SUMMARY OF RESEARCH NEEDS

A. CURRENT GAPS IN RESEARCH EFFORTS

Most research on earthen buildings has focused on walls and wall materials. Only limited research has been conducted regarding configuration of earthen buildings, common components, and other elements. Research has focused on adobe buildings and other common types have not been fully examined.

B. RESEARCH NEEDS

The following research needs have been identified:

1. Structural Research

a. Research on roof design, configurations and materials.

b. Research on design of doors and exits.

c. Research on popular design features, including:

--- porches
--- ornamental facades
--- design features for climatic adaptations

d. Research on building configurations commonly found in seismic zones.

e. Research on optimum size and dimensions of various types of earthen buildings.

f. Research on strengthening multi-story buildings.

g. Research on the interaction between earthen and non-earthen building components and systems.

h. Research on alternative methods for using the basic materials.

i. Research on connections between walls and other critical components of the buildings.

j. Research on methods to instrument, observe and record performance of earthen buildings during seismic events.

2. Materials Research

a. Increased research on use of locally available materials to stabilize earthen building materials.

b. Increased research on methods for improving the durability of earthen materials.

c. Increased research on the preservation of other materials used in reinforcing earthen walls, including:

--- wood and timber
--- metal components (wire, nails, etc.)
--- coatings and washes (stucco, lime, etc.)

d. Increased research on new methods of bonding earthen building materials.

3. Research Related to Implementation

a. Compilation of data concerning earthen buildings in seismic areas, including:

--- catalogue of building types, styles, features, etc.
--- identification of traditional methods used to increase earthquake resistance or safety
--- centralization of data on performance of earthen buildings in past earthquakes

b. Research on program models for:

--- vulnerability reduction and mitigation
--- post-disaster reconstruction programs

c. Expanded research on social and cultural constraints to modification efforts.

d. Expanded research on traditional construction methods.

e. Expanded research on methods of transferring housing technology.

f. Expanded research on codes and standards and possible alternatives.

RECONNAISSANCE OF DAMAGE TO EARTHEN BUILDINGS

A. DESCRIPTION

An accurate base of data derived from assessments of damage to earthen buildings is required in order to provide a base for research. To date, organized reconnaissance surveys have not significantly contributed to the expansion of the data base for the following reasons:

1. Superficial Examinations. Except in a few cases, reconnaissance teams have not included specialists in adobe construction, and the primary emphasis of reconnaissance efforts has been on other types of buildings. Discussions of earthen buildings have been minimal and superficial.

2. Differing Terminology. A complete, standardized terminology describing damage to earthen buildings is not utilized.

3. Lack of Standardized Methodology. No standard forms or methodologies for assessing damaged buildings are in widespread use.

4. Timing of Assessments. Many of the damage assessments that have been conducted have been delayed due to problems in funding. Thus many valuable examples have been lost to demolition and clearance activities. (This problem is heightened because earthen buildings are more likely to be demolished if they are heavily damaged than are other types of structures.)

B. RESEARCH NEEDS

In order to improve the quality of the data developed by reconnaissance surveys, the following actions are suggested:

1. Development of standard terminology.

2. Adoption of standard evaluation forms using the standardized terminology.

3. Establishment of a clearinghouse for information about earthen buildings in seismic areas and associated research. This clearinghouse should be the focal point for post-earthquake reconnaissance emphasizing rapid reaction.

C. PAST EFFORTS

The following efforts are noted:

1. In 1977, the Earthquake Engineering Research Institute published Learning from Earthquakes: Planning and Field Guides, which included checklists for assessing damage to buildings and a proposed standard terminology. The structural evaluation forms are not considered thorough enough for development of base data for earthen building research.

2. In 1978, the Office of Research and Standards (OIN/Peru) and INTERTECT jointly developed a structural assessment form for evaluating damage to adobe, quincha and rock buildings. The form is thorough and includes a definition of terminology. The form could be the basis for a standardized assessment form.

