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Application and Evaluation of the New Standard for Existing Masonry Structures: Case Studies and Proposed Refinements

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ABSTRACT

In March, 2024, the Existing Masonry Guidelines (EMG) task group of The Masonry Society (TMS) convened a design summit to advance the creation of a new consensus standard for the assessment and rehabilitation of existing masonry structures, TMS 405. The summit brought together a diverse group of technical experts from the United States and Canada, encompassing academia, industry, and professional engineering practice. The initial draft provisions developed during this summit have been entrusted to the newly formed Existing Masonry Standards Committee (EMSC) of TMS, which will oversee their further refinement, review, and balloting.

A key objective of the EMSC is the development of detailed worked examples that apply the new standards to representative case study projects. These examples are essential in demonstrating the practical application of the proposed standards while also serving as an important tool for identifying areas that may require further modification prior to codification. Specifically, the examples highlight potential gaps, ambiguities, and instances where the provisions may result in overly conservative or insufficiently rigorous outcomes. This paper presents these case studies, offering an analysis of the draft standards in action, and providing a roadmap for refining the guidelines to ensure their robustness, practicality, and effectiveness for use in professional practice.

KEYWORDS

Codes and standards, evaluation standards, existing masonry, historical constructions, repair design, The Masonry Society

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INTRODUCTION

In March, 2024, the Existing Masonry Guidelines (EMG) task group of The Masonry Society (TMS) convened a design summit to advance the creation of a new consensus standard for the assessment and rehabilitation of existing masonry structures, TMS 405. The summit brought together a diverse group of technical experts from the United States and Canada, encompassing academia, industry, and professional engineering practice. The initial draft provisions developed during this summit have been entrusted to the newly formed Existing Masonry Standards Committee (EMSC) of TMS, which is currently overseeing their further refinement, review, and balloting. Formal balloting is scheduled to begin in March, 2026, with TMS Technical Activities Committee review and public comment period planned for 2028. The standard is projected to be published in Fall, 2029.

This paper presents a parallel effort of the EMSC to develop worked examples to test the application of the proposed language on representative case study projects. These examples are essential in demonstrating the practical application of the proposed standards while also serving as a tool for identifying areas that may require further modification prior to codification. Specifically, the examples highlight potential gaps, ambiguities, and instances where the provisions may result in overly conservative or insufficiently rigorous outcomes. This paper presents preliminary case studies, offering an analysis of the draft standards in action, and providing a roadmap for refining the guidelines to ensure their robustness, practicality, and effectiveness for use in professional practice.

BACKGROUND

Previous papers summarized the impetus for developing an Existing Masonry Standard in the United States, following a logical organization and flow of information [1], [2]. The EMSC effort to develop TMS 405 is further building upon the parent effort within the concrete industry which introduced American Concrete Institute (ACI) 562, *Assessment, Repair, and Rehabilitation of Concrete Structures* to the engineering community [3]. To assist engineers with understanding the provisions for existing concrete, ACI in partnership with the International Concrete Repair Institute (ICRI) published a guide book [4] following each chapter of ACI 562, showing how to use the provisions for representative case study projects. Because TMS 405 is still in development at the time of this writing, these case studies were selected with variety and quality control - of the draft standard - in mind. Each of the four case study projects highlights a different aspect of working with existing masonry, spanning a variety of historical construction periods and end-use functions. They represent a range of structural forms—including bridges, buildings, and monuments—and address common challenges such as building envelope investigations, localized stabilization, and durability.

CASE STUDY 1: HISTORIC BUILDING WITH PREVIOUS INTERVENTIONS

Structure Description

The Haj Rajab Ali Mosque, built in 19th-century Iran, is a historic mosque renowned for having the unique architectural plan of its era and, due to its diverse architectural and structural features, was referred to as "the faculty of Iranian architecture". Its design features a central elliptical dome over the main hall. It is supported by two semi-domes (originally symmetrical to the east and west), though the eastern semi-dome no longer exists. Two rectangular prayer halls (Shabestan) flanked the dome, but the east hall was demolished in the 1960s, and the western hall's roof partially collapsed in the 1990s. The mosque’s structure relies on heavy piers and load transfer mechanisms, like ribs and squinches, to distribute loads to the foundation. Primary materials include brick, lime-sand, and gypsum-clay mortars (Figure 1a).

