IV–20. Evaluating the Condition of Masonry Buildings in Service

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ABSTRACT

Structurally sound masonry buildings can be designed and constructed with a high degree of reliability. Standard tests are available to insure the quality of materials and to a lesser extent the quality of workmanship.

However, masonry buildings, like all other buildings, will deteriorate with the passage of time. Masonry which was originally structurally sound can not be relied on to remain that way without some timely maintenance and occasional effective repairs.

Too often, maintenance and repairs are undertaken at significant expense, without first accurately assessing the condition of the masonry, and secondly without determining the cause of the deterioration.

Based on experience gained by evaluating the condition of more than 1000 masonry structures, some useful field and laboratory testing procedures will be discussed which may be helpful to other professionals.

INTRODUCTION

When evaluating the condition of masonry buildings in service, there is no substitute for experience, experience not only in designing and detailing masonry buildings, but experience in knowing how masonry materials behave and the manners in which they can fail.

An experienced professional can often accurately determine the condition of a masonry building by no more than a close up visual inspection and by cutting a few inspection openings into the masonry at locations exhibiting significant distress or deterioration.

This paper has been prepared to briefly discuss laboratory and field tests which are available to the professional who has visually examined the masonry on a building, cut inspection openings and finds that he is still uncertain as to the condition of the masonry or the cause of some distress or deterioration he has observed.

LABORATORY TESTS

Standard ASTM Tests for Bricks

If bricks are deteriorating on a building, samples of bricks from a still sound area can be removed, cleaned and be subjected to the same standard ASTM tests that new bricks are subjected to. The brick samples can be tested for compression strength, absorption, saturation coefficient, effloresence and freeze-thaw resistance. If the bricks fail to satisfy any of the standard ASTM tests, numerous other laboratory tests can be performed to study the bricks in more detail.

Petrographic and Chemical Analysis of Bricks

An experienced petrographer can often detect internal conditions which may be contributing to a problem but are not visually apparent to the naked eye. If the bricks are spalling, the petrographer may be able to detect unusual laminations which are providing internal planes of weakness or he may discover that the face of the brick has been coated with an improper waterproof coating. If the bricks are deteriorating, he can see if the bricks appear to be properly fired or he may be able to detect the presence of potentially harmful chemicals, salts or contaminants that may have penetrated into the face of the brick.

The findings of the petrographic analysis can be further substantiated and extended by the chemist. If the petrographer suspects that a brick has not been adequately fired, the chemist can verify the adequacy of the firing by measuring the mullite crystal content by x-ray diffraction. If a coating is found on the face of the brick, or contaminants are found to have penetrated the brick, the chemist can identify them.

Testing for Moisture Expansion of Bricks

Where cracking and distortions of masonry walls are occurring, and proper expansion joints have been provided, it is possible that the bricks are experiencing unusual moisture expansion. To make an accurate measurement of moisture expansion, it is necessary to measure the product soon after firing and to measure it again after some exposure to water vapor; however, to get an indication of moisture expansion, it is also possible to reheat a brick removed from a building and to measure the shrinkage. This latter process is beset with difficulties because micro cracking may retard shrinkage, but if the limitations of the reheat test are understood, the results can still often be of significant value.

Petrographic and Chemical Analysis of Hardened Mortar

If severe mortar deterioration is occurring, the petrographer and chemist can determine a wide variety of things. From a hardened sample of mortar, they can determine if the cement, sand and lime meet ASTM standards; if the sand gradation is proper; if the proportions are proper; if any improper admixtures were used; if the cement has hydrated properly; and if the mortar froze before it set, just to site a few examples.

The petrographer can also examine the bond face between the mortar and the brick and comment on the quality of the bond and the watertightness of the joints.

Accelerated Weathering Tests of Brickwork

Accelerated weathering tests are regularly used to determine the relative durability of materials when subjected to a wide range of environmental exposures, and when used with care, these tests can also be used to give an indication of the potential longevity of materials that are in service. A comprehensive accelerated weathering test should include freeze-thaw, exposure to ultraviolet and infrared lighting, and exposure to contaminants found in a normal urban environment such as salts, acids and dirt.

