This paper proposes that engineering for preservation be as dominant a goal of the engineering community as engineering for seismic safety.

There is tension in the dialectic between engineering and preservation whenever historic buildings undergo the scrutiny of a seismic assessment — tension that is not prone to being resolved through compromise. The engineering community, intent on assuring seismic safety in accordance with codes for new construction, is, for the most part, disinclined to analyze archaic structural systems for actual performance and is frequently unwilling to live with anything less than full compliance with prescriptive code requirements.

As an alternative, so-called state-of-the-art performance-based standards might be offered up — standards such as ASCE 31 and ASCE 41 — that are, despite representations to the contrary, just as prescriptive and ill-suited for application to historic structures as the building codes that govern new construction. At the same time, the preservation community, well-intentioned but hobbled by limited expertise in matters of seismic safety, is reliant on the engineering community and is, for the most part, unable to negotiate from a position of knowledge. In the end, as preservation goals become subservient to safety concerns, preservationists reluctantly but silently acquiesce, and nearly all historically sensitive obstacles with the potential to derail the engineering goals fall. If sufficient funds are found to employ top-end seismic-mitigation strategies, such as base-isolation, the majority of the original character-defining features may sometimes be saved. However, in the normal course of events, nearly as great sums are spent to create a “re-enactment” of the original features that are torn out to make way for a code-compliant seismic-resistant structure.

But what if seismic-safety considerations did not always necessitate such difficult choices and impossible compromises between the goals of preservation and seismic safety? What if engineering for preservation were as dominant a goal of the engineering community as engineering for seismic safety?

Recently, in San Francisco, California, just such a project in which the dialectic described above was radically transformed saved a masterful and beautiful building, Sherith Israel, from the wrecking ball. While various technical aspects of this project have been described elsewhere, the focus of this paper is to articulate a new philosophy and framework — demonstrably successful in the case of Sherith Israel — for the seismic assessment and strengthening of a more general class of historic structures.
That code, which explicitly addresses the assessment but also permitted use of the California Historical Building Code (CHBC). This code, which explicitly identifies a prescriptive methodology for the assessment, identified an alternative proviso for Sherith Israel. The ordinance required either demonstrating that the building would protect life safety in the event of a major earthquake or upgrading the building if it were determined to be deficient. The ordinance language identified a prescriptive methodology for the assessment but also permitted use of the California Historical Building Code (CHBC). This code, which explicitly encourages the use of alternative methods to demonstrate equivalence, ultimately provided the mechanism that permitted the building to be saved. While various engineering firms had been engaged over the course of two decades to assess the building and to develop solutions that complied with the ordinance, all of them opted to employ prescriptive approaches in the regular code rather than the alternative provisions of the CHBC.

Goals and Methods Overview

At the outset of the project, it became clear that an entirely new approach was needed to accommodate the physical distinctiveness of the structure. Successfully preserving the building while providing seismic safety would require overcoming the predisposition of all modern earthquake engineering methods, even industry-accepted performance-based procedures, to penalize structural systems and configurations that do not fit neatly into pre-established categories that are designed primarily to address the most common mid-twentieth-century construction types. For example, while the vast majority of seismic mass of many historic masonry buildings originates in the exterior walls, the vast majority of the seismic mass of nearly all mid-century buildings originates in the floors. This single difference had the potential to result in vast disparities between the likely behavior of Sherith Israel and the behavior anticipated by modern engineering practice. During the seismic assessment, it was recognized that this specific mass disparity must be accounted for if the assessment were both to correctly identify the beneficial attributes of the original structure that could be leveraged to improve the overall building response to ground shaking and to pinpoint the critical vulnerabilities that needed to be mitigated. Thus, the overarching goal of the approach for Sherith Israel was to establish a set of assessment priorities that could be used to fairly assess the seismic adequacy of the historic, non-conforming structure.