Located in a seismically active region, the mosque's foundation rests on soft soil with poor bearing capacity, consisting of three layers of brick over a lime mortar mixture. Excessive moisture from sewage leaks and local qanats has eroded the soil beneath the foundation. Tests reveal soil permeability rates of approximately 10^{-6} cm/s (3.94×10^{-7} in/s) and high porosity due to a natural moisture content of 14%. These conditions have reduced the soil's bearing capacity and increased the potential for differential settlement.

The Problem

Severe structural distress is evident in the southern wall, with widespread settlement, deformation, and structural failure. The load-bearing elements in this section exhibit tilting, bending, and wide cracks. Crack indicators demonstrate movements, confirming the ongoing settlement (Figure 1b). Field studies identify the southern area, particularly near the altar, the most critical zone, with settlements caused by water-saturated soil layers. Surrounding buildings display similar cracks, highlighting regional soil weaknesses. Moreover, due to the collapse of half of the western prayer hall's vault, the static load transfer path has been altered and disrupted in this area.

Attempts to mitigate the damage include installing six columns under the dome in 1964, connecting foundations with ties in 1973, enlarging the foundations of the dome hall with reinforced concrete in 1979, and a buttress behind the altar in 2018. A steel ring was later added around the dome to stabilize it (Figure 1c). However, these measures have failed to address underlying problems like groundwater infiltration and soil erosion. The metal ring, made of incompatible materials, now exacerbates damage through thermal expansion and contraction [5].

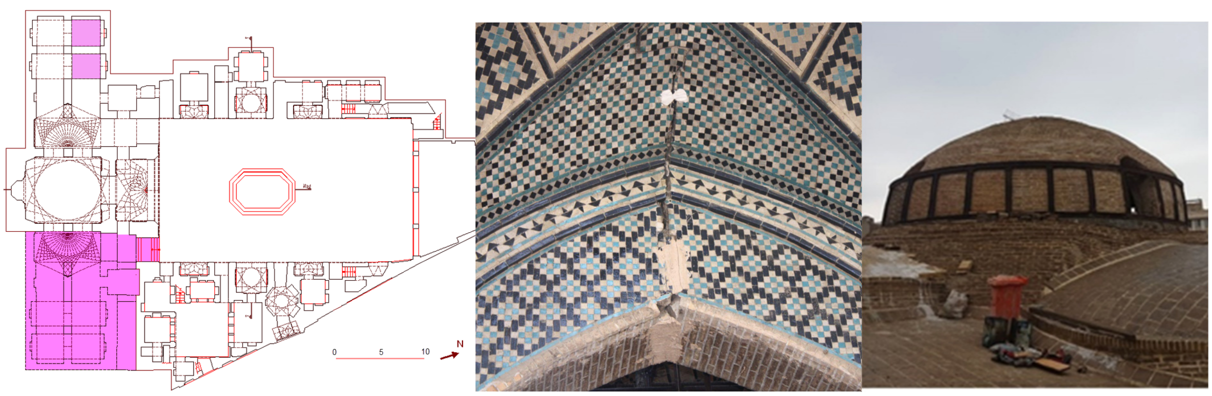

Figure 1: (a) The original plan of the mosque, the highlighted region indicates the collapsed parts through the ages; (b) Active crack in the pointed arch of the dome hall; (c) Structural intervention by adding a steel belt around the dome

Using Draft TMS 405

To address the identified problems in the building according to Draft TMS 405 a structured approach was followed:

In Section 1.6, *Scope and Application*, the draft outlines the need for defining the scope of evaluation for masonry structures and establishing appropriate assessment procedures. This includes ensuring the evaluation process is adapted to the specific structural condition being addressed and where required, the code guides the user to refer to the appropriate sections of the document for further evaluation.

Due to the continued settlement, instability of some parts of the building that pose an imminent risk to life or safety, and some missed elements, according to Section 1.6.5, *Deficient Conditions,* the building is classified as *Dangerous, Potentially Dangerous, and Substantially Deficient* (Sections 1.6.5.1 to 1.5.6.3).

The standard defines the necessary actions that should be implemented to protect the health and safety of the public against Section 1.5.6 conditions in Section 1.6.6, *Mandate Actions* (Sections 1.6.6.3 and 1.6.6.4). In this regard, Section 7.3.1, *Stability,* emphasizes immediate intervention to stabilize the masonry systems to prevent collapse or further significant damage.

