When the Numbers Don’t Work: Engineering Judgment for Historical Building Façades

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**Abstract**

Do the structural provisions in modern building codes dictate methods of evaluation that are inappropriate for historical structures? Many components and systems in older buildings do not meet current structural code requirements, and yet the vast majority have been in service for decades in the United States and centuries throughout the rest of the world. Does the lack of meeting each new set of standards automatically designate a building as unsafe? And more importantly, what does it mean if a building is “not up to code”? The presenters will provide an overview of some common components and systems in historical buildings that do not comply with current code requirements. Representative examples will be cited, ranging from smaller detailing elements and wall systems to entire structural systems. The case studies are intended to illustrate that engineering judgment plays an important role in redeveloping historical buildings.

**Speakers**

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Edward Gerns is a principal with his firm. He has extensive experience with investigation and repair of existing buildings. He has performed evaluations of historical masonry façades and has overseen preparation of documents for the repair of numerous terra cotta-clad buildings.

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Rachel Will is a senior associate at her firm and has experience with investigation and repair of existing buildings. She has performed evaluations of historical masonry façades and has overseen preparation of documents for the repair of numerous terra cotta-clad buildings. Will’s master’s thesis focused on the integration of structural codes and rehabilitation of historical buildings.
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ABSTRACT

Do the structural provisions in modern building codes dictate methods of evaluation that are inappropriate for historical structures? Various structural components and systems in many older buildings do not meet current structural code requirements, and yet the vast majority have been in service for decades in the United States and centuries throughout the rest of the world. Building codes—especially the structural provisions written into these documents—have evolved due to construction experience, engineering and architectural research, material and system testing, the ability to model intricate structural systems, and lessons learned from various building and structural failures. Does the lack of meeting current standards automatically designate a portion of a building as unsafe? And more importantly, what does it mean if a building is “not up to code”?

Building code requirements triggered by significant rehabilitation of existing structures can have a dramatic economic impact on the expenses related to rehabilitation projects. Based on our experience, lack of understanding of the reuse and adaptive reuse regulations have often discouraged rehabilitation projects. This stems from the often arbitrary, unnecessary, or unjustified application of new construction requirements to buildings constructed outside the governing authority of the current standards. A lack of engineering judgment with regard to the code regulations relative to the existing structures often causes many unnecessary structural upgrades to existing building structures, including support elements for the façade because the original structure does not seem to work structurally “on paper.” Furthermore, current regulatory approaches relying extensively on the judgment of local building officials lead to unpredictable and inconsistent results, unwarranted loss of historical fabric, and excessive expense for arbitrary structural retrofits—both for the building structure and the façade elements—in what might otherwise be viable adaptive reuse and rehabilitation opportunities.

This paper provides an overview of some of the common components and systems, specifically related to the façades of historical buildings that do not comply with current code requirements. Representative examples, ranging from smaller detailing support elements for façades, wall systems, and the integration of the façade support with the building structural systems, will be included. These exemplars are intended to illustrate that engineering judgment plays an important role in redevelopment of historical buildings.

INTRODUCTION

The discussion of building regulations in the United States is as old as the country itself—beginning with the founding fathers, George Washington and Thomas Jefferson, and remaining a constant source of discussion for architects, engineers, contractors, and code officials. Both of these men were proponents of devising regulations to provide minimum standards of building. These general standards were not realized until the late nineteenth century, with the introduction of model building codes addressing life safety as well as many aspects of the building industry.

Codes are typically enacted in response to hazardous situations that threaten public health, safety, and welfare, or to natural disasters such as floods, fires, and earthquakes. Fire protection was the first major issue leading to the establishment of early building codes. In 1896, the National Fire Protection Agency (NFPA) was founded with the intention of establishing uniform sprinkler standards for the mills and warehouses of the northeastern United States. First published in 1897, NFPA standards were used until the mid-twentieth century.1

Like fire protection, many of the health-, safety-, and welfare-related aspects of current codes originated in the 19th century when reform movements were working to correct urban social issues such as density, decay, light and air, poor living conditions, and safety. These reformations resulted in the establishment of various codes and ordinances (for instance, the New York Tenement Laws authored between the 1850s and 1910).2 These laws addressed minimums for living conditions, not specifically relating to building construction, but rather, to occupancy and cleanliness.