Fair assessment was judged to be not achievable using established performance-based standards such as ASCE 31 and ASCE 41, in part because they were written for a different and newer inventory of buildings; because they
penalize the structural particulars of most historic buildings; and because they can be expected to fail all buildings that do not exhibit the structural characteristics and configuration that are encouraged by the codes and standards that govern new design. The framework developed included the following criteria, which were implemented in both a philosophical and a practical sense. These criteria are generally applicable to the seismic assessment of any historic structure.

**Create and enforce a hierarchy of equals between seismic or structural and preservation goals.** This hierarchy is envisioned as the embodiment of the notion of “engineering for preservation.” Neither seismic safety nor preservation took precedence in the Sherith Israel project; both were worthy goals that were pursued simultaneously and with equal intensity. Of note, on complex seismic-assessment and strengthening projects for historic buildings, one sure way to begin the project on the wrong track is to parse these dual goals between the disparate disciplines of engineering and architecture, as is normally done. These dual goals cannot be properly pursued in isolation by design professionals whose views of the built environment are fundamentally not reconcilable and who see fundamentally different things when they examine a historic building. Therefore, on the Sherith Israel project, these dual goals were treated as if they were one, and both goals were paramount from the inception of our involvement. At every turn, the focus was on trying to find structural means for achieving seismic safety with less historic impact, including crediting the existing structure to the greatest extent justifiable, modifying and/or relocating structural interventions to minimize impact, and studiously considering the requirements of installation.

**Seek to preserve historic structural system as much as preserving finishes.** Historic structure, the bones of the building, as opposed to its finishes, is not only a valuable historic asset in its own right; it is also usually valuable as a structural asset. The existing structure likely already provides substantial seismic resistance and should not be dismissed out of hand as noncompliant. Though the structure may not incorporate modern-day precepts of how a building should be constructed to resist earthquake ground shaking, the structure certainly has inherent strengths that can be leveraged and employed to achieve equivalence or near-equivalence to modern-day accepted levels of seismic safety. Whether the historic structural components are hidden behind finishes or not, their preservation is a worthy goal, without which structural interventions will necessarily be more damaging than they would otherwise need to be. Moreover, at Sherith Israel preservation of the historic structure as a contributor to seismic resistance, not as a non-participatory museum piece, was a primary goal. Supplementation of the existing structure was preferred over supplantage. The tendency of the engineering profession to view historic structures as a quaint but incompetent and unreliable component of a rehabilitated structure only encourages the destruction of what could be preserved.

**Implement “beyond-code” thinking to avoid destroying a building’s historic value while attempting to save it.** The prescriptive provisions in the International Building Code (IBC), which has been by now adopted nearly everywhere in the U.S., were developed under the premise that the buildings to which they are to be applied have not yet been constructed and are only in the initial stages of conception. Just as this premise is wholly inapplicable to historic buildings, the provisions in the IBC are wholly unsuitable to application to historic buildings. Forcing a historic structure into a set of guidelines designed for new construction is the quickest way to undermine preservation goals.

In the last decade in the U.S., the International Existing Building Code (IEBC) has been developed and sporadically adopted. Although this code is specifically intended to regulate work that is being done on existing buildings, it is just as prescriptive as the IBC and is not appropriately responsive to the needs of historic buildings. Fundamentally, its goal appears to be to require that existing buildings ultimately get structurally strengthened to satisfy the lateral force requirements of the IBC. Though its preamble language states otherwise, it allows none of the flexibility that is required to properly assess or improve non-conforming structural systems. The reader is strongly encouraged to look to resources other than International Code Council (ICC) documents when addressing historic buildings and to avoid referencing these documents during the initial stages of a project, when all project participants will get locked into them as project criteria. The use of alternative analysis procedures that make sense for the structure being evaluated, similar to those set forth in the CHBC, is strongly recommended. If appropriate published procedures applicable in the jurisdiction do not exist, then the engineering team may have to justify their assessment and strengthening recommendation using first principles. In contrast to prescriptive ICC documents, ASCE 31 and ASCE 41, the CHBC provided the flexibility needed to address the special considerations required to simultaneously preserve and seismically strengthen Sherith Israel.