D. REFERENCES

1. Learning from Earthquakes: 1977 Planning and Field Guides, Earthquake Engineering Research Institute, Oakland, CA, 1977.

2. "Damage Assessment Form - Earthen Housing", Report on a Damage Assessment Survey, Arequipa, Peru, Following the February 1979 Earthquake, INTERTECT (Dallas, Texas) and Oficina de Investigación y Normalización (Peru), 1979.

COMMON PROBLEMS IN STRUCTURAL TESTING

A. IDENTIFICATION OF COMMON PROBLEMS

1. Variations in Materials. Due to variations in the materials used in earthen buildings, the quality of the workmanship, and the widespread differences in construction techniques, it is difficult to derive information that may be universally applicable. Nonetheless, standardized testing procedures and methods can be helpful.

2. Full-scale Testing. The full-scale testing of earthen buildings is considered extremely difficult due to the nature of the materials involved and their relative weight. Alternative methods for full-scale testing are required, and methods such as tilt tables and explosive arrays may offer means of observing an entire house and its components under seismic loading.

3. Difficulties in Modelling. Scale-model testing of earthen buildings is not considered practical because of the difficulty of developing a scale model which

   a. accurately depicts the weight of the building, and

   b. accurately simulates the cementation and connections between materials in the building.

   New methods of scale-model testing need to be developed for earthen buildings. One method that should be explored is the use of a centrifuge (such as the one at Ames Research Laboratory in California).

4. Problems in Instrumentation. The instrumentation of earthen buildings to record seismic-induced stresses is difficult due to the nature of the materials and variations in construction techniques/workmanship. Thus most information to date has been limited to "before and after" comparisons and studies of damage to buildings after earthquakes. New methods of instrumenting and/or observing earthen buildings under seismic conditions should be developed. One possibility is the utilization of close range photogrammetric equipment linked to and triggered by seismographic recording devices.

5. Standardization of Testing Procedures. The standardization of testing and testing procedures is made difficult by the wide variation of materials and building features found throughout the world. Furthermore, there is no common terminology in use among those conducting research on earthen buildings, and few standardized methodologies have been developed.

6. Fragmentation of Research. Much of the research on earthen buildings has been fragmented, and information exchange among researchers has been on an ad hoc basis. No international effort has been established to promote information-sharing or coordination in this field.

7. Focus on Walls. Most research on earthen buildings has focused on walls and wall materials. Other parts of an earthen building may contribute more to ultimate vulnerability than do the walls. Of special concern are:

   a. Heavy roofs

   b. Unreinforced gables

   c. Interior walls

   d. Split-level roofs

   e. Roof attachments to walls

   f. Porches and verandas

   Researchers should be encouraged to take a more wholistic approach to the study of earthen buildings.

8. Lack of a Centralized Data Bank or Clearinghouse. No international center currently exists which compiles and disseminates information on earthen buildings in seismic areas. Thus it is often difficult for researchers entering the field to obtain information helpful to their research efforts.

B. PRELIMINARY RECOMMENDATIONS

1. An international center/clearinghouse for information about earthen buildings in seismic areas should be established. The center should:

   a. Establish and maintain a research library;

   b. Host periodic conferences on earthen buildings in seismic areas;

   c. Translate key documents so that the information can be more widely disseminated.

2. An association of researchers specializing in earthen construction in seismic areas should be established to promote more effective coordination and dissemination of research results. This association should be a component or affiliate of an existing international society such as the International Association for Earthquake Engineering.

3. A group of experts should be impanelled to develop standards for:

   a. Terminology

   b. Reconnaissance procedures

   c. Reporting

   d. Testing

4. Increased linkages with researchers in related fields (e.g. unreinforced low-quality masonry) should be encouraged.

OBSTACLES TO VULNERABILITY REDUCTION

A. DESCRIPTION OF THE PROBLEMS

Common problems relating to comprehensive vulnerability reduction efforts include:

1. Methods for strengthening earthen buildings to resist seismic forces are often too costly for implementation by low-income families.

2. Results of research on methods for strengthening earthen buildings are often presented in literature which is far too technical for the agencies involved in implementation.