FIELD TESTS

Water Leak Testing

Water leak testing by experienced professionals can successfully locate the source of water leakage through masonry walls. Method of spray, controlling the sequence of surface exposure, and the proper equipment are all essential factors.

To evaluate the water tightness at selected locations on masonry walls, portable aluminum test frames can be attached to exterior walls to perform a modified version of ASTM E 514 "Standard Method of Test for Water Permeance of Masonry." Figure 1 shows one example. The rate of water application and air pressure in the frame are in accordance with E 514, but because of the in situ condition, the evaluation of water entry is substantially different.

Moisture Meters

Moisture meters can be used to help locate sources of water leakage in masonry walls. To get useful results, however, it is normally necessary to drill holes into the walls at locations of interest to allow insertion of the moisture meter's probe.

A moisture detection device which may work on masonry walls under certain circumstances without the drilling of holes is the nuclear moisture meter. The nuclear moisture meter is primarily used to detect moisture in flat roofs.

A small neutron source is used to detect moisture by measuring the hydrogen present. By taking regularly spaced readings over an area, the pattern of the moisture present can be plotted.

Metal Detectors

Frequently, areas of masonry distress are associated with the omission of or the improper placement of supporting angles and masonry ties. Where such a condition is suspected, it can often be quickly checked nondestructively with a metal detector. With a properly calibrated metal detector, it is even possible to determine the distance to the nose of the shelf angles, and thus, to verify if the bricks above it have adequate bearing.

Infrared Image Systems

The infrared image systems which are capable of detecting small differences in surface temperature are still somewhat experimental as a tool for investigating masonry problems, but they do have considerable promise.

The locations of bands of mortar droppings in an insulated cavity wall which was leaking were easily detected (Fig. 2). Large voids in solid masonry walls have been detected (Fig. 3), and occasionally, the location of masonry wall ties has been visible.

Dynamic Response Testing

The dynamic response technique can be useful in trying to identify prefabricated masonry panels that require more detailed in-depth evaluation. To be a realistic candidate for dynamic response testing, the masonry elements being studied must all be of similar size and all must be supported in a similar manner.

The dynamic response technique consists of impacting the elements with a unit force and measuring their dynamic response. Both the natural frequency at which the elements oscillate, as well as their initial displacements, are normally recorded.

Significant variations in the physical properties of materials of which an element is constructed or variations in its condition of support are often detectable.

Strain Relief Testing

The masonry walls of many of our older buildings were constructed without horizontal expansion joints. These older buildings are prone to develop high levels of compressive stress, especially in the vertical direction. Being able to measure the levels of stress in these older masonry walls has proven invaluable in clearly determining the cause of observed distress, in evaluating the probability that undamaged areas of masonry will continue to perform satisfactorily, and in being able to evaluate the potential for the success of proposed repair procedures.

To measure the level of stress which exists at a specific location in a masonry wall, strain relief tests are regularly performed. Electrical resistance strain gages are attached to the face of the exterior wall, and wires are attached to measuring equipment in the building, as shown in Figs. 4 and 5. After the gages are in place, readings are taken. The segment of wall to which the gages are attached is then cut out, as shown in Fig. 6, and the gages are again read. The change in gage readings gives a measure of the strain released. The changes in strain recorded are then converted to stress by laboratory tests on the removed pieces of wall. Care must be taken during the strain relief testing to compensate for changing temperature during the day, to compensate for heat induced by cutting, and to insure that no hairline cracks developed that crossed any of the gages.

The extent to which the strains measured are thermally induced can be determined very easily at the same time the strain relief test is being performed. If the gages are installed early in the morning, the gages can be used to monitor the effects of temperature as the day warms up, and the strain relief testing can be done in the afternoon.