**Resist the temptation to turn the building into one that performs like a modern structure.** Independent of the degree of seismic safety they afford, historic structures will necessarily behave differently in an earthquake than new, code-conforming structures, due to inherent differences in construction materials, construction technology, configuration, massing, etc. There is simply no way to make an older structure behave like a modern one during strong ground shaking, unless the pre-

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Fig. 3. Sherith Israel, 1906. Courtesy of Bancroft Library, University of California, Berkeley.
existing structural system is replaced by a new one. These differences in response should be embraced to the greatest degree justifiable; they are not necessarily problems that need to be overcome. Properly evaluated, many historic buildings will be found to require little intervention relative to that involved in replacement, because they already have structural systems with substantial ability to resist lateral forces.

By embracing the differences and leveraging the capacity that the existing system provides, the extent of disruption necessary to achieve the required level of seismic safety can often be minimized. Unfortunately, whether by misunderstanding or misapplication of the codes and municipal requirements, relative difficulty of proper analysis, concerns about liability, or a desire to make a small engineering involvement larger, the engineering community is highly motivated to severely discount the seismic capacity of existing non-conforming structural systems and thereby create an implicit need to replace old with new. At many times during the course of a seismic project involving historic structures — and most often in its early stages, when criteria are being developed and agreed upon — there will be decisions on the table where the temptation to make the building behave like a modern one can greatly ratchet up the eventual disruption to character-defining features. The initial stages of the project are the critical time to set expectations as to the project goals.

**Key Aspects of the Approach**

The approach described below was developed to minimize the potential for conflicts between engineering goals and preservation goals at Sherith Israel and was a natural outgrowth of the criteria described above, tailored to the specifics of its structural type, its documented history, the specific requirements of the San Francisco Unreinforced Masonry Building Ordinance, and the concerns of the congregation. In general, this approach is applicable to the seismic assessment and strengthening of any historic structure.

**Identify the positive attributes of the existing structural system and develop “surgical” approaches to leverage them.** The Sherith Israel project was successful because of the deep focus on developing an understanding of and appreciation for the structural system already in place, rather than yearning for a structural system that did not exist. Every historic structural system has one or more competent structural features with inherent positive attributes that are potentially capable of providing a framework for conceptualizing, designing, and then building a complete seismically resistant system. Therefore, initial steps in any historic-building seismic-assessment and seismic-strengthening project ought to include defining these features and attributes and outlining what beneficial behavior they already contribute to seismic safety.

These features should not be viewed as something that must either be overcome or removed, simply because they do not comply with current prescriptive code provisions for new construction. Rather, the goal of this process is to initiate the identification of the existing structural features that are the best potential candidates for leveraging, thus taking a first step down the path toward development of targeted engineering methods to leverage them, which both provides an engineering-based reason for retaining and re-using the existing system and sets the groundwork for minimizing disruption to the building as a whole. The core competence of the features identified during this process should be viewed as the best available foundation for satisfying the project’s seismic-safety goals while utilizing the existing historic structure to the greatest extent possible — the essence of “engineering for preservation.”

The basic steps used for Sherith Israel, which are possible approaches for other historic buildings, are as follows:

**Employ the historical record.** The historical record for Sherith Israel provided a significant amount of information that was used to provide perspective on the seismic characteristics of the building. In addition to the few architectural drawings retained by the congregation, the archives of local historical societies and universities and of Sherith Israel yielded the following: an eyewitness account of the 1906 earthquake damage to neighboring buildings, including important information on the severity of shaking; an eyewitness account of the exterior damage to Sherith Israel, which provided solid information on the behavior of the exterior masonry walls during the earthquake; receipts related to earthquake-damage repair; and a photograph of the building exterior during repairs (Fig. 3). This infor-
mation proved invaluable in benchmarking studies to assess the seismic resistance of the building.

