Infrared Inspection of Masonry

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Inspection and testing of concrete masonry unit (CMU) wall construction has always been challenging. There are a number of factors that contribute to the overall strength of the wall. These include:

- Block unit strength, grout strength, and mortar strength
- Grout consolidation
- Vertical reinforcing spacing and placement within each cell
- Horizontal bond beam reinforcing spacing
- Placement of grout within reinforced cells
- Lap splices for reinforcing
- Size and spacing of horizontal joint reinforcing
- Lintel and jamb reinforcing and grout around openings

Not all of these areas can be visually inspected to the extent that they need to be. Even with the best intentions of the mason, periodic site observations by the structural engineer, and diligent on-site testing by a third party, the walls may not be built satisfactorily. This can go unnoticed unless additional means of testing and inspection are utilized.

The most thorough method to verify which cells are grouted in a CMU wall can also be done relatively quickly. It involves a technology called thermography. Thermography is the use of an infrared imaging camera to measure thermal energy (heat) emitted from an object. Thermal, or infrared, energy is light that is not visible to the human eye, because its wavelength is too long. Infrared thermography cameras produce images of invisible infrared or "heat" radiation.

The way this technology works on CMU walls is that the grouted cells are higher in mass, and therefore absorb and release heat more slowly that the ungrouted or insulated cells which are considerably lower in mass. Through trial and error, we have determined that the ideal time to take infrared pictures of a CMU wall is between 11:00 p.m. to 3:00 a.m. following a relatively sunny day. After the wall is heated throughout the day, the grouted cells cool down at a much slower rate than the ungrouted cells. Although not an ideal time for visiting a construction site, the differences in quality of information obtained from pictures taken during the night and day on an infrared camera are significant.

Figure 1: Exterior View of a CMU Wall Taken with a Digital Camera

Examples

Images taken with an infrared camera show a distinct difference between the grouted cells and ungrouted cells, creating a clear indication of which cells are grouted. *Figure 1* shows a picture of a CMU wall taken with a standard digital camera during the day. *Figure 2* shows a picture of the same wall taken with an infrared camera at night. The lighter areas in *Figure 2* indicate cells that contain grout. The darker areas are either ungrouted or contain insulation. Most infrared cameras can take images in either color or black and white. Using black and white pictures shows a more distinct difference between grouted and ungrouted areas. Areas where the lighter vertical portions of the wall are discontinuous indicate inadequate grouting of the cells.

There are a number of additional uses for thermography on buildings, including utilizing an infrared camera to find moisture in a roof membrane, detecting heat escape through walls, and finding leaks below slab. The use of an infrared camera to check for grouted cells was first discovered during testing for heat escaping through CMU walls.

Before infrared testing was available, the methods for testing CMU walls for the existence of grout were largely destructive in nature. The most common methods for verifying grouted cells are to either drill or hammer a number of holes into the wall, or to remove entire face shells. These methods are rarely thorough enough, since it is impractical to drill holes throughout every location

