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Standard Guide for Evaluation and Rehabilitation of Mass Masonry Walls for Changes to Thermal and Moisture Properties of the Wall[1]

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1. Scope

1.1 This guide addresses the evaluation of existing mass masonry walls for the potential addition of interior insulation and continuous air barrier or vapor retarder or other changes to the thermal and moisture management properties of the wall.

1.2 This guide describes methods for evaluating ~~causes of water infiltration or other~~ moisture accumulation related problems specific to mass masonry walls. This guide does not apply to walls that include provisions to manage bulk water through internal drainage, flashings, or other measures other than the moisture storage capacity of the wall.

1.3 This guide describes analysis, design, and specification of materials with the required ~~thermal~~ thermal, air, and vapor resistance to improve the energy performance of an existing mass masonry wall, but that would not create problematic conditions to the masonry units or within the masonry wall or interior of the building.

1.4 This guide applies to walls of ~~solid or multiwythe~~ masonry construction meeting the requirements of a "mass masonry wall" as defined ~~herein and having an overall thickness of solid masonry not less than 8 in.~~ herein. This guide does not apply to masonry walls that, by design, are intended to manage water as a barrier wall system or drainage wall system.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

[1] This guide is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.24 on Building Preservation and Rehabilitation Technology.

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1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C20 Test Methods for Apparent Porosity, Water Absorption, Apparent Specific Gravity, and Bulk Density of Burned Refractory Brick and Shapes by Boiling Water
~~C67~~C67/C67M Test Methods for Sampling and Testing Brick and Structural Clay Tile
C1046 Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components
C1155 Practice for Determining Thermal Resistance of Building Envelope Components from the In-Situ Data
C1498 Test Method for Hygroscopic Sorption Isotherms of Building Materials
C1794 Test Methods for Determination of the Water Absorption Coefficient by Partial Immersion
~~E96~~E96/E96M Test Methods for Water Vapor Transmission of Materials
E398 Test Method for Water Vapor Transmission Rate of Sheet Materials Using Dynamic Relative Humidity Measurement
E631 Terminology of Building Constructions
E2128 Guide for Evaluating Water Leakage of Building Walls

2.2 *Other Standards:*

ASHRAE 160 Criteria for Moisture-Control Design Analysis in Buildings[3]
International Energy Conservation Code [4]
Secretary of The Interior's Standards for Rehabilitation [5]

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

[4] Available from International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001, http://www.iccsafe.org.

[5] Available from Technical Preservation Services (TPS), National Park Service, 1849 C Street, ~~NW (org 2255),~~ NW, Mail Stop 7243, Washington, DC 20240, http://www.nps.gov/tps.

3. Terminology

3.1 *Definitions:*

3.1.1 *liquid ~~transport coefficient,~~ transport, absorption*—describes the capillary uptake of water (liquid moisture) when the imbibing surface is fully wetted. In the context of building physics, this corresponds to rain on a ~~facade.~~facade or retained water in an undrained space.

3.1.2 *liquid ~~transport coefficient,~~ transport, redistribution*—describes the spreading of the imbibed water when the water source is shut off. No new water is taken up by the material, and the water present in the material begins to redistribute. In a building component, this corresponds to the moisture permeation in the absence of rain.

3.1.3 *mass masonry wall*—~~solid~~ wall constructed of ~~more than one wythe of~~ masonry including all types of natural and unit masonry, ~~such as brick, stone, and concrete masonry. "Mass masonry walls" refers to the mechanism of water management for the wall, specifically masonry walls with~~ not less than 8 in. thick (nominal), and where moisture storage within the wall is the mechanism for water management. Specifically the masonry wall shall have the ability to store and subsequently release bulk water.

3.1.4 *moisture*—generally refers to the presence of water in either the liquid or vapor form.

3.1.5 *moisture issues*—refers to any complaint or deficiency attributable to moisture. Typical issues include occupant discomfort, biological growth, corrosion, wood decay, staining, freeze-thaw damage, or other durability issue related to the presence of moisture.