Employ physical research. The best way to develop an understanding of a building’s attributes is through on-site detective work, especially when the building of interest has undergone few modernizations. Hands-on physical study of Sherith Israel, initiated long before more formal engineering studies, revealed 1906 earthquake damage throughout the building, particularly in plaster finishes and in the masonry gable-end walls (Figs. 4 and 5). The physical research yielded clear, fact-based data on the manner in which Sherith Israel moved during the shaking, offering both a glimpse of its likely response mode in a future large earthquake and a baseline against which to conduct benchmarking studies.

Conduct engineering simulations of displacement. Computer-based quantitative simulations of building displacement are relied upon heavily in earthquake engineering assessments. For Sherith Israel a suite of analyses was designed to explore multiple aspects of the behavior of the structure and of its primary components. Dynamic analyses using SAP 2000 were conducted, in part to define the shapes that the building structure takes on during swaying (Fig. 6). Nonlinear analyses of the masonry walls subjected to in-plane and out-of-plane excitation permitted the simulation of the damage to the walls that would occur during a “design earthquake.” These studies can be used with great effect, particularly for identifying the specific areas most prone to experiencing safety-compromising damage, thus enabling the focus of interventions to be narrowed to areas that actually require mitigation. For the masonry walls in Sherith Israel, state-of-the-art adaptive pushover techniques using ADINA, a general-purpose finite-element analysis program well-suited to nonlinear analysis, were used (Figs. 7 and 8). By application of these analytical methods, the predicted behavior of the masonry walls in a future earthquake was benchmarked by comparing the explicit predictions of cracking in the masonry that were generated by the analyses to the cracking observed during surveys of the masonry walls in the building (Figs. 9 and 10). Such verification, conducted during a series of benchmarking studies, is critical to the process of developing a sound understanding of the expected strengths and weaknesses of the structural system. Although studies of this type were complex, time-consuming, and expensive, they were more than justified by the reduction in the degree of intervention required, reducing project costs by an even larger factor.

Employ engineering artfully. As a general rule, the best engineering is that which accomplishes the most with the least materials, elegantly. The corollary to this for historic structures is that the best engineering accomplishes the most with the least disruption, elegantly: it accomplishes the greatest degree of preservation by continuing to the greatest degree possible the useful function of that which already exists. Brute-force engineering is neither artful, elegant, nor desirable. Of course, the fact that every historic structural system has some positive attributes does not necessarily mean that those attributes are sufficient in and of themselves to form a structural system that provides resistance to earthquake loading adequate to satisfy the project’s safety or performance criteria. What it does suggest, however, is that by careful identification of positive attributes and by careful selection of intervention methods, their attributes can be leveraged to accrete additional seismic benefit.

The key to this step is in seeking targeted, low-impact or disruption-free methods for accomplishing the leveraging; this approach requires balancing the benefit gained with the disruption required to accomplish it. This exercise does not seek to merely identify the least
material that must be added; it is critical that the engineer also explicitly consider the means of access that is necessary for the contractor to add the structure envisioned. It may be that the existing structure can be made seismically adequate by, for example, adding a single, inexpensive bolt at each existing connection, but if the disruption caused by accessing each connection is great, then the result is not desirable, and the project will be a failure, no matter the elegance of the single-bolt solution.

Identify the critical vulnerabilities of the existing structural system and develop “surgical” approaches to mitigate them. The Sherith Israel project was successful because of the focus on the need to place its potential vulnerabilities into a meaningful and practical context in lieu of seeking to eliminate every possible vulnerability. Every historic building has numerous vulnerabilities that are potentially capable of introducing risk to life safety in the event of an earthquake, but not every vulnerability introduces the same level of risk. Initial steps in any seismic-assessment and strengthening project for a historic building therefore ought to include defining the potential vulnerabilities and attempting to conceptually isolate the critical ones, i.e., those that introduce sufficient risk such that they clearly require mitigation or, at least, management.

