity, as shown in Figure 2. In every case, the UBC Standard test showed significantly less strength than grout from the same batch poured in a brick cavity.

There are five differences between these two tests that are possible sources of the disagreement in strengths:

1. The surface-to-volume ratio of the UBC specimen is larger than for the actual hollow units.
2. UBC specimens are cast against the exterior faces of bricks rather than against the die-skin of the grout cavity.
3. UBC specimens are cured wet rather than dry. (UBC specimens were allowed 48 hours to dry before testing in this project.)
4. UBC specimens are rodded rather than vibrated.
5. Paper towel "bond-breaks" separate the grout from the brick surface in UBC tests.

Changes in brick properties and the geometry of the grout space are not likely to cause such dramatic changes in strength. Based on experience with concrete, the humid curing conditions should cause an increase rather than a decrease in strength. Therefore, it can be concluded that either the consolidation technique or the bond-break are detrimental to strength. The paper towel may significantly inhibit the migration of water from grout to brick, thus increasing the final water-cement ratio.

5. CONCLUSIONS

Some conclusions regarding the parameters studied are listed below. Conclusions are based only on the data collected in this project, and apply only to grouted hollow clay unit masonry.

1. Mechanical vibration produces a more thoroughly consolidated core than rodding.
2. There appears to be no optimum time for reconsolidation, because grout shrinkage continues after grout ceases to be fluid enough to vibrate. For hollow clay units with high rates of absorption or grouts with low water contents, the grout can become too stiff to vibrate as soon as two minutes after pouring. Thus,

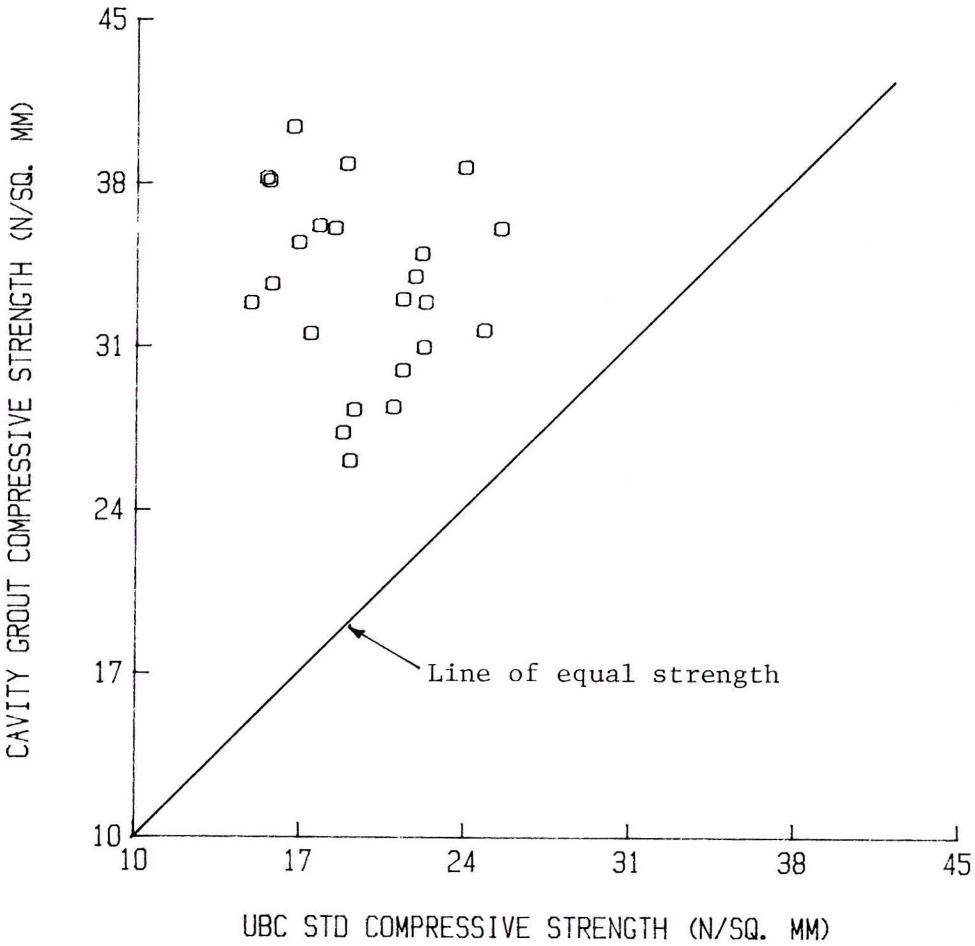

Figure 2

tended purpose of eliminating grout shrinkage cracks, it could potentially destroy the integrity of a grout core if performed at the wrong time.

3. Admixtures which most successfully decreased grout shrinkage either (a) eliminated its source by permitting a decrease in initial water content without a loss of pourability, or (b) counteracted it by causing a slight expansive action in the grout. Super-plasticizers were moderately successful, and Grout aid was extremely successful in minimizing shrinkage cracks. Admixtures that improved the water retentivity or workability of grout had little effect on grout shrinkage.

4. Hollow clay unit size and absorption properties had little effect on the size and number of shrinkage

cracks in grout, however, bricks with very high IRA's caused shrinkage to occur at a quick rate, thus affecting the amount of time available for consolidation.

5. The amount of water absorbed from grout by a particular unit seems to be a function of the initial water content of the grout rather than the absorption properties of the bricks. The higher the initial water content of the grout, the more water will be absorbed from it by the surrounding masonry, and thus more shrinkage occurred.
6. Grouts with coarse aggregates showed less shrinkage than grouts with fine aggregates.
7. The UBC Standard No. 24-22 method for constructing field test specimens for grout results in a significant underestimation of actual grout strength. More realistic values of compressive strength can be obtained removing grout cores from the actual walls in question or from prisms built identically to the walls.

In general, it seems that the common practices for grouting of masonry structures have not been subjected to serious scrutiny, but have developed empirically. In particular, the practice of reconsolidation, required in the Uniform Building Code, does not perform its intended service and may seriously damage the integrity of a masonry wall. The UBC Standard No. 24-22 field test specimen also does not perform its intended function of representing the properties of grout in a masonry wall. In light of these results, further testing needs to be done on different masonry types to determine their generality, and changes in the current codes may be in order.

6. REFERENCES

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