3.1.6 *moisture permeation*—a process in which moisture (water or vapor) enters, flows, spreads within, and discharges from a material.

3.1.7 *water ~~absorption coefficient—~~ absorption*—mass of water absorbed by a test specimen per face area and square root of time.

3.2 See E631, Standard Terminology of Building Constructions, for general terminology.

4. Significance and Use

4.1 Energy conservation is being addressed more often on existing and historically significant buildings constructed with solid exterior mass masonry walls. Without proper evaluation, changes to the thermal and moisture properties of the exterior walls could have serious negative ~~impacts.~~impacts on the existing masonry, new or existing wall components, and building operations.

4.2 A thorough understanding of the ~~existing construction, condition,~~ original construction and subsequent alterations, condition of materials, properties, initial moisture content, ~~and~~ water and air leakage ~~potential~~ potential, and building operations are necessary before undertaking the addition of interior insulation, air barrier, vapor retarder, or other changes to thermal or vapor resistance of the wall.

4.3 Degradation of the existing masonry along with moisture related problematic conditions and indoor air quality issues could develop if alterations are undertaken in an improper manner to the exterior wall assembly.

5. Review of Project Documents

5.1 Available construction documents should be reviewed as outlined in Guide E2128.

5.2 Prior to undertaking a field evaluation and, if available, the original documents from time of construction should be reviewed to determine the general wall thickness, composition, and geometry. The presence of ~~voids~~ intentional annular spaces or other ~~annular space~~ voids should be identified.

5.3 Inspection reports, surveys, repair or alteration drawings, or other available documentation should be reviewed to gain a better understanding of the current condition of the exterior walls.

5.4 Since many buildings featuring mass masonry walls were constructed prior to modern construction delivery methods, it is recognized that construction documents are typically non-existent or limited. As such, any available photographs or other documentation of the building throughout time should be reviewed to help identify which portions of the building or wall assembly is original and which portions were added at later times.

6. Determination of Service History

6.1 Using the methods outlined in Guide E2128, a thorough evaluation of the building's service history should be conducted. The following activities should be included in the evaluation:

6.1.1 Documentation of physical symptoms of moisture damage or presence of moisture.

6.1.2 Interviews with occupants, maintenance staff, contractors, or other first-hand observers to correlate moisture related issues with the building ~~maintenance/operation~~ maintenance and operation history or weather patterns, or both. Changes to the building's mechanical systems or mechanical system operations should be ~~pinpointed~~determined as best as possible.

6.1.3 Review of maintenance and repair records for both the mechanical systems and building enclosure.

6.1.4 Review of vicinity weather records.

6.1.5 Correlations of moisture issues with other factors such as season of year, building elevations, wall height, interior conditions or use.

6.2 If readily available, identify where the existing materials were sourced and review the performance of similar materials on nearby existing buildings.

7. Initial Evaluation

7.1 The overall thickness of the wall should be determined or verified with field measurements at various locations throughout the building.

7.2 When accurate drawings of each wall section are not available, it will be necessary to determine the wall composition and wall assembly details of each critical or unique wall section.

7.3 Mass masonry walls historically have been constructed with a wide range of materials to ~~include: brick,~~ include, but not limited to: brick, mortar, clay tile, concrete masonry units (CMU), terra cotta, cast stone, and stone.

7.4 The exact wall composition should be verified through small discrete exploratory openings. The historic integrity of the existing wall should be carefully evaluated when selecting the locations to make the exploratory openings.