Elimination of all seismic risk cannot be put forth as a reasonable goal for any building, even those that are completely compliant with every prescriptive provision in the IBC. Although in the design of new construction the engineer may not expressly conduct any relative ranking of the seismic risk that ensues from his design, especially since such an exercise would fall outside the stated requirements of the building code, seismic risk associated with the product of the code-design process still exists, and an engineer so inclined could carry out such a ranking exercise. However, for historic buildings there is a real need to identify and prioritize the extant risks, not merely because this provides a rational means for gaining insight into the likely performance of the building during an earthquake, but also because it is a necessary step toward meaningful incorporation of an “engineering for preservation” philosophy into the project methodology. The attitude that seismic risk must be eliminated wholesale will only lead to unreasonable demolition and removal of the historic features of the building that are the targets of the preservation project; there is no reason that historic buildings should be held to seismic safety standards that are greater than for new construction.

Like the process of identifying the positive attributes of the historic structure that can be best leveraged, segregation of the critical vulnerabilities from the others is a major step down the path toward development of engineering methods to mitigate them “surgically.” Such a distinction provides both an engineering-based reason for retaining and re-using as much of the existing system as possible and sets the ground-
work for minimizing disruption to the building as a whole.

The steps used for Sherith Israel, which are possible approaches for other historic buildings, are those that were described above. The documented historical record, hands-on physical examination of the building, and engineering simulations of displacement, both for the purpose of developing insights into the conceptual behavior of Sherith Israel likely to occur during strong ground shaking and to explicitly conduct benchmarking studies, were all extremely valuable exercises. No published methodology could possibly have provided the level of validation achieved by these complementary studies. Having a firmer understanding of which portions of the structure and finishes presented the greatest risks enabled the project to focus on mitigation of the risks that mattered most, thereby eliminating wasteful and time-consuming assessment and design time, as well as wasteful and expensive disruption to the building itself.

The Solution for Sherith Israel

The seismic-strengthening plan for Sherith Israel was developed to fully leverage the inherent capacity of the unreinforced masonry structure, as well as satisfy the intent of and the provisions in the CHBC that permitted utilization of analysis and design method-ologies alternative to those in the regular code. The plan was permitted in 2009, and the first phase of the construction has been completed. The scheme leaves untouched essentially every historically significant interior finish in the sanctuary and nearly all historically significant finishes elsewhere in the building — a degree of preservation that would have been impossible to achieve had traditional seismic-strengthening methods been employed.

In addition to heavy reliance on the study of the physical evidence of 1906 earthquake damage and historical documents describing damage in San Francisco in general and to Sherith Israel in particular, development of the plan relied on modern-day estimates of the intensity of shaking during the 1906 event; on a variety of analytical structural studies of the building, including state-of-the-art adaptive pushover techniques; and on laboratory testing of state-of-the-practice structural materials that would be incorporated into the design. The structural solution not only preserves the historic fabric of Sherith Israel but also preserves and fortifies the positive structural attributes that enabled this building to survive the 1906 earthquake while nearby masonry structures were damaged beyond repair.

Specifically, the solution takes advantage of the dynamic separation between the modes predominated by in-plane and out-of-plane wall shaking, an attribute that is normally eliminated when floor and roof diaphragms are stiffened in the usual course of seismic strengthening. The solution employs a combination of established and innovative interventions, each developed to minimize disturbance to the nonstructural finishes and retain the structure’s original dynamic characteristics while improving its integrity. These interventions include center-cored reinforcement of the masonry walls; a system of tension ties in the attic that interconnect the four perimeter walls, yet circumvent the domed sanctuary; and nonlinear, compression-only pilasters and fiber-reinforced polymers, in addition to more typical technologies such as bond beams and floor-to-wall ties. Every system and component of the design was expressly developed with a close eye on the degree of disruption required to install it.

Center cores consist of shafts drilled within the plane of the masonry walls, both horizontal and vertical, into which reinforcing DYWIDAG threaded rods and grout are placed. The center cores in Sherith Israel were designed primarily as “integrity steel,” which would cross potential cracks as predicted by the nonlinear analyses and restrain the growth of those cracks, thus limiting the potential for large pieces of masonry

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**Fig. 10.** Wide stepped cracking, believed to have formed during the 1906 earthquake, appears in the south wall in the attic at a major plan articulation. The crack was strong-backed by bolted steel angles at an unknown date.

