Summary of Discussions

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Almost two decades ago, the Getty Conservation Institute (GCI) began researching and developing methods to provide seismic stabilization for historically and culturally significant buildings located in seismic regions. The Getty Seismic Adobe Project (GSAP) investigated less-invasive, stability-based alternatives to existing strength-based retrofitting methods. After studying historic adobe buildings, analyzing recent earthquake damage, and developing and testing new retrofitting techniques, GSAP devised ways to provide seismic protection while preserving the authenticity of historic adobe structures in California.

The methods and techniques proposed by GSAP can be adapted for use in communities with limited resources around the world. Several years after the GSAP guidelines were published and disseminated, the GCI hosted the Getty Seismic Adobe Project 2006 Colloquium, which gathered a multidisciplinary group of professionals working on the seismic retrofitting of earthen structures, both within California and outside of the United States, to discuss the applicability of these guidelines and techniques in a variety of contexts. The first two days of discussions focused on previous experiences with stability-based, earthquake-resistant design, appropriate testing methods, and building codes and standards specific to earthen architecture, along with case studies from around the globe.

The third and final day of the colloquium was designed to promote discussion among all of the participants, with the aim of jointly creating a list of recommendations for moving the field of conservation of earthen buildings in seismic regions forward. To facilitate discussion, a series of roundtables was organized around four topics: (1) the California State Historic Building Code, specifically the shift from a strength-based to a stability-based design approach for the seismic retrofit of earthen structures; (2) national building codes for earthen architecture; (3) future research and testing; and (4) information dissemination and training. Following each roundtable, the topic was opened to the entire group for discussion.

During the concluding session, four rapporteurs synthesized the day's discussions and presented a draft list of recommendations that emerged from those exchanges. The main points are summarized below.

1. Shift from a Strength-Based to a Stability-Based Design Approach for the Seismic Retrofit of Earthen Structures

The GSAP guidelines represent a shift away from mainstream, strength-based methods of retrofitting earthen structures, which add independent structural systems of steel or reinforced concrete to historic buildings and can result in the removal of substantial amounts of historic material in order to accommodate new structural elements. In a manner similar to techniques of some vernacular construction traditions, the methods recommended in the GSAP guidelines allow buildings to move and crack in an earthquake, thereby dissipating energy. However, GSAP's stability-based retrofits also help prevent collapse by adding flexible, interactive structural elements that provide overall structural continuity and keep walls from overturning by minimizing the relative displacement of cracked wall sections. While this principle was agreed upon by colloquium participants, the following points were suggested in order to advance the concept:

- A shift in design approach from strength-based to stability-based design will require the reeducation of many site managers, engineering and design professionals, architectural conservators, and policy makers, as well as building occupants and the general public. This education will require an active program for disseminating alternative design criteria and their supporting test results, in a manner and language that are thoroughly understood by diverse audiences.
- While it was agreed that materials in retrofit projects must be *durable*, *readily available*, and *compatible* with the original materials, and that interventions should be *minimally invasive* and *reversible,* if possible, it was apparent that the definitions of these terms were not consistent among the various disciplines. Efforts must be made to standardize the understanding and use of these terms across disciplines.
- The design of a structural retrofit project should include a methodology for evaluating the project over time and should be carried out by a multidisciplinary group of professionals.

2. National Building Codes

National building codes, norms, or standards, if well conceived and rigorously enforced, result in safer buildings and consequently protect public safety and save lives during earthquakes. Codes legitimize construction materials and methods that are included in a code, and they essentially outlaw methods and materials excluded from a code. It is therefore important that earthen construction, as well as intervention methods for historic earthen structures, be introduced into every national building code. In order to develop earthen building codes in different countries, the colloquium participants suggested the following:

- Model guidelines and standards should be crafted to serve as references for governments developing their own building codes for earthen structures.
- Model guidelines and standards should be based on sound engineering principles and draw upon the best existing codes, guidelines, and standards to formulate their content. Guidelines and standards should allow for revision over time, based on any new understandings gained from earthquakes and testing programs.
- Codes must address the care and sensitivity to character-defining features required when existing historic buildings are retrofitted. This is generally different from requirements for new construction or for the retrofitting of nonhistoric vernacular buildings.
- Complementary building codes, standards, guidelines, and manuals addressing the conservation of historic earthen sites in seismic regions should be designed to target different audiences (i.e., professionals, builders, and the general public). If this is not possible, illustrations should be included in the code itself to make the content accessible to users with different levels of technical understanding.
- Slenderness ratios specified in existing codes should be standardized in relation to local seismic zones, to allow real comparison among codes and case studies.
- While addressing the structural components of earthen buildings, codes should consider the masonry, mortar, and plaster as one complete wall assembly. Tests such as those recently carried out at PUCP have shown that earth- or lime-based plasters dramatically improve the strength of earthen walls and control cracking during earthquakes while protecting walls from direct contact with water.
- Codes should consider the local and regional cultural contexts and settlement patterns, and the resulting building traditions. A national code may well need to address several very different regional patterns, construction techniques, and building cultures.
- Codes for earthen architecture borrow heavily from codes for stone masonry, brick, and con-

crete. It is important to study the possibility that aspects of codes for earthen architecture, especially in reference to historic resources, could influence the codes for other building materials as well.