Monitoring Gages

To determine the cause of masonry distress, it is sometimes valuable to monitor the behavior of cracks in the wall. If the movements of the cracks are very large, they can be measured with a ruler, but usually, the movements are not large and a more sensitive measuring device is required.

A simple dial gage can be used to monitor the widening of a crack, but to give an accurate reading, it should normally be installed firmly in position across the crack and be left in place. The protecting of a dial gage from the elements when it is attached to the face of a building is sometimes quite a difficult undertaking. A preferable method of monitoring crack movements is to use a Whittemore gage. The Whittemore gage has the accuracy of the dial gage but has the distinct advantage of being removed and replaced as desired. The Whittemore gage is a mechanical indicator which measures change in length between two points which are permanently affixed to the masonry wall, one point being on either side of the crack being monitored.

Another type of gage which might be considered to monitor crack movements is the scratch gage. The scratch gage is a device that has the advantage of being able to continuously monitor crack movements unattended. The gage records movements on a replaceable brass button. The movements are recorded as scratches on the brass button which are read with a calibrated microscope. The disadvantage of the scratch gage is that it is not as sensitive as the Whittemore or dial gage.

Load Testing

Load testing is normally quite expensive and is only used after other more economical testing methods and analysis procedures have yielded inconclusive results.

Lateral loading tests are normally the easiest type of loading tests to perform on masonry walls. First because lateral loads are usually not particularly large, and secondly, because lateral loads can normally be applied with a vacuum frame. A vacuum frame is an airtight box which can be anchored to the face of the wall. Figs. 7 and 8 show two examples of vacuum frames. The lateral pressure is applied by pumping the air out of the box. Lateral pressures of up to about 250 psf are easily attainable. Lateral pressures of up to 3000 psf have been achieved with special equipment to test nuclear reactor structures.

Vertical loading tests on masonry walls are normally quite difficult to perform. First, because vertical test loadings often have to be very large, and secondly, because it is often difficult to apply a vertical load to a masonry wall anywhere except at the roof.

Vertical loads on masonry walls are normally applied with hydraulic jacks. It is often necessary to remove areas of wall above the elements to be tested to install the jacks. It is also often necessary to remove material completely around the element being tested to insure that it alone is resisting the test load as shown in Fig. 9.

During the load tests some type of shoring or device should always be provided to catch the element being tested should it collapse.

CONCLUSION

There is no substitute for experience when evaluating the condition of masonry buildings, but laboratory and field tests, when properly interpreted, can aid the professional in developing a more complete understanding of the existing conditions, and if necessary, to develop the optimum repair.

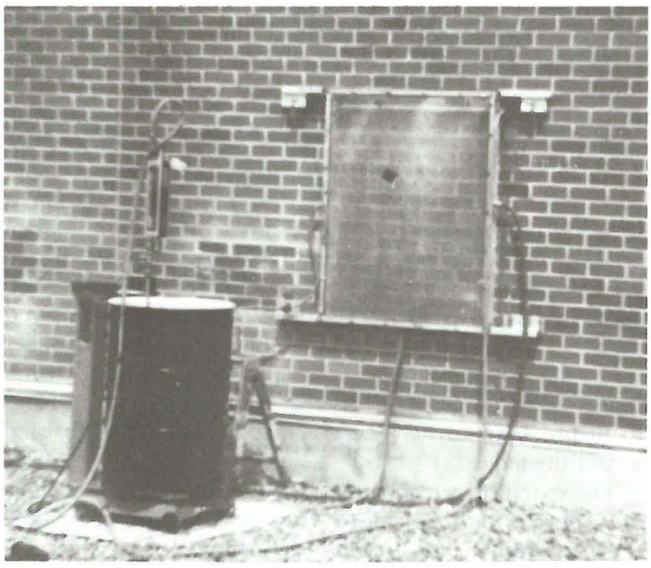

Figure 1. Modified version of ASTM E 514 for field testing Water Permeance of Masonry.