**Fig. 11.** Laboratory test result of nitinol wire cycled in tension between zero load and 4 percent elongation at three different temperatures.
Use of nitinol in Sherith Israel is to survive the 1906 earthquake. As of the system that enabled the structure and to provide a “self-centering” action, restrained the walls from falling outward super-elastic nitinol wires, designed to ties in Sherith Israel, however, rely on of masonry bearing walls. The tension to supplement the out-of-plane stability, they have been relied upon for millennia due to the thermal change associated with curing, and cost and to improve consolidation.

The reinforcing that was dropped into the center-core holes projected above the top of the holes and was terminated into the reinforced-concrete bond beam along the top of the wall. The reinforced-concrete bond beam replaced the original interior sandstone coping that had been rooted over and hidden.

Tension ties in monumental houses of worship are by no means innovative; they have been relied upon for millennia to supplement the out-of-plane stability of masonry bearing walls. The tension ties in Sherith Israel, however, rely on super-elastic nitinol wires, designed to be lightweight and easy to install, to restrain the walls from falling outward and to provide a “self-centering” action, while maintaining the inherent flexibility of the system that enabled the structure to survive the 1906 earthquake. As demonstrated by laboratory testing conducted in support of the mitigation technology designed for Sherith Israel, nitinol wire can be “stretched” to about 105% of its length and fully recover its original length when the load on it is released (Fig. 11). Nitinol is used most commonly in medical and optical applications but only rarely in structural ones. Although it has been extensively studied for seismic purposes in university laboratories, to date nitinol is known to have been used in seismic applications only in Italy to improve the seismic response of medieval cathedrals damaged during the Assisi earthquake in 1997. Use of nitinol in Sherith Israel is believed to be the first application for improving seismic resistance in the U.S. and to be the first application of this type (employing wires in direct tension without need of machining) anywhere.

The nonlinear, compression-only pilasters were employed selectively to improve the performance of Sherith Israel’s north wall, which was the only exterior wall of the structure without significant plan-articulation; it was also lacking adjacent horizontal diaphragm segments equivalent to the other exterior walls. Without the stabilizing pilasters that originate from the “folding” of the wall in plan and significant supporting diaphragms, the north wall was determined to be more vulnerable that the others. The absence of these articulations and floor diaphragms was accommodated to some degree in Pissis’s design by locating the stairwells and the four plaster-sheathed walls that bound these stairs against the north wall. However, movement of the wall during 1906 caused the most significant cracking in the plaster in the building.

Because the north wall is along an alleyway and is effectively shielded from view from the street, external pilasters were designed to supplement its out-of-plane stability, thereby avoiding disruptive work in the interior of the building. The compression-only pilasters support the wall to prevent it from falling away from the building toward the north. However, by the incorporation of special releases that allow the pilasters to uplift, they permit the wall to freely displace southward when the building as a whole sways toward the south. This detail was considered to be necessary to prevent the new pilasters from tearing the building apart when forces induce displacement toward the south.

**Conclusion**

A new approach and philosophy for the seismic assessment and strengthening of historic buildings has been described, as well as a methodology for its implementation. The approach was recently implemented on Sherith Israel, a monumental, unreinforced-masonry synagogue in San Francisco, with a domed, mural-painted sanctuary and an austere but magnificent sandstone exterior. The approach resulted in a seismic-strengthening scheme that literally saved the building from the wrecking ball, since prior solutions were both too disruptive to Sherith Israel’s character-defining features and too expensive to implement.

**Notes**


pect to the prescriptive structural requirements. Although they pertain to performance-based engineering and set forth performance criteria, they are highly prescriptive in that they dictate how to achieve the stated performance levels and provide virtually no flexibility unless the engineer is willing to ignore or modify the published provisions, as suggested by other standards. References are provided in endnote 3 that discuss some of the many problems with these documents.