Regarding the structural interventions using concrete and steel the standard in Section 1.6.12, *Non-masonry elements* suggests the assessment of these parts according to ACI CODE 562 and Appendix 5 of ANSI/AISC 360 [6] respectively. Section 1.7.3, *Substantial Structural Damage,* investigates the vertical elements of the gravity-load-resisting system and the vertical members of the lateral-force-resisting system for both the damaged and pre-damaged conditions. This can be beneficial for the assessment of the columns of the dome hall and the walls (Sections 1.7.3.2 and 1.7.3.3). Section 1.7.3.4 presents the design-basis criteria for the conditions explained in Sections 1.7.3.2 and 1.7.3.3.

Chapter 5, *Assessment and Evaluation*, provides a detailed methodology for evaluating masonry structures, emphasizing visual inspections, material testing, and the overall structural performance assessment. Section 5.3.6.2, *Load Path and Functions,* emphasizes that the distribution of loads and forces in the complete structural system shall be considered which relates to the changes in the static load transfer due to the collapse of half of the vaults in the western prayer hall and the collapse of the eastern semi-dome. Additionally, Section 4.12.6 notes that structural analysis for repair design shall consider the sequence of material removal, placement of new material, and load application during the phases of the assessment and repair process. According to Section 7.3.8, *Serviceability and Envelope Function*, the performance of the new mosque in the envelope and its effects on the historic part shall be evaluated.

In Section 5.3.6.4, *Materials,* the code indicates that *"Analysis shall consider material properties and condition, member geometry and deformation, lateral drift, duration of loads, shrinkage and creep, interaction with non-structural components."* In Chapter 5, analysis of the interaction of the structure with the supporting foundation and soil is addressed. However, evaluation methods and probable problems of the foundation and the soil including subsidence and settlement are not addressed. Section 5.3.6.5, *Previous Repairs,* emphasizes considering the effects of interventions on the behavior of the structure which in the case of Haj Rajab Ali Mosque which has experienced several interventions is very important. Section 6.3, *Structural Intervention*, requires durability to be considered when implementing structural interventions and the accompanying commentary provides guidance on material compatibility, temporary shoring, and moisture management.

Section 7.3.5, *In-plane Shear Capacity,* emphasizes on establishment of the in-plane shear capacity of the masonry components which is relevant to the southern wall of the building that is cracked due to the heterogeneous settlement. Section 7.3.8.1, *Water Barrier or Control,* emphasizes on control of moisture movement in exterior masonry components and systems ensuring significant degradation of the building systems is avoided. In this section, the water sources are not described. This is important for the studied building which suffers from a high water table. Section 7.3.8.4, *Thermal Strain and Movement*, for control of thermal movement of masonry components and systems to avoid significant degradation of the building systems is relevant for the thermal effects imposed on the building by the steel ring.

Settlement is identified as the root cause of the building distress. The code Section 7.4.7, *Foundation Stabilization or Strengthening,* offers methods for repair of the foundation while Section 8.2.3.1, *Design of shoring and bracing,* outlines contractor responsibilities for temporary bracing and shoring. However, it should be noted that Section 7.4.7 does not address settlement issues, such as significant or ongoing settlements, which may require more detailed procedures or additional external resources for thorough evaluation. It can be concluded that Draft TMS 405 does not address the foundation and soil problems including subsidence and settlement adequately at this time.

CASE STUDY 2: BUILDING ENVELOPE FAILURES

Structure Description

The JMK Building (building name has been anonymized) is a government building in the central business district of a former industrial city in the eastern United States. The building was originally constructed in the mid-twentieth century as two separate department stores: a two-story building with exterior mass masonry bearing walls and steel framing and a four-story concrete-framed structure with exterior multi-wythe masonry walls. A renovation project was performed in 1986 to convert the two buildings into a single office building by erecting a three-story CMU addition in the intervening alleyway and cladding the entire building with an exterior insulation and finish system (EIFS) and granite tiles. The building was acquired by the current owner in 2004 to house a governmental agency.

The Problem

In 2021, a portion of the adhered granite tile veneer spalled off of the building (Figure 2a). The building owner also reported spontaneous window breakage (Figure 2b), interior water leakage, and cracking and other failures in the EIFS cladding. An investigation was performed to assess the causes of the deficiencies and develop a proposed repair scope for the building.