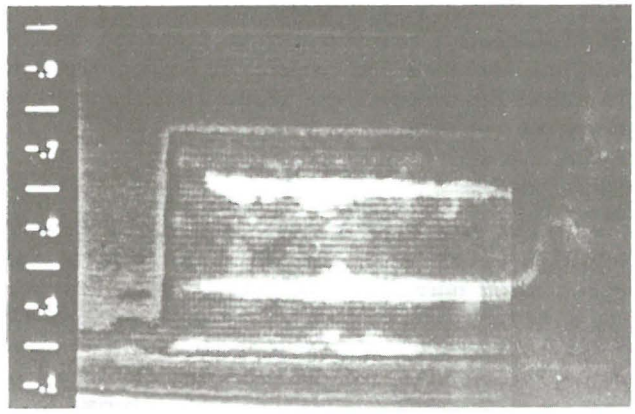

Figure 2. Infrared photo of insulated masonry cavity wall. Horizontal bands of white indicate locations of mortar droppings in cavity.

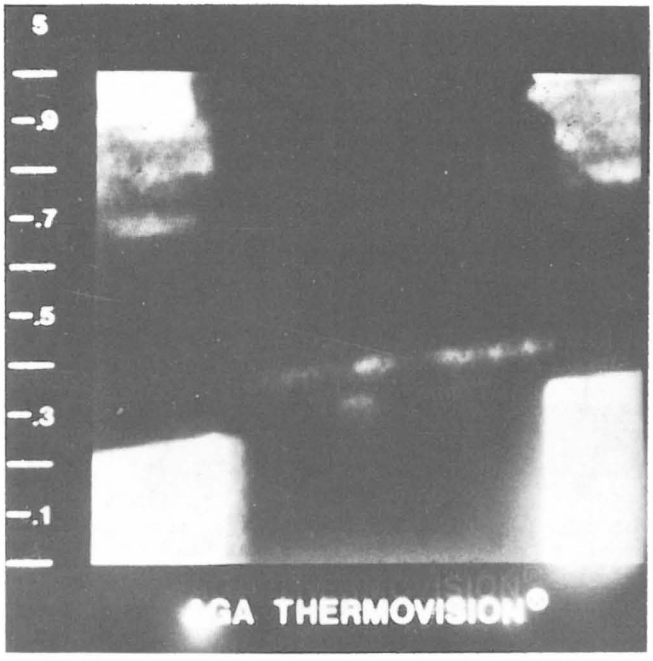

Figure 3. Infrared photo of column beam intersection. Horizontal white line at top of lower column locates large void in back up in old solid masonry wall.

Figure 4. Installing strain gages on face of building.

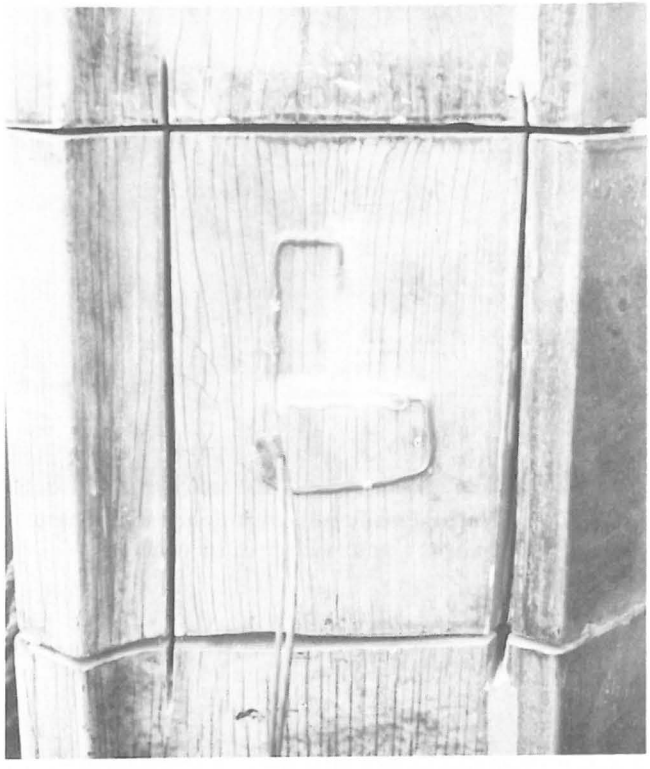

Figure 6. Material on which strain gages is attached, cut free from face of building.