7.5 The wall composition can be determined through a combination of exterior and interior probes, borescopes, targeted removals, and various non-destructive testing techniques. The number and size of the openings should be kept to the minimum that is necessary to determine the composition of the wall, but sufficient to gather pertinent information on a representative sample of existing construction. At a minimum, the following should be recorded:

7.5.1 Overall thickness of the wall;

7.5.2 Type of material(s) present within the ~~wall;~~wall. Distinguish original construction or retrofit materials where possible to include if the existing masonry had previously been repaired or altered and the condition and presence of the joint between original and retrofit materials;

7.5.3 Number of wythes;

7.5.4 Thickness of each material or wythe;

7.5.5 Condition and material type of each wythe;

7.5.6 Presence and thickness of collar joint or voids within the wythes;~~ and~~

7.5.7 Presence of water.

7.6 Examine the condition of all other materials making up the wall assembly. Determine if there is any existing evidence of previous freeze-thaw damage. Determine if any ~~existing~~ corrosion of any metallic elements such as veneer ties or embedded structural supports are present. Determine if there is any biological growth or other moisture related damage on existing organic materials.

7.7 If a collar joint is present, qualitatively assess how complete or full the joint is and ~~if it is slowing moisture transport. Consideration should be given as to whether or not the collar joint will behave more like an air space and provide a capillary break between wythes or if the space is mostly solid and will provide bridging for moisture movement between wythes.~~its impact on air and moisture transport.

7.8 Qualitatively assess any air movement through and across the assembly to determine if drying potential is offered via convection, utilizing methods such as infrared thermography, smoke pencil, or other visual observations.

7.9 Determine whether the existing masonry features an existing coating or water repellant on interior or exterior surfaces. If so, determine what impact this product would have on the permeance and the liquid transport coefficient. Consideration should be given to how this product has performed historically and what the expected useful service life is for the proposed product.

7.10 ~~Determine representative~~ Simultaneously determine representative interior and exterior surface temperatures, ambient interior and exterior relative humidity and temperature, building differential pressure and initial moisture contents and moisture permeation patterns of the existing wall using procedures described in Field Determination of Existing Moisture Content (Appendix X1).

8. Evaluation of Material Properties

8.1 The properties of the materials comprising the ~~wall and also the properties of the~~ wall, to include variations between the same type of ~~materials within the wall~~ material can vary ~~widely~~ and will result in inaccurate hygrothermal models if testing to determine the properties of the actual material properties of each component within the wall is not undertaken. Published generic material property data may not match the existing materials in the building or ~~structure.~~structure and may not be specific enough to make valid assumptions.

8.2 If possible, representative samples should either be removed from the interior from the locations of exploratory openings or from other discrete locations. If a solid grout or collar joint is present, samples of such material should be included to determine the hygrothermal material properties. Consideration should be given to the location and number of samples to be removed and tested. Representative samples should be removed to ensure the variance in materials from the differing elevations, floors, and wythes are evaluated.

8.3 The following hygrothermal material properties should be determined using testing procedures indicated. Published values for a material of similar type and density are allowed to be used if samples are not available or project parameters will not afford the time for laboratory testing:

8.3.1 Bulk density per Test Methods C20.

8.3.2 Moisture storage function (sorption-isotherm curve) per Test Method C1498.

8.3.3 Test Methods ~~E96~~E96/E96M (or Test Method E398 for sheet materials) vapor permeance at range of moisture contents to develop the permeance as a function of moisture content.

8.3.4 Porosity per Test Methods C20.

8.4 The following material properties should also be determined. Empirical testing required to determine these properties can be costly and complex. It is acceptable to determine these properties analytically or using engineering judgment as described.

8.4.1 *Heat Capacity*—Selected using engineering judgment from published values in any of the referenced documents for a material of similar density.

8.4.2 *Thermal Conductivity*—Selected using engineering judgment from published values in any of the referenced documents for a material of similar density.

8.4.3 *Water Absorption Coefficient*—Test Methods C1794.

8.4.4 Once the water absorption coefficient is known and the moisture content at free saturation is determined from the sorption isotherm curve, the approximation of the liquid transport coefficient (absorption and redistribution) can be determined.