3. Future Research and Testing

Colloquium participants agreed on the need to develop scientific data on historic earthen sites, including material behavior and seismic information, then use that data when designing retrofitting plans. Documentation collected should include historic structure reports, tests, and, most of all, statistical data on ground and structure behaviors. The following list addresses potential engineering and conservation research topics and testing methods or programs that could be useful in advancing engineering and conservation knowledge pertaining to seismic issues in earthen sites.

- Expand the types of models used in future shake table testing. Data from shake table tests thus far are based on newly constructed models of simple, one-room adobe structures with relatively lightweight roof systems. Include in future testing more complex floor plans; construction techniques for earthen buildings other than adobe/mud brick, such as rammed earth (pisé) and wattle and daub (also called *bahareque* or *quincha*); structures with massive roofs (i.e., domed or vaulted structures); and historic material.
- Carry out evaluations of traditional construction in seismic zones by multidisciplinary teams. While such teamwork is challenging because of the difference in professional languages and attitudes, multidisciplinary input is essential to a full understanding of these complex cultural resources.
- Identify retrofit methods and materials most appropriate for a particular region. Available materials, financial resources, and technical skill levels vary significantly throughout the earthquake-prone regions of the world where earthen architecture is common.
- Explore the potential for virtual earthquake testing through computer modeling. Computer modeling could answer some of the shortcomings of costly shake table tests and could test more complex building configurations under multidirectional impulses. This type of testing tool should consider variations in existing site conditions, such as types and conditions of the soil, masonry moisture content, and existing structural cracks, among others.
- Expand our understanding of field conditions. Laboratory test data have been derived from samples made of clean, homogeneous material, while in fact, material properties of existing earthen structures are generally different because of such factors as the presence of salts, moisture, and biological infestation.
- Carry out research and testing of building components, construction details, and material assemblies to answer fundamental questions and provide necessary data for computational models.
- Explore the feasibility of base isolation and other energy dissipation techniques for the retrofitting of historic earthen architecture.
- Investigate methods of structural crack repair—stitching, grouting, and rebuilding—to identify the appropriate application and materials for each method.
- Identify materials that are compatible with earthen construction and that can be used for grouting, crack repair, and structural retrofitting. In particular, investigate soil-based grouts that could replace epoxies now commonly used. Carry out tests on injectability and penetration behavior.
- Define performance expectations for earthen building materials under dynamic conditions. Current performance standards are for static loads only.

4. Dissemination and Training

Research programs, such as GSAP, have identified appropriate methods for strengthening earthen buildings against earthquake damage. The pressing challenges are to disseminate this information throughout the diverse, earthquake-prone regions of the world and to train and support those who will implement these retrofit methods before the next major earthquake occurs. The following is a list of recommendations to facilitate better dissemination of the GSAP guidelines, as well as their adaptation to different cultural contexts:

- Use the Internet, which is becoming an accessible tool for growing numbers in the earthen architecture community. Publications on specialized topics, such as these proceedings, are often of limited print runs and tend to be expensive and difficult to obtain, particularly in the developing world. The Internet should be exploited to facilitate and encourage regional and international communication networks, as well as publications.
- Keep local building officials apprised of advances in research pertaining to earthen architecture.
- Support face-to-face exchange of information—a mode of communication that remains important. Seminars, colloquia, and international conferences should continue to be organized and supported.
- Develop an array of educational materials targeted to specific audiences. These audiences will range from academics and national policy makers to rural community members. Each audience will have its own needs, expectations, and limitations. Illustrations enhance understanding and can be a means of bridging between technical and nontechnical audiences.
- Establish a centralized database and Web site where interested parties can find appropriate methodologies, case studies illustrating best practices, model codes, and information on traditional knowledge and building techniques in active earthquake regions. This database could include an atlas of significant earthen buildings and prototypes, as well as a network of professionals working in the field.
- Integrate the engineering of earthen architecture into the curricula of existing academic programs in schools of engineering, architecture, architectural history, conservation, and allied fields, encouraging an interdisciplinary approach to teaching this subject at the university level.
- Strengthen links between professional activities and academic work by engaging schools of engineering, architecture, conservation, and construction in retrofitting projects.
- Address the challenge of persuading policy makers of the viability of reinforced earthen architecture in seismic zones.
- Capture and disseminate the intangible and oral traditions associated with earthen architecture in seismic regions. Include local people with traditional knowledge in this process.
- Encourage the two-way exchange of knowledge between traditional builders and professional "experts."

The GSAP colloquium provided the opportunity for a creative, multidisciplinary group of professionals working on the conservation of earthen sites in seismic regions to meet and discuss ideas and challenges and to collectively identify steps to advance the field. The ideas expressed in this summary of discussions will serve as the basis for designing the GCI's future work in this area. It is hoped that the colloquium discussions will also encourage other institutions, organizations, and practitioners to continue working to improve the preservation of earthen heritage sites in seismic areas throughout the world.