Based on the results of the investigation, it was determined that glass breakage was most likely caused by loose structural anchorages of the curtainwall framing system. Water leakage was observed to be caused by cracking and other deficiencies in the EIFS cladding, failure of sealant joint, deficiencies in the curtainwall and windows systems, and poor architectural detailing. The repair scope included fully replacing the EIFS cladding in-kind, replacing the curtainwall with ribbon windows, and installing an anchored brick veneer at the former location of the granite tiles.

Using Draft TMS 405

Chapter 1, *General Requirements,* serves as a guiding framework for the entire document, referencing the other chapters and outlining the conditions under which they are applicable. Chapter 1 is organized with three groups of sections: Group 1 includes Sections 1.1–1.4 and Section 1.9, Group 2 includes Section 1.5, and Group 3 includes Sections 1.6–1.8. Groups 2 and 3 are mutually exclusive depending on whether the Authority Having Jurisdiction (AHJ) has adopted an existing building code. Based on the jurisdiction having adopted the International Existing Building Code (IEBC) [7] at this project location, the applicable sections in the Draft TMS 405 Chapter 1 are included Sections 1.1 – 1.4 and Section 1.5.

Figure 2: (a) Spalled granite tiles; (b) Broken glass

Section 1.5, *Assessment, Design, and Construction Requirements If Used with an Existing Building Code,* outlines the requirements for assessment and rehabilitation to supplement the requirements in the existing building code adopted by the AHJ. Section 1.5.3, *Assessments,* requires assessments be performed in accordance with Chapter 5, *Assessment and Evaluation.* The investigation scope performed at the building is defined by Section 5.2.3, *Assessment Process.* During the review, it was observed that the draft standard includes requirements for performing an assessment but does not explicitly require that an assessment be performed.

During the project investigation, it was observed that the remaining portions of the adhered granite tiles were not well-bonded to the masonry substrate and posed an unsafe condition for pedestrians at the sidewalk below. Section 5.3.3.1, *Dangerous or Unsafe Conditions,* requires stakeholders to be immediately notified and informed of measures necessary to mitigate the unsafe conditions. The language in Section 5.3.3.1 does not provide a required timeline for installing the temporary measures and is very limited compared to the requirements in Sections 1.6.5, *Deficient Conditions,* and 1.6.6, *Mandated Actions.* The language in these latter two sections is more descriptive and enforceable and was originally nested under Section 1.6, *Assessment, Design, and Construction Requirements If Used as a Stand-Alone Code,* out of concern for avoiding conflicts with adopted existing building codes. However, review of the corresponding language in the IEBC (the most prevalent existing building code) identified that the IEBC's requirements only apply to the building official and not to the Licensed Design Professional (LDP) or building owner. Sections 1.6.5–1.6.6 should be moved to Chapter 5 so that these requirements can apply to all projects. References back to these sections should also be provided in Chapters 7 and 8 in the event that unsafe conditions are discovered during the design or construction phases.

Section 6.4.5, *Retrofit and Alterations,* requires that water management should be considered with respect to the new and existing materials. Since the first-floor walls beneath the windows lie partially below grade, it was decided that using a brick backing instead of metal framing behind the EIFS and in front of the CMU would better contribute to the water management strategy.

The change from curtainwalls to ribbon windows required first-floor windows to be supported on the first-floor walls. A support angle was required to transfer the load from the first-floor windows into the CMU wall, which was located behind the plane of the windows. Section 7.3, *Performance Requirements for Masonry Systems and Components,* requires the existing CMU to be evaluated for the eccentric loading from the window system. Section 7.4.6, *Post-Installed Anchors,* defines requirements for designing the attachment of the new angle to the face of the existing CMU wall. Chapter 4, *Loads, Load Combinations, Strength Reduction Factors, Allowable Stress Factors, and Nominal Capacities,* defines the parameters to be used for performing the structural analysis of the walls. For simplicity in analyzing the walls, Section 3.2, *Materials,* permits the use of default values to be used in the analysis in lieu of performing testing of the existing materials. The analysis establishes that the CMU must be strengthened and it is decided to partially reinforce the CMU. Section 7.4.3.2, *Steel or FRP Bar Reinforcement,* provides requirements for strengthening the CMU at these locations.