New standards were developed in the early 20th century in response to catastrophic events and other natural disasters. For instance, the NFPA 1927 Building Exits Code, later incorporated into the Life Safety Code and fire safety of various other building codes—including the New York City Building code—were developed in response to the 1911 New York City Triangle Shirtwaist Company fire.3 Similarly, the 1903 Iroquois Theater Fire in Chicago contributed to the advent of the life safety code.4

CURRENT BUILDING REGULATIONS

In 1915, code enforcement officials from all areas of the country met to discuss common problems and concerns experienced in the building industry. Three organizations of code enforcement officials resulted from these meetings. Created in 1915, the first of the three organizations was known as Building Officials and Code Administrators (BOCA) International, Inc., which represented building officials and code administrators from eastern portions of the United States, along with the Midwestern states.5 BOCA’s international headquarters are located in Country Club Hills, Illinois, with regional offices in Pennsylvania, Ohio, Oklahoma, and New York. The second organization of this type was formed in 1922 and known as International Conference of Building Officials (ICBO), representing the code officials from the western United States. ICBO’s headquarters are located in Whittier, California.6 Code officials from the southern United States formed the Standard Building Code Congress International (SBCCI) in 1941. SBCCI’s headquarters are located in...
Birmingham, Alabama. Based on material and design knowledge, each of these organizations established a model building code. BOCA published the BOCA Code, ICBO published the Universal Building Code (UBC), and SBCCI published the Standard Building Code (SBC), thus providing regulations based on geographical location in the United States.

Although these regional codes have proved to be reasonably effective and responsive to the specific needs of government or local design conditions for decades, the need and desire for a single (universal) set of building codes was inevitable. Thus, in 1994, the three organizations collaborated to create the International Code Council (ICC) that was free of regional limitations. With the introduction of the ICC, the International Building Code (IBC) was developed to consolidate existing building codes into one uniform code that could be used nationally and internationally to construct buildings free of regional limitations. The IBC was first published in 1997, but it was not until 2000 that the first coordinated edition of the IBC was published. All three organizations (BOCA, ICBO, and SBCCI) agreed to adopt the IBC and cease development of their respective individual codes.

The IBC supersedes the BOCA/NBC, UBC, and SBC codes, and states and local governments began to adopt the new consolidated code with the understanding that they would have local amendments and other changes. For the purpose of this topic, one of the most important features of the IBC was the development of a code specifically related to existing buildings and structures, the International Existing Building Code (IEBC), which was first published in 2003 and could be adopted in conjunction with the IBC or as a stand-alone document.

Building codes’ purpose is to protect the public health, safety, and welfare by regulating construction. Construction and building codes not only control new construction, but also portions of the rehabilitation of existing structures. It is apparent by the numerous historical buildings that “do not comply” with modern structural standards that building codes are intended to regulate the activity of building rather than the existence of a structure. This activity can result from the action of ground-up new construction or by changes to existing buildings.

While building codes are enacted by state and local governments, the actual derivation, deliberation, and acceptance of the code language is completed by private organizations such as NFPA, ICC, BOCA, the American Concrete Institute (ACI), the American Institute of Steel Construction (AISC), the American Society of Civil Engineers (ASCE), etc. The primary enforcement of these standards and codes occurs through local building departments and code officials during construction inspection and plan review.

Building codes are typically updated on three-year cycles to address new markets and incorporate new knowledge from various sources such as construction experience, engineering and architectural research, material and system testing, the ability to model intricate structural systems, and numerous proven building/structural successes and failures. New inventions such as computer analysis programs, complex modeling techniques, and new structural materials and systems continue to result in further development of new building code standards. While keeping codes relatively current to existing knowledge for new construction, it often creates confusion about the application to structures erected prior to the acceptance of the new requirements.

Figure 1 – “Paths of the Initial Appraisal” (source: Structural Aspects of Building Conservation).
Does the inability to meet each new set of updated standards automatically designate a building as unsafe? Certainly not. More importantly, what does it mean if a building is not “up to code”?