8.5 If the building is located in a region where freeze-thaw damage is of concern, the following properties should be determined for any material included in the wall that would be subject to freeze-thaw exposure:

8.5.1 Saturation coefficient per Test Methods ~~C67~~C67/C67M.

8.5.2 50 cycle freeze-thaw test per Test Methods ~~C67~~C67/C67M.

8.6 Engineering judgment will be required to interpret the results of the brick material testing conducted in accordance with Test Methods ~~C67~~C67/C67M. A direct comparison of the values of historic masonry units should not be made to the requirements for modern masonry materials as the properties of masonry materials may have changed over time.

9. Evaluation of As-Built Thermal Properties

9.1 Thermal mass, a property directly related to a wall's heat capacity, is a phenomena that enables building materials to absorb, store, and later release significant amounts of heat. The materials within the wall absorb energy slowly and hold it for longer periods when compared to more light weight, modern framed, and thinner wall assemblies. The ability to store heat delays and reduces heat transfer through the mass wall, which generally impacts the need or level of required additional insulative materials.

9.2 The impact of the thermal mass should be carefully evaluated prior to undertaking any alterations to the wall or the addition of insulating materials to meet the U-factor requirement of energy codes.

9.3 U-factors do not account for the effects of thermal mass and may be inadequate in describing the heat transfer properties of mass masonry walls when considered independently. The heat flow through the wall is dependent on the materials' density, thermal conductivity, specific heat, and thermal diffusivity. Most energy codes and standards take the thermal mass into account in a limited manner when stipulating the prescriptive minimum insulation and U-factor requirements. As such, the U-factors and insulation requirements prescribed in such codes and standards are reduced for mass walls.

9.4 The project specific energy improvement performance goals and metrics should be defined by the project team. The compliance path of any particular codes and standards should be defined. Both the thermal mass of the existing wall and the U-factor of the upgraded assembly should ultimately be considered when assessing the potential energy savings of the proposed design compared to the existing performance. Alterations to the existing wall to improve energy performance should be evaluated to ensure a positive impact without creating detrimental effects to the long term performance of the existing masonry.

9.4.1 Based on the project specific energy improvement goals and requirements, the need for additional insulating materials (if any) should be carefully determined, evaluating the impacts of the existing thermal mass behavior of the wall and the targeted energy performance.

9.4.2 The thermal properties of the wall should be evaluated in accordance with one of the following methods:

9.4.2.1 *In-situ Testing*—Standard procedures exist for determining the actual thermal resistance of wall assemblies in the field, utilizing Practice C1046 and Practice C1155. It is challenging to use field methods to determine the thermal resistance of mass masonry walls due to the heat capacity of the wall when compared to more modern framed wall assemblies. Measures should be taken to have a large and somewhat constant temperature difference across the wall for 12 to 24 h during the test period. These evaluations are typically more accurate if undertaken on the elevation with the least direct solar radiation and that is protected with natural or artificial shading devices. It is important that engineering judgment be applied during the testing and when interpreting the results from the in-situ evaluation to ensure that the results reflect the actual performance of the wall assembly.

9.4.2.2 *Computer Modeling*—To accurately account for the thermal mass, an energy simulation software program that utilizes the attributes of the materials' density, thermal conductivity, specific heat, and thermal diffusivity, and is able to model the dynamic performance of the wall over time could be used.

9.4.2.3 *U-Factor Calculation*—The thermal conductance for each material observed in the wall assembly and the thickness of that material will be required to determine the total U-factor of the existing wall assembly. Unless there is repetitive and consistent thermal bridging, large air spaces or non-homogenous wythes, a one-dimensional U-factor calculation should be sufficient for an estimate of the U-factor. If conditions create frequent or significant thermal bridging, two-dimensional heat flow software should be used to determine an overall U-factor.

(1) Published industry references can be used to determine the thermal conductivity of each material if this data is not collected during evaluation of material properties provided the published values match the density and composition of the materials within the wall assembly. With the thermal conductivity values and the known existing material thicknesses, the U-factor of the existing mass masonry wall can be analytically determined as follows: