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Preservation and Engineering: The necessity of joint research

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As geologists continue to study earthquakes, and continue to warn the public of earthquakes occurring with greater frequency and magnitude, local jurisdictions are responding by increasing the design code requirements for the built environment. The engineering community is being asked by building owners to provide more seismic protection at lower costs. The increase in seismic design criteria has the greatest impact on our historic resources.

This impact is often exacerbated by several factors: a misconception that historic structures are inherently weaker than new structures; a general lack of available information on historic building materials; and the lack of research by the engineering community on the behavioral characteristics of historic building systems.

The culture of the United States is particularly prone to investing a greater reliance on new material than on outdated material. Despite a growing recognition of the wastefulness of our society, we are still a country that consumes 80% of the world's resources with only 20% of its population. Our economy, for all practical purposes, is based on the allure of invention, refinement, and new gadgetry. And our pervasive culture extends to the built environment. The very phrases of "urban renewal" or "urban revival" hardly connote the imagery of transforming existing structures into new vibrant centers of social commerce. On the contrary, most individuals equate urban renewal with the demolition of entire sections of existing fabric followed by the erection of brand new structures. However, when great urban revival successes are mentioned, like Fanueil Hall in Boston, Massachusetts, San Antonio's riverfront, the Presidio in San Francisco, and to a lesser degree, Portland's four-block area of Pioneer Square, Pioneer Courthouse, and Pioneer Square Mall, accolades abound and the public speaks of the richness of their community embodied in the rehabilitation of its older structures. Had it not been for city officials and development teams debunking the myth of newness, much of our nation's rich heritage would have been lost. Within these examples, it is probably safe to comment that the economic "weakness" was overcome, but it is likely that the engineering evaluation of the structures included defacto strengthening of the old, "weak" buildings.

Unless an engineer has developed a passion for historic structures, chances are high that they have not made a habit out of scourging used booksellers to augment their collection of turn of the century material testing evaluations. They probably also don't make a habit of browsing the local library's collection of Architect and Builder, published in the early 1900's. However had they so been inclined, the existing resources are quite scarce on engineering data. Whereas Architect and Builder may contain many advertisements for "Pyrobar," as well as many articles extolling its "new" superior fireproofing qualities over plain old clay tile, the engineer will find almost no information on the strength characteristics of the material. Likewise, Powell's Books' will contain many copies of early twentieth century "Handbooks on Engineering." Reading one hundred-year-old text describing the difference between point loading and distributed load will hardly be awe inspiring for the engineer.

The fact is, very few resources exist for the engineer to fully understand and appreciate historic building materials. Therefore, most engineers default to readily known characteristics of older structures in the evaluation of a building's strength. These characteristics include: weaker grouts, poor firing techniques for clay masonry, the lack of uniform standards for steel strength, and a misconception that greater erection tolerances equates to poor construction techniques. And based on these characteristics, potentially erroneous deductions are made that conclude the weakness of one material creates a weakness in a system of materials.

An extremely condensed version of western architectural history would present early engineering knowledge resulting directly from trial and error building. If a structure fell during the course of erection, the builder would simply start again and vary the components until the structure stood. And once standing, the results were recorded for posterity and the builder became an "engineer." It is well known that Gothic cathedral building evolved towards ever-higher vaulting on more and more slender stone columns until repeated collapses signaled the engineering limitations of the materials. Thus was born the master builder, the individual whom was architect and engineer and contractor. The master builder was doing nothing less than in-situ testing of material strength, albeit at great cost. The notion of trial and error engineering is further supported by recent thermal evaluation of the great flying buttresses at Chartres cathedral. When scientists evaluated the loading patterns of the individual stone components of the buttresses through the measuring of heat dissipation, they expected to see the giant capstones providing much of the gravity load that kept the buttress anchored. The evaluation, in fact, showed the capstones to be almost free of contribution to the loading and that it was the spring blocks that were resisting both the vertical and lateral loads. The scientists had preconceived the structural load characteristics of the historic church based on their knowledge of modern structural design. The flying buttress was acting in unexpected patterns revealed only through sophisticated field-testing.

The above example of Chartres cathedral demonstrates the lack of predictability inherent within historic structures. It was not until the advent of modern building materials like concrete and steel that mathematical engineering analysis overtook "common sense" as the preferred means of construction practice. Prior to controlled laboratory analysis of individual material components, it was accepted knowledge that strength was correlated with wall thickness and material rigidity. In Chicago, the Monadnock Building was erected in 1891 with six-foot thick masonry walls in order to support sixteen floors. Whether or not historic structures perform in the manner to which they were designed is not predictable without field or laboratory testing.

Few engineering firms in the United States perform in-situ testing of historic structural systems in order to determine the inherent strength of the entire building. In Japan, a culture that places a high value on tradition, and a country that experiences severe earthquakes, many of the national heritage buildings are wood frame structures built without foundations. In order to better understand how to protect these structures during an earthquake, the government commissioned local universities with the task of research and development. Because the structures were built in a craftsman technique unmatched in modern construction practices, the universities recognized the need for a new paradigm of test techniques. Taking advantage of "shake" tables built for seismic testing, the university teams re-erected an entire historic structure on top of the shake table. In this manner, the researchers were able to control the shaking, repeat the ground motion, and ascertain the best position of reinforcing with the least impact on the historic integrity of the structure.

Testing of this nature is yet to be performed in the United States. Whereas adequate information is available from static testing of individual components (bolt shear, dead loading, etc.), little testing has been performed on historic building systems. Clay tile covered with 1" thick lath and plaster is inherently stronger than clay tile alone. And this type of wall is rarely free standing. More often the plaster wall is keyed to a plaster ceiling providing a degree of lateral strength unaccounted for in engineering evaluations. The same is true for solid load bearing heavy exterior stone structures. If we were master builders today, our "practical" knowledge would be asking the rhetorical question as to why some our hundred year old structures have survived recent earthquakes undamaged. This is not to imply that all historic buildings respond well to earthquakes. On the contrary, the high degree of variability in historic construction techniques and materials requires a more technically diverse engineering analysis. A sophisticated system by system approach is likely to yield far different results than can be expected from an analysis of individual components.

As codes continue to evolve with increased knowledge of geological information, it is imperative that the engineering community rises to the challenge of better understanding of historic building materials. Our rich heritage of architecture will depend on a broader understanding and technically more sensitive approach to seismic strengthening if that heritage is to survive.