Code regulations often discourage design professionals working on rehabilitation projects. This frustration stems from inconsistency in the regulation of rehabilitation projects across the nation and by the often arbitrary or unjustified application of new construction requirements to structures built prior to the governing power of the current standards. Many current regulatory approaches rely extensively on the judgment of local building officials, which leads to unpredictable and inconsistent results, unwarranted destruction of historical fabric, and presumed unsafe or inadequate conditions, in what might otherwise be viable adaptive reuse and rehabilitation opportunities. These concerns exemplify the need for an in-depth analysis of the modern structural provisions of the current building codes relating to existing buildings, especially historical masonry facades, along with the development of an improved approach to regulating rehabilitation.

**STRUCTURAL EVALUATION OF THE REHABILITATION CODES**

The generalized format of the structural evaluation, as required by many of the compliance alternative provisions in the rehabilitation codes, is outlined in Figure 1. This assessment procedure is implemented in many rehabilitation projects for the evaluation of an existing building to determine its structural integrity. Structural performance in an existing building can be analyzed through a process called a “structural appraisal,” which is used to develop a report for alternative code compliance as outlined in the IEBC. The structural appraisal is most beneficial for determining a consistent approach for completing a structural analysis for the rehabilitation of an existing structure. This can be related to a full building retrofit or when looking at specific elements, such as masonry facades, which will be highlighted in greater detail in this paper.

The following outlines an accepted procedure for completing a structural evaluation for an existing building. Structural performance in an existing building can be analyzed through a process known as “structural appraisal” as fully described by the 1980 report by the Institute of Structural Engineers entitled “Appraisal of Existing Structures.” Information for the structural appraisal can be obtained through various means related to the physical facts of the structure; this information is then analyzed to ensure that it will be adequate for the intended use of the building.

These conditions include:

- When defects of general design or construction have been discovered or are suspected as a result of apparent substandard behaviors (such as large deflections).
- When significant deterioration of structural members has been discovered or is considered a probable risk (such as rotten timbers or severely corroding metal).
- When there have been accidental or other damages to the structure in the past (such as undermining of the structure in various remodeling efforts).
- When refurbishment for continued use is considered to include improvements or additional services (such as ventilation ducts or computer wiring).
- Whenever a change of use is considered.
- Where there is going to be a major change of ownership or tenancy.

A structural appraisal encompasses many aspects of structural performance of a historical structure. Overall stability and robustness, load-carrying capacity, serviceability, fire resistance, and durability are the major elements of structural performance.

- **Overall stability and robustness is the building’s ability to withstand minor damages and its overall structural soundness.** Will the building experience catastrophic failure with minor damage to a structural member?
- **Load-carrying capacity addresses the ability for the structure to withstand various live and dead loads with a reasonable factor of safety.** Does an acceptable margin of safety exist under the loads that are likely to be imposed by the intended new use and/or upgrading of the building?
- **Serviceability with respect to the amount of movement a building experiences and how it affects its occupants.** Are there going to be excessive deflections or vibrations of floors causing dizziness and nausea? Will significant cracking be expected during the life of the building?
- **Fire resistance is the ability of the structure to remain standing during a fire, the types of failure experienced, and the amount of time the inhabitants will have to escape.** Will the structure stand up long enough to allow occupants to evacuate safely and give emergency response reasonably secure access (i.e., loss of strength of cast iron in a fire, instability of unreinforced masonry façades following an earthquake)?
- **Durability relates to the structure’s need for maintenance and its soundness.** Will the owner/tenant be faced with disproportionate repair costs in order to maintain structural integrity meeting modern structural standards?

All of these aspects are evaluated during the structural appraisal to determine a historical building’s structural integrity and performance. A format for a typical structural appraisal is outlined in Figure 1. This or a similar structural assessment is often required by rehabilitation codes as part of a compliance alternative. A typical appraisal usually includes a document search, inspection, measurements and recording of the structure, and limited structural analysis. Material testing, load testing, computer modeling, or other methods of analyzing a portion of the structure are sometimes included as well. The process is iterative between collection of data and analysis of the information.

Based on the results of the testing and analysis, design professionals develop reports for review by the building official to determine adequate code compliance.