The predominant exterior wall system at the building was an unreinforced 30 cm (12 inch) composite wall comprising 20 cm (8 inch) hollow CMU and a single brick wythe laid in common bond with bonded brick headers. The walls needed to be evaluated to verify they would satisfy the strength and deflection requirements for the EIFS. The walls also needed to be analyzed for additional loads from the new spandrel wall framing anchored to the masonry at the window jambs. The original construction documents were not available for the building and it was not possible to determine the original building code for the two original buildings, the original design wind parameters, or original material properties. In the absence of original wind load parameters, Section 4.2, *Loads and Load Combinations,* permits the evaluations to be performed using the loads and load combinations from the current edition of ASCE/SEI 7 [8].

Evaluation of the walls under the additional loading was performed using the approaches in Section 7.3 and Chapter 4. Since the composite wall comprised multiple materials, the analysis required consideration of the different material stiffnesses along the wall section. The material properties used in the analysis were based upon historical values, as permitted in Section 3.2 of the draft standard. The standard does not address the analysis procedure for composite masonry walls. At a minimum, the standard should include a requirement that the relative material stiffnesses be considered when evaluating composite masonry walls. Consideration should be given to providing additional guidance in the commentary for these cases.

The analysis established that the wall section was not sufficient to resist the additional loads. At the window jambs, the solution was to fully grout the final column of cells in the CMU adjacent to the opening while leaving the section unreinforced. Evaluation of this repair approach would be in accordance with Section 7.4.3.1, *Grout Injection.* The current scope of Section 7.4.3.1 is limited to restoring composite characteristics and engaging embedded reinforcing components. The section's scope should be expanded to encompass grouting as a direct means of strengthening the masonry section.

The analysis established that the exterior masonry walls at the first floor required strengthening because of the greater vertical span at the first floor. Strengthening of the walls was performed using the approach described in Section 7.4.3.2, *Steel or FRP Bar Reinforcement.* The strengthened composite wall section was evaluated considering the relative stiffnesses of the CMU, brick, and reinforcement.

Chapter 8, *Construction & Quality Assurance,* provides requirements for construction documentation, shoring and bracing, temporary controls, and quality assurance. Section 8.2.2, *Construction Technique*s, includes a subsection for sample panels. The scope of this section should be expanded to encompass all mockups. Sample panels are only one type of mockup and are more appropriate for new work or for demonstration of preservation techniques. In masonry repair work, in-place mockups are more economical and more representative of the actual field conditions.

Case Study 3: Masonry Bridge

Structure Description

The Shah Abbasi Bridge in Karaj, Iran, originally constructed during the Seljuk era (11th-12th) and restored and completed during the Safavid period (16th-18th), is a notable historic structure. The bridge spans 61.2 m (200.7 ft) in length, 9.27 m (30.4 ft) in width, and has a maximum height of 13 m (42.7 ft). Its asymmetrical design features two arches of differing dimensions. The larger arch, located on the Eastern side, measures 20.20 m (66.3 ft) in length and 12 m (39.4 ft) in height, with a double-layer pointed arch design. The smaller arch, measuring 7.40 m (24.3 ft) in length and 9.40 m (30.8 ft) in height, was constructed to facilitate water flow during floods (Figure 3a).

The bridge's foundations were built using rubble stone and pebbles bound with lime mortar and traditional Sarooj (a combination of lime, clay, and organic materials), while its superstructure was constructed with bricks bonded with lime mortar. Historically, the bridge served as a vital transportation route.

The Problem

In 2006, a section of the bridge deck collapsed due to falling rocks from the surrounding mountains, but was subsequently repaired. However, the same section collapsed again in 2020 (Figure 3b). Field investigations revealed that during prior restoration efforts, transverse wooden ties supporting the arches were removed, which subjected the arches to increased stress from both dead and live loads. Additionally, cracks and voids in the deck allowed significant infiltration of snowmelt and rainwater. This led to increased dead loads, material erosion, degradation of mortar between bricks, and weakened connections. Over time, these factors destabilized the structure, ultimately causing the deck to collapse again. The recent collapse also suggests improper application of construction techniques during previous restoration.

Further investigations identified outward tilting and deviation from plumb in the bridge's northeastern section, accompanied by cracking. This deformation indicates the potential settlement of the eastern foundation. Flowing river water, containing chemical materials, contributed to the decomposition of the foundations, resulting in material degradation and moisture penetration. Efflorescence is also visible in various parts of the façade, highlighting the structure's vulnerability to moisture-related damage [9].