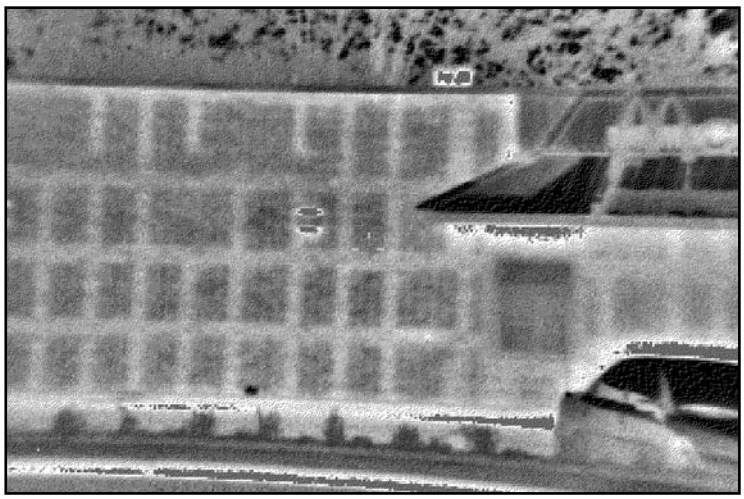

Figure 2: Exterior View of a CMU Wall Taken with an Infrared Camera

Figure 3: Infrared Picture of a Properly Grouted CMU Wall

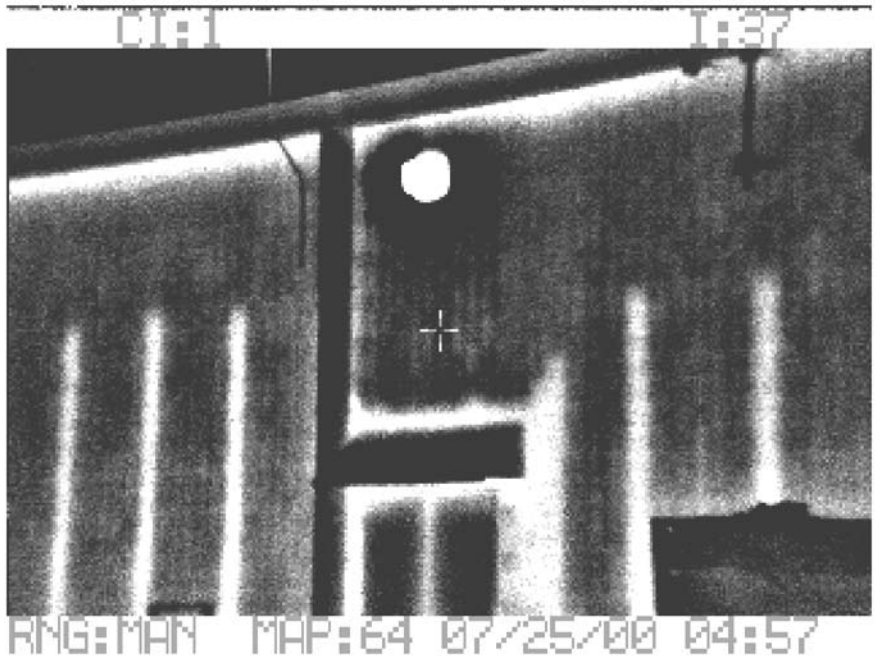

Figure 4: Infrared Picture of a CMU Wall with Discontinuities in the Grout

in the building that should be grouted. This method can also take weeks or even months to complete.

We received validation of the viability of the use of infrared testing on a project where we had performed an infrared test and another firm was hired by the contractor to do follow-up testing utilizing destructive methods. The following is an excerpt from the report done after the testing was complete:

"During the week of September 11 through September 18, at your request, structural examinations including destructive demolition were performed on the referenced buildings. The purpose of the structural examinations was to assess the general condition of the masonry wall construction of both buildings and to offer an independent review of the Wallace Engineering Reports. Our examinations revealed numerous structural deficiencies and discrepancies from the structural contract drawings. The destructive demolition and observation points found the infrared video and photos to be extremely accurate in their depictions. In fact, no discrepancies from the infrared surveys were found."

Figures 3 and *4* show examples of infrared inspections of CMU walls of similar size. In *Figure 3*, regular spacing of vertically grouted cells within the wall are present and the correct spacing can be confirmed. Horizontal

bond beams at the top of the wall and near the center of the wall can be verified. Grouting in the lintel and jambs can be confirmed around the openings. In *Figure 4*, discontinuities in the vertical reinforcing are indicated. The grouted cells around the opening are discontinuous, and the spacing of the vertical cells is not consistent. For repair drawings, the oval indicators shown in *Figure 4* are used to highlight areas that require repair, a key plan and list of the areas requiring repairs is issued, and repair details are provided. An example repair detail is shown in *Figure 5*. The detail includes information on the appropriate steps required to remove face shells, place missing grout and reinforcing, and replace face shells.

Equipment

There are a number of different infrared cameras available, with a variety of features. Many of the cameras have features that are not needed for an infrared inspection of a CMU wall. The ones we have found the most success with are flexible enough to allow a standard video camera to be attached, so that both still shots and video shots can be taken. This combination has allowed us to perform an infrared inspection of a building with approximately 50,000 square feet of CMU wall within one to two hours.

The use of an infrared camera for thermal imaging by itself does not check all of the items that need to be verified. Typically, we have found that if the grout has been placed correctly the reinforcing is also placed correctly, but this is not always the case and it does need to be verified. The best way to verify the existence of reinforcing in a cell is with a rebar locator, often called an R-meter. A systematic check of a representative sample of the vertical and horizontal reinforcing should provide a good indication of whether or not the reinforcing bars are placed correctly.

As with infrared cameras, there are a number of R-meters on the market with various features. While many of the rebar locators work well for locating reinforcing within three inches of the face of a concrete wall, it is more difficult to find one that properly locates reinforcing at the center of an 8 - or 12-inch CMU wall.

A thorough program consisting of full-time on-site testing and visual inspection is also recommended for verifying the placement of reinforcing and grout. Repairing or eliminating problems as they occur is the most efficient way to keep construction on schedule. If the reinforcing is checked prior to grouting the wall, adjustments can be made immediately. Full time on-site testing and inspection is the recommended method for verifying the remainder of the items contributing to the strength of the wall, including block unit strength, grout strength, mortar strength, and lap splices. Requiring a prism test to verify the overall strength of the blocks and grout is also recommended.