**EXEMPLARS**

Applying modern structural evaluation criteria and contemporary standards/codes to historical buildings—especially masonry facades—without rational, practical engineering judgment can result in excessive conservatively analyses and unnecessary repairs. Distress in historical masonry facades typically includes displacements,
spalling, and cracking. Often this distress is caused by corrosion on the underlying steel support, but there are many instances when the cause is not corrosion-related, such as the differences in historical and contemporary materials, revised load paths, poor installation or field modifications, and previous inappropriate repairs. Addressing corrosion is necessary to prevent further distress, but alternative, potentially less invasive repairs may be appropriate when the distress is not corrosion-related or a life safety consideration. The exemplars outlined in this portion of the paper will focus on the necessity of structural repairs to address visible distress for various different masonry façade elements, including in-plane elements (intermediate support, hung components, and combined support), projecting elements (cornices and water tables and parapets) and dual exposure elements (balustrades and finials).

In-Plane Façade Elements

In-plane elements generally refer to units within the plane of the main façade, and can be grouped into three categories: intermediate support (i.e., units supported by supplemental steel elements or masonry backup, which is in turn supported by the structural steel elements), hung elements (units that are typically concentrated at openings in the façades and are hung with j-hooks and rods or other expansion types of anchors from the supporting structural steel), and combined support elements (units that are generally located at the interfaces of piers and spandrels or two different support conditions). Each of these different support conditions presents unique distress scenarios particularly related to the structural support of the unit, and therefore potentially require different repair approaches.

Intermediate Support Elements

Elements with intermediate support are units supported by supplemental steel elements or masonry backup, which is in turn supported by the structural steel elements that typically are located at floor lines, window/door heads (Figure 2), corners of the building, or other locations where support of the masonry was empirically necessary. Distress at intermediate supports is often related to the configuration of shelf angles anchored back to the structural framing and the lack of accommodation for movement. In these instances, distress is often the result of discontinuous support of the masonry. Examples include corners of the building where the shelf angles from the two different façades do not align or are held short of the corner (Figure 3) or discrete lintel elements that are limited to openings rather than continuous shelf angles extending around the perimeter of the building. These conditions frequently result in vertical cracking due to the change in relative stiffness of the support. Additionally, distress related to intermediate supports can be a result of unit geometries, unanticipated load paths, inadequate bearing, construction tolerances, and inadequate or inappropriate field modifications to the masonry units themselves.

In the case of continuous piers and corners, the effect of differential movement between the masonry and the underlying structure can result in significant internal stresses within the cladding system, leading to localized crushing and cracking or outward buckling or displacement of units. The manifestation of this distress typically occurs where the masonry is restrained, such as at supports within piers or at intersecting walls at the corners of the building. Masonry cladding with distress related to discontinuous or inadequate intermediate support generally requires repairs. Often these repairs address the structural support by removing masonry units, repairing or replacing the steel to establish adequate bearing, and installing soft joints. In some instances, “stitching” the masonry together to allow the units to act compositely may be

Figures 2A and 2B – Intermediate support at spandrel units. Typical original industry detail (left); as-built condition at 1912 terra cotta high-rise (right).

Figures 3A and 3B – Lack of continuous intermediate support at corner. Original construction detail (left); as-built condition (right).
Corrosion-related distress at hung elements can no longer support design loads. The anchors can be so advanced that the corrosion by-product and its confinement result in spalling, cracking, localized crushing, and displacement of the masonry creating unintended forces within the wall, thus making the masonry part of the structure rather than just cladding supported by steel elements.

**Hung Elements**

Hung elements typically exist at openings in the façades. The individual units are hung with j-hooks and rods or other expansion-type anchors from the supporting structural steel above (Figure 4). Distress in hung components is often related to corrosion of the anchorages rather than other structural issues. Historical masonry walls were constructed with corrodiible metals, such as carbon steel, without flashings. As a result, the support components are highly susceptible to corrosion. The corrosion process converts the original steel material into corrosion by-products, which have no structural capacity and occupy four to ten times the volume of the noncorroded steel. The increased volume of the corrosion by-product and its confinement within the wall by the adjacent masonry create unintended forces within the wall, resulting in spalling, cracking, localized crushing, and displacement of the masonry and adjacent building materials. Corrosion of the anchors can be so advanced that the system can no longer support design loads. Corrosion-related distress at hung elements needs to be addressed to maintain adequate structural support, because as the hanger elements (typically j-hooks with dowels) corrode and lose cross-sectional area, the structural capacity of a specific element is significantly reduced and could result in failure due to the lack of redundancy of support. Significant corrosion of the lateral anchorage can also compromise the stability of the wall system and should be addressed.