To ensure a comprehensive restoration, it is imperative to conduct detailed evaluations of the foundation for potential settlement issues. Additionally, traditional construction techniques used in the bridge's original design must be carefully identified and accurately applied during restoration efforts. This approach will preserve the structural and historical integrity of the Shah Abbasi Bridge while addressing the underlying causes of its deterioration.

Using Draft TMS 405

In the Shah Abbasi Bridge, the main problems include first the soil problem and foundation problem that caused the settlement and unplumbness of the northeast part of the bridge which shows a decrease in out-of-plane shear capacity of the bridge in this area according to Section 7.3.6, *Out-of-plane Shear Capacity*. Secondly, the faulty application of traditional techniques combined with the water infiltration has accelerated the destruction of the bridge's deck. The water infiltration shall be addressed according to Section 7.3.8.1, *Water Barrier or Control*.

Figure 3: (a) Shah Abbasi Bridge; (b) Deck collapse in 2020

According to Section 7.3.8, *Serviceability and Envelope Function*, the effects of the green space and its irrigation system in the envelope in the East part of the bridge, which also imposes a buck amount of soil in this area, must be evaluated.

The foundation and water problems are similar to what was explained for Haj Rajab Ali Mosque.

CASE STUDY 4: PARAPET STABILIZATION

Structure Description

The Sapphire Building is a government building located in the central business district of a former industrial city in the eastern United States. The building comprises three interconnected sections constructed over the course of the 20th century. The focus of this case study is the unreinforced masonry parapet of the 7-story section built at the northwest corner in the late 1940s. The typical wall construction of the building consists of an exterior wythe of brick veneer bonded to a clay tile backup with decorative terra cotta units throughout the facade. The building utilizes a steel structure above grade, concrete over metal lath floor slabs, and a gypsum concrete roof deck.

The Problem

Several deficiencies were observed by the building owner, including significant water leakage at the seventh-floor roof and cracking and shifting of the facade of all three buildings. An investigation was performed to determine the cause and extent of the deficiencies and to develop a proposed repair scope for the building, beginning with the roofs and parapets.

The investigation revealed that the steel angles and plates supporting the building parapets underwent significant corrosion, causing section loss and expansion throughout the exterior of the building. Due to this expansion, the brick masonry parapets at the seventh-floor roof displaced as much as 2.54 cm (1 in) out of plumb (Figure 4a), and the steel elements are no longer adequately supporting the exterior wythe of brick. Significant cracks were noted at the corners of the building (Figure 4a), and the exterior brick de-bonded from the backup with no positive anchorage to hold it in place. Mortar has pushed outward from the bed joints and, in some locations, mortar fragments have fallen from the face of the building. The brick movement has also caused cracking and spalling of the decorative terra cotta units (Figure 4a), and portions of terra cotta units were observed to have spalled from the façade and fallen from the building to the ground level below. The reinforced gypsum-concrete roof deck also displays substantial deterioration at the roof perimeter due to water infiltration through the parapets.

Figure 4: (a) Parapet damage; (b) Parapet repair section

The root cause of the damage to the parapets was determined to be water infiltration leading to corrosion and expansion of steel embedded in the masonry as well as unaccommodated expansion of the brick due to the lack of expansion joints. Due to the extent of damage to the parapets and roof deck, the decision was made to remove and replace the clay tile backup with CMU instead of repairing the parapets in place and to remove and replace the perimeter of the gypsum-concrete roof deck (Figure 4b). The exterior wythe of brick will be salvaged and reinstalled, and the terra cotta units will be salvaged, repaired, and reinstalled, or replaced with glass fiber reinforced concrete (GFRC) units as necessary.

Using Draft TMS 405

Based on the jurisdiction having adopted the IEBC at this project location, the applicable sections in the Draft TMS 405 Chapter 1 included Sections 1.1 – 1.4 and Section 1.5. Section 1.5.3, *Assessments*, requires assessments be performed in accordance with Chapter 5, *Assessment and Evaluation*. The investigation scope performed at the building is defined by Section 5.2.3, *Assessment Process.* The assessment included a review of renovation documents from 1999 using the approach in Section 5.2.4, *Archival Investigations,* a visual and tactile survey of the building using the approach in Section 5.2.5, *Visual and Tactile Investigations,* measurements of the building and the damaged areas using the approach in Section 5.2.6, *Nondestructive Investigations*, and exploratory openings and probes using the approach inSection 5.2.7, *Destructive Investigations*.