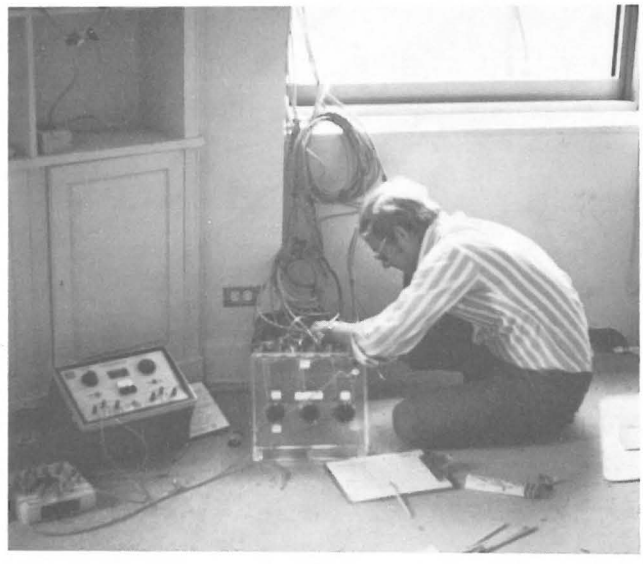

Figure 5. Wiring strain gages to recording device inside building.

Figure 7. Lateral load test being applied on marble building with vacuum frame.

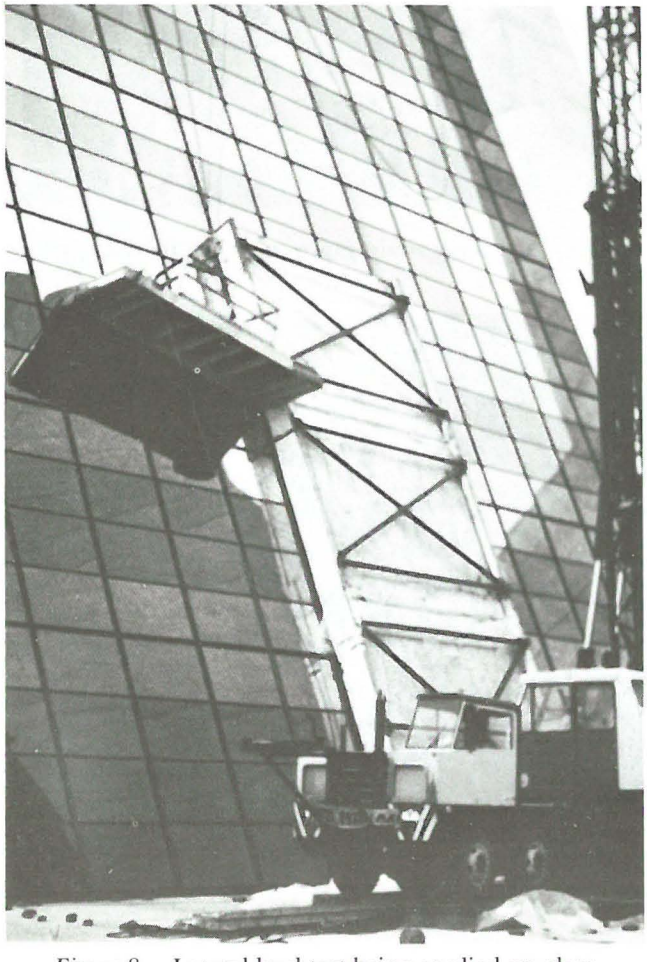

Figure 8. Lateral load test being applied on glass building with vacuum frame.

Figure 9. Vertical load test being applied to concrete masonry units with hydraulic jacks.