The noncorrosion-related distress is typically associated with displacement of the units due to the flexibility of the support. When displacements or deflections of the supporting lintel are observed, it does not necessarily warrant repairs. If the condition of the steel can be verified and it is determined to be serviceable, deflections may be a result of installation tolerances, catenary behavior, inelastic bending, or building movements. Often repairs are not necessary to “correct” the deflections. Generally, the masonry at these locations will behave as an arch in addition to the support provided by the hanger elements. Thus, while the hanger elements may not work “on paper,” they remain functional and typically can be “repaired in kind” as shown in Figure 4.

**Combined Support Elements**

Elements with combined support are units that are located at the interfaces of piers and spandrels or two different support conditions. Distress at masonry units with combined support is often a result of the load sharing between support elements (i.e., units that extend between the lintel and the piers, sills and piers, etc.). Load sharing typically results in cracking at the corners of the windows, including the lintel units and sills, and is likely the result of these units extending between the piers and spandrel area, causing differential stress within the unit (Figure 5). The portion of the units within the pier is subjected to significantly higher compression stresses and restraint than the portion within the spandrel. This differential stress within the same unit often causes cracking at the transition of support conditions. In glazed masonry products, such as terra cotta, the stress occurring within these units often is apparent by the crazing in the glaze, which behaves like a stress coating as an indication of the alternated load path (Figure 5).

Masonry with distress related to elements with combined support often does not require structural repairs. The configuration of the existing units and structural support is difficult to change, and as long as significant out-of-plane movement or displacement are not observed, the associated cracking of the units is the masonry providing its own relief. Minor repairs inclusive of treating cracks and pinning units to establish supplemental lateral anchorage for the “two units” are generally the repairs that are necessary to limit water infiltration and keep portions of the units from dislodging. Excessive repairs implemented due to
current regulations may consist of installing supplemental steel support at every floor line that will change the geometries of units and require extensive rebuilding and eventually become future maintenance issues. Additionally, the installation of expansion joints between pier and spandrel elements would be required per current masonry regulations, but the expansion for the existing masonry units is complete and would be unjustified unless large amounts of new material were installed.

**Projecting Façade Elements**

Projecting elements generally refer to units that project out from the plane of the main façade and are grouped into two main categories: 1) cornices and water tables, and 2) parapets. These two element types present specific distress scenarios particularly related to the structural support of the unit. These types of elements often require extensive repairs, and meeting current structural regulations is challenging.

Projecting masonry elements that experience cracking and displacements are likely the result of accumulated stresses within the façade. These stresses are due, in part, to the inability of the wall construction to accommodate thermal and moisture movements of the cladding materials, as well as differential movements between the masonry and the underlying structure.

Fired clay products, such as terra cotta and brick, permanently expand during the first
few years after fabrication due to the absorption of moisture from the atmosphere. The rate of expansion slows as the moisture content of the masonry material stabilizes over time. Over the service life of a building, the façade materials also expand and contract regularly due to thermal changes. If the moisture expansion and thermal expansion are not accommodated through means such as expansion joints or slip joints in the façade, internal stresses accumulate within the cladding system. These internal stresses often result in cracking and displacement in long, continuous bands of masonry, such as parapets, cornices, water tables, and continuous spandrel areas.

**Cornices and Water Tables**

Cornices and water tables are horizontal bands around the perimeter of the building that project from the adjacent plane of the wall. Distress at cornices and water tables is often related to corrosion of the anchorages rather than other structural issues, similar to hung elements. This is not surprising since cornices and water tables often include hung elements.

The noncorrosion-related distress is typically associated with displacement of the units due to the flexibility of the support, unaccommodated expansion, original construction techniques (including filling units), and lack of maintenance or inappropriate maintenance over the years. While the flexibility of the system generally does not work “on paper” with current code-prescribed loadings, in some instances, the flexibility may actually improve the performance of the system—such as seismic loading.