The CHBC was specifically designed and written to promote performance-based assessments and rehabilitation and to allow the engineer to use discretion rather than dictating how to do assessments prescriptively. The CHBC contains no triggers that lead to building-wide structural strengthening. In addition to the performance criteria that it sets forth, it contains a single prescriptive chapter that may be invoked if seismic strengthening is triggered by some other action, such as a local ordinance. Every year, however, strong pressure is exerted by some members of the engineering profession to turn this last true performance-based document into another prescriptive code. These efforts reinforce the dire need for the philosophy of engineering for preservation to be forcefully promoted by the preservation community.

The San Francisco UMB Ordinance is a prescriptive portion of Chapter 16 of the San Francisco Building Code that was adopted in response to a statewide requirement that unreinforced masonry buildings be seismically evaluated. The ordinance is highly prescriptive; however, it permits historic buildings to be addressed using the CHBC.

A comparison between these documents is beyond the scope of this paper. What can be positively asserted is that all ICC documents, the IBC and the IEBC included, are prescriptive by design and intent, and they are traditionally enforced prescriptively by building departments throughout the U.S. In most editions of the IEB with seismic work is triggered, whether by alterations or repair, the entire building has been required to conform to current IBC requirements. However, IEB provisions for historic buildings are rapidly evolving. IEBC Chapter 11 has long required that for historic buildings, a report be prepared that itemizes the contributing features of the building that would be damaged by compliance with the structural requirements of other chapters, items not in compliance, and how compliance with the intent of the provisions is to be achieved. It also requires that in higher seismic-design categories, a structural evaluation be performed that describes the load path and earthquake-resistant features. Although this is, perhaps, a step in the right direction, nothing in these editions fulfills the “motherhood” language of the IEB, which states that its intent is to provide flexibility to permit the use of alternative approaches. Until the 2012 edition, the IEB set forth no substantive exceptions for historic buildings with respect to the prescriptive structural requirements or to any of the upgrading triggers, which are onerous from the standpoint of preservation. In the 2012 edition, however, substantial changes were made that appear to provide greater latitude for historic structures, particularly with respect to repair. However, as with much new code language, there are inconsistencies and ambiguities, particularly with respect to alterations, that need to be resolved before the real impact of these new provisions can be determined.

The ASCE documents referred to are standards; they are neither prescriptive codes nor performance codes. Although they pertain to performance-based engineering and set forth performance criteria, they are highly prescriptive in that they dictate how to achieve the stated performance levels and provide virtually no flexibility unless the engineer is willing to ignore or modify the published provisions, as suggested by other standards. References are provided in endnote 3 that discuss some of the many problems with these documents.

The San Francisco UMB Ordinance is a prescriptive portion of Chapter 16 of the San Francisco Building Code that was adopted in response to a statewide requirement that unreinforced masonry buildings be seismically evaluated. The ordinance is highly prescriptive; however, it permits historic buildings to be addressed using the CHBC.

Photograph and eyewitness account are in the collection of the Bancroft Library, University of California, Berkeley, Calif.


ADINA R&D Inc. (2005), “ADINA: Theory and Modeling Guide,” Report ARD 05–7, Watertown, Mass. Stress plots and crack plots from nonlinear analyses are designed to consolidate and quickly communicate volumes of information about structural behavior on a single sheet, but they must be viewed with a practiced eye. The multi-wythe masonry walls of Sherith Israel were necessarily idealized as continuous homogenous systems and then discretized, through their thickness and across their length and height, meaning that local effects due to variable construction quality, for example, cannot be accurately captured. On the other hand, plotted values are output element by element or node by node, meaning that the plots have the appearance of being highly accurate at the local level. In reality, analyses of this type are most reliable for identification of larger-scale behavior. One such behavior revealed by the Sherith Israel studies was the tendency for the plan-articulated walls to “unfold” during out-of-plane response. This predicted behavior causes cracking at or near the articula-