The unsupported brick above the steel lintels at the parapets and the risk of masonry, mortar, and terra cotta falling from the facade presented an unsafe condition to pedestrians and building occupants. Stakeholders were notified immediately of the dangerous condition using the approach in Section 5.3.3.1, *Dangerous or Unsafe Conditions*. An emergency protection plan was put in place including temporary shoring, retrofit ties, and netting to hold the loose masonry in place and a sidewalk shed at the ground level to provide overhead protection to pedestrians. Section 5.3.3.1 directs the user to Section 7.4.1, *Temporary Bracing and Shoring,* for the design of temporary bracing, but other potential protection measures are not mentioned.

The retrofit for the roof and parapet was designed in accordance with Chapters 6 and 7. The original design conditions are unknown, so the elements to be disassembled and reconstructed were designed using Chapter 4 per Section 7.4.3.4, *Disassemble and Reconstruct.* In accordance with Section 1.5.7, *New Elements,* the new CMU parapet walls were designed using the Current Building Code. Following Section 7.4.2.1, *Evaluation of temporary conditions from removal of material during repairs*, the structure was evaluated for the temporary condition with the parapet walls and roof deck removed. To avoid creating unstable conditions, the parapet and roof deck replacement will be done in phases alternating demolition and repair around the perimeter of the building. New dampproofing and flashing will be added within the masonry wall sections in accordance with Section 6.4, *Water Management Improvement,* to limit future water infiltration. Deteriorated steel lintels will be replaced and embedded steel beams to remain will be cleaned and recoated per Section 6.6, *Corrosion Mitigation of Embedded Steel.*

RECOMMENDATIONS

These case studies illustrate several areas where the in-progress draft Existing Masonry Standard, TMS 405, provides sufficient guidance for design professionals to assess, evaluate, and design repairs for existing masonry structures, but they also identify several areas where future work is warranted.

Specifically, the draft standard includes requirements for performing an assessment, but does not *explicitly* require that an assessment be performed, and it should. The required timeline for installing temporary measures for dangerous or unsafe conditions in Chapter 5 is vague and is at odds with requirements in Chapter 1. This needs to be coordinated. Sections 1.6.5–1.6.6 should be moved to Chapter 5 for broader applicability. References back to these sections should also be provided in Chapters 7 and 8 in the event that unsafe conditions are discovered during the design or construction phases.

Although Chapter 5, *Assessment and Evaluation*, and Chapter 7, *Rehabilitation Design*, provide valuable general guidance for the evaluation and rehabilitation of masonry buildings, they do not sufficiently cover foundation-related issues, such as techniques for monitoring settlement over time, or specialized corrective actions required for structures affected by soil subsidence and settlement. This gap highlights a need for additional content or reference materials to adequately support the evaluation and remediation of foundation-related problems.

Section 7.4.1, *Temporary Bracing and Shoring,* should be expanded to include potential protection measures beyond the design of temporary bracing. Section 7.4.3.1 should also be expanded to encompass grouting as a direct means of strengthening the masonry section. Water sources should be more expressly described in Section 7.3.8.1. Section 8.2.2 should be expanded to encompass in-place mockups which are commonly used in practice.

Finally, the standard should more clearly address the analysis procedure for composite masonry walls, including a requirement for consideration of relative material stiffnesses.

CONCLUSION

Four case studies were analyzed through the lens of Draft TMS 405 to identify areas of over-conservatism or insufficient rigor in the proposed provisions to inform refinements that will bolster Draft TMS 405's robustness, practicality, and effectiveness for use in professional practice.

Draft TMS 405 provides a clear framework for assessing and evaluating existing masonry structures, designing durable masonry repairs, and using the document as a stand-alone standard in absence of a formally adopted existing building code. Its contents are structured to be broadly applicable across the many different typologies and functions of masonry construction with helpful Commentary language to guide the Licensed Design Professional.

More work is needed in the area of provisions for foundation settlement, general coordination between the Chapters, expanded consideration of mockups, composite masonry walls, grouting, and protection methods beyond temporary bracing.

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