Many drastic “repairs” were made to cornices and water tables as they became maintenance concerns. In extreme instances, repairs included removal or partial removal of the elements to protect public safety. If the residual impact of the removal were not properly detailed, unanticipated distress related to water infiltration may have resulted. When intact, repairs may include rebuilding portions or all of the projecting system to access the existing structural steel and install movement capability provisions. These systems were designed empirically, often with convoluted load paths, and, therefore, it is extremely challenging to “upgrade” the support to current
standards. Often the most appropriate and rational approach for the repairs is “in-kind” replacement using noncorrodible elements for the anchors, hangers, etc.

Figure 6 is a representative example of the original cornice anchorage detailing as compared with the contemporary repairs. The failure mechanisms in this instance were that the units were backfilled with concrete and suffered a lack of maintenance, contributing to excessive moisture infiltration and corrosion of the support elements. Figure 7 shows existing conditions of the cornice support structure following selective demolition.

The load path for these elements is circuitous at best, so repairs or replacement of structural elements are typically guided by replacement “in-kind” and use noncorrodible elements for the anchors, hangers, etc. Figure 8 illustrates another cornice repair example where similar hanger anchorages to the original configuration were utilized, but were fabricated out of noncorrodible elements rather than the carbon steel elements that had corroded and caused distress, leading to repairs.

Parapets

Historical masonry parapets typically are multi-wythe elements comprised of brick, terra cotta, stone, or a combination and are rarely reinforced. The non-corrosion-related distress at parapets generally is related to bowing, bulging, and displacements, which are often a result of the stresses from unaccommodated expansion/movement. Certainly general deterioration due to freeze-thaw exposure can also contribute to these conditions. In some instances, the noncorrosion distress is exacerbated by previous repairs such as installed flashings that introduced a slip plane into the system without accommodation of anchorage of the portions of the wall above and below the slip plane (Figures 9 and 10). While all of these conditions may warrant some level of repair, it is the engineering judgment for each specific real-world instance and weighing factors such as serviceability, past performance, and current regulations that need to be evaluated to determine the level of repair that is required for each condition.

Displacements, bowing, and bulging of parapets do not always require significant structural repairs. Significant displacements and bowing may justify reconstruction of the parapet to account for appropriate lateral anchorages and accommodation of thermal and moisture expansion and other movement, but may not require redesign to fully meet all of today’s additional code regulations (such as seismic and increased window), which are likely not necessary on a building façade that has been standing, functioning, and meeting the real-world load test for a long period of time. While out-of-plane displacement may not be ideal, judgment relative to geometric stability and loading eccentricity could and should be considered. There are also instances where only one wythe of the masonry roof side or opposite side may
be effective at addressing the observed distress; thus, essentially replacing roof side and/or exterior wythes in kind may be a viable option. Understanding the behavior of both the roof and the parapet wall, along with the observed distress, are essential in evaluating the potential repair options for these projecting elements.

**Balustrades**

These are ornamental rails and copings supporting a series of balusters (i.e., spindles) that can be single or multiple units. Balustrades were intended to act as monolithic elements with the function of the tensile bond capacity of the mortar, and mortar keys between units in combination with the metal bars extending through the units and across the top rail, acting as the main load-resistance mechanisms (Figure 11B detailing). As the mortar deteriorates and the metal corrodes, the balustrades experience distress, including displacements, cracking, and bowing. As long as vertical bars are installed in the balusters, and

**Dual Exposure Façade Elements**

Dual exposure elements are projecting elements that generally experience wind as well as other loading from both sides. These tend to be located near the top of the building and are similar to many of the characteristics of the projecting elements. The original designs typically relied on the mass of the masonry and keying together of specific units in order to address overturning. Often steel rods were used to “string” the units together, but were not necessarily thought of as reinforcing for loading purposes or specifically designed as lateral restraints.

![Figures 11A and 11B – Replacement balustrade (left), NTS terra cotta detailing, 1927 edition (right).](image)

![Figures 12A and 12B – Previous repair for terra cotta balustrade, meeting all current code provisions (left). Authors’ repair for terra cotta balustrade, meeting intent of current code (right).](image)
bars stitching the top and bottom rails are intact, the “unreinforced” balustrades may experience deflections and displacements, yet still have adequate resistance against overturning and may not require repair or reconstruction.