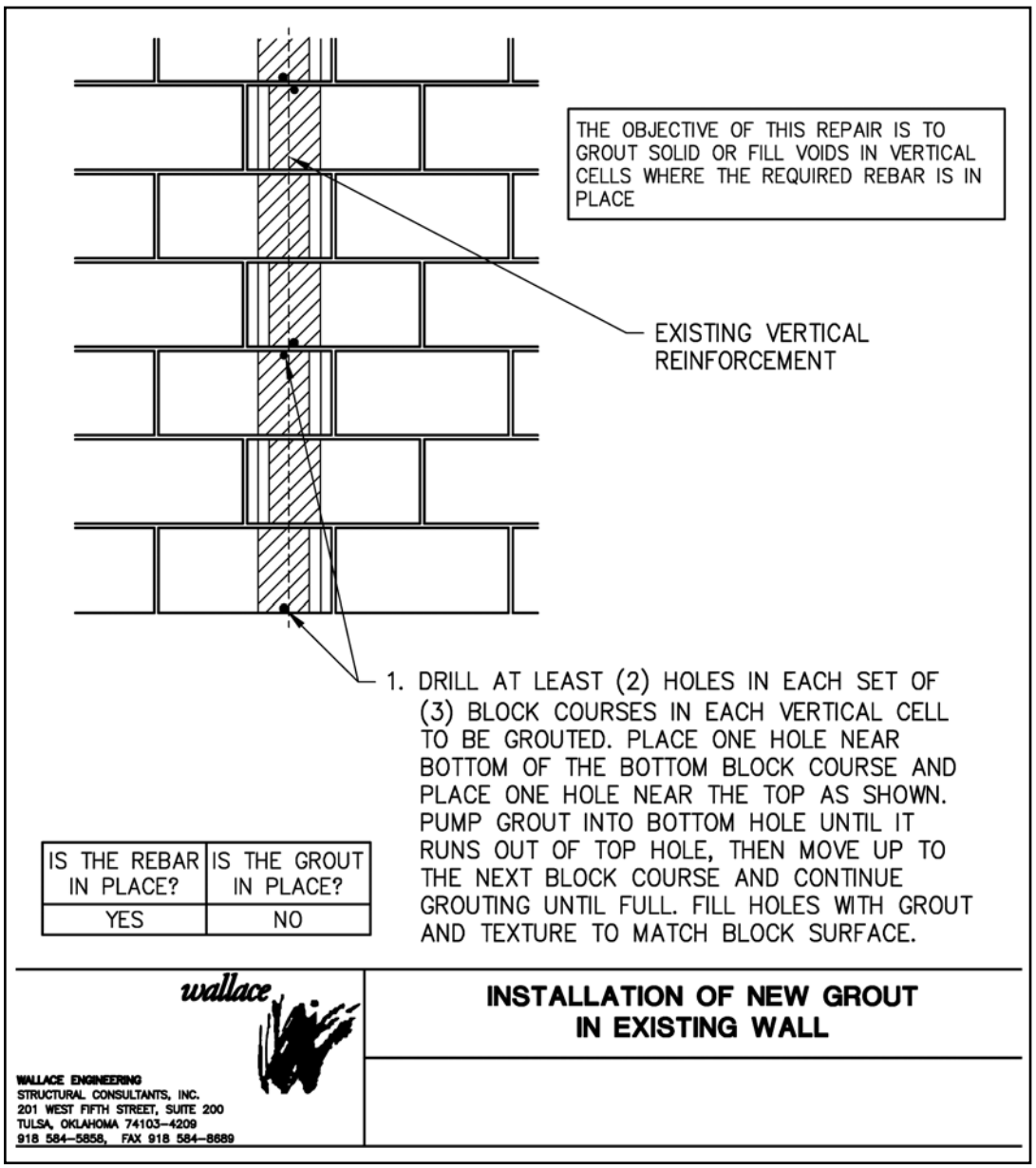

Figure 5: Sample Repair Detail for a CMU Wall with Vertical Discontinuities

Conclusion

The combination of an infrared camera, an R-meter, and a thorough program of on-site testing and visual inspection of the wall during construction provide a great deal more insight into the quality of the finished product of CMU walls. If all of these factors are used properly and deficiencies are repaired, a higher quality CMU wall will be achieved.▪

Carrie Johnson and Tom Wallace are principals at Wallace Engineering Structural Consultants, Inc. with offices in Tulsa, OK, Kansas City, MO, Oklahoma City, OK, and Castle Rock, CO. Wallace Engineering has provided structural engineering services on CMU buildings throughout all fifty states.