Current codes typically treat balustrades as handrails or guardrails, and it is often assumed that meeting these loading criteria is required, resulting in significant repairs to “reinforce” the system. As shown in Figure 12A, the balustrade was dismantled and reconstructed utilizing the principles for reinforcing CMU construction with grout and reinforcing steel to create a rigid element to withstand current code-prescribed loads.

The comparative approach for “repairs in kind” is outlined in Figure 12B, and the completed installation is shown in Figure 11A. These “in-kind” repairs can consist of dismantling the balustrade and reconstructing with stainless steel threaded rods and reestablishing the tensile capacity of the mortar by installing new mortar at the full bed joint of the unit. This repair approach generally functions as a “replace in kind” and is analogous to a net that keeps elements from dislodging from the building rather than performing invasive repairs to reinforce the balustrade elements to meet the code-prescribed loads.

Finials

Finials, as originally constructed, were intended to act as monolithic elements with an overall resistance against overturning by means of the tensile bond capacity of the mortar in the joints between units in combination with metal pin(s), as well as the cumulative weight of the units. Over time, the bond between the mortar and masonry will eventually fail. When the bond fails, the finials no longer behave monolithically, and the overturning capacity is reduced based on the plan dimensions at the debonded joint(s), pullout capacity of the pin(s), the bearing capacity of the masonry, and the cumulative weight of the units. Generally, as long as substantive pins are installed in the joints between units, the finials have adequate resistance against overturning, regardless of the mortar bond between units. However, if the pins are not installed, or are undersized, or have minimal embedment, the excess capacity (i.e., safety factor) against overturning is significantly reduced and cannot be determined with the current structural evaluation methods. Due to the safety concerns associated with elements of the finial falling as the mortar deteriorates, structural repairs are often necessary. Repairs typically consist of removing mortar and fully pointing the joint or dismantling the finials and reconstructing with stainless steel threaded rods.

CONCLUSION

The examples presented in this paper illustrate the benefits and downfalls of the current rehabilitation regulatory requirements and how applying modern structural evaluation criteria and contemporary standards/codes to historical buildings without rational and practical engineering judgment can often result in excessively conservative or unnecessary repairs. These examples revealed many of the issues faced with completing rehabilitation work, and how the structural provisions in the code can be used to minimize interventions or over-strengthening in some instances. They also were selected to show that compliance with current construction standards often leads to extreme interventions (similar to the balustrade reconstructions for the previous repairs and other types of seismic repairs for unreinforced masonry structure) or simply bypassing the existing structure. The selected structural façade exemplars provide insight into the additional regulatory issues surrounding rehabilitation that are not explicitly addressed by the current regulation—such as analysis procedures, building officials’ interpretation for historical structures, and structural repairs for recurring conditions.

The process of structural rehabilitation and code compliance, as seen with issues surrounding application of the code, often gets lost in translation for many reasons. A fear of “liability” is often one of the most common reasons for design professionals completing rehabilitation projects utilizing standards for new construction. While building officials typically bear the responsibility of determining what loadings need to be considered, the fear of being questioned may lead them to revert to current codes.
for new construction, even though this may be unnecessary. Design professionals often perceive being less stringent as “sticking their necks out.” As a result, the work is not often completed by design professionals whose specialty is existing structural systems. In some cases, successful rehabilitation utilizing existing building codes can be done by providing an understanding that a building designed per any previous code is not also required to meet current regulations; and, through the use of sound engineering judgment, professionals can provide justification for “repairing in kind” in many instances.

Without further development of the regulatory system, the question of how to bring an existing building up to “modern” code standards remains. The largest issue stems from this question: Does a building necessarily have to meet “modern” structural provisions to provide for life safety? And more important, what does it mean if a building is “not up to code”? Thus, the need for sound engineering judgment with an understanding of historical systems and their behavior is essential in the successful utilization, application, development, regulation, and modification of the structural rehabilitation codes.

This paper has attempted to show that current regulatory approaches relying extensively on the judgment of local building officials rather than rational engineering judgment can lead to unpredictable and inconsistent results, unwarranted loss of historical fabric, and excessive expense for arbitrary structural retrofits—both for the building structure and for the façade elements in what might otherwise be viable adaptive reuse and rehabilitation opportunities.

**FOOTNOTES**

3. Ibid.
6. Ibid.
7. Ibid.

**REFERENCES**