3. Implementing agencies often do not have the trained staff or technicians required for implementing vulnerability reduction activities. Many members of housing staffs are not familiar with the available literature on methods for reducing the vulnerability of earthen buildings, and the research community in general has few linkages to implementing agencies.

4. Often the families residing in earthen buildings are those most resistant to change. In addition, these people may be the most difficult to reach due to illiteracy and unfamiliarity with related technical aspects.

5. The conditions under which families will modify or accept modification to their houses are not fully understood. The available literature on this topic is minimal.

6. Official constraints are often imposed by governments on vulnerability reduction efforts in order to discourage continued use of earthen buildings. For example, funding for families building with earth may be restricted to encourage conversion to other types of building materials.

7. Vulnerability reduction efforts are often hampered by the provision of poor sites or sites that are subdivided in such a way that building in a safe manner is inhibited.

B. PAST EFFORTS AND RESEARCH

Most vulnerability reduction efforts have occurred after an earthquake and have been directed toward improving the design and construction of new housing, rather than toward the reduction of vulnerability of existing housing.

Comprehensive post-disaster vulnerability reduction efforts have been conducted in:

1. Guatemala. Innovative post-earthquake programs were conducted by OXFAM/World Neighbors in the Department of Chimaltenango from 1976 through 1980, and by the Save the Children Alliance in the Department of Quiché from 1976 through 1979. In both programs, extensive efforts were made to introduce technology to improve the performance of earthen buildings (adobe and bajareque) and to develop incentives to encourage the widespread use of these techniques. Extensive literature about these programs is available through the implementing agencies.

   Other (although less comprehensive) vulnerability reduction programs were conducted by CARE, Catholic Relief Services/ CARITAS, the Summer Institute of Linguistics, and the U.S. Agency for International Development (USAID). General information on earthen buildings was distributed widely through the cooperatives, CEMAT (an appropriate technology center) and other relief agencies.

2. Peru. A comprehensive research program in adobe construction (COBE) resulted from the 1970 earthquake in the Department of Ancash. The program, carried out jointly by the Ministry of Housing & Construction and various universities, produced numerous demonstration houses, extensive literature, and comprehensive sets of training aids for implementation activities.

3. Turkey. The Government of Turkey, through the Ministry of Reconstruction & Resettlement, has sponsored extensive research in support of comprehensive vulnerability reduction. The Earthquake Engineering Research Institute of the Middle East Technical University has actively supported this program in both research and field efforts. An extensive body of information has been developed and various reports outlining post-disaster implementation efforts, as well as mitigation measures taken in seismic zones, have been produced.

C. WORK IN PROGRESS

Comprehensive programs of vulnerability reduction as a mitigation measure are currently in progress in the following countries:

1. Dominican Republic. The National Institute of Housing (INVI) is currently preparing to conduct a nationwide program for reduction of vulnerability of traditional housing in disaster-prone regions. While primarily aimed at reducing vulnerability to hurricanes, measures taken will include the reduction of vulnerability of wattle-and-daub buildings to earthquakes. The program is assisted by the Office of Housing, U.S. Agency for International Development.

2. Peru. Continuing efforts to reduce vulnerability of earthen housing have resulted from the 1970 earthquake reconstruction program and the COBE program. Nationwide implementation has been delayed by funding difficulties.

3. Turkey. The Government of Turkey is continuing its mitigation efforts through a public information campaign designed to provide information on safer building techniques. A number of private agencies are also active in these efforts.

D. RESEARCH NEEDS

Research needs can be divided into two categories: technical research and program research.

1. Technical Research. Priorities include:

   a. Low-cost methods for modifying/retrofitting existing buildings.

   b. Study of the interaction of earthen materials with non-earthen structural components (e.g. wooden posts and frames).

   c. Increased research on the relation of non-earthen components (roof, overhanging porches, decorative facades, etc.) to overall vulnerability.

   d. Expanded research on other types of earthen buildings (bajareque, rammed earth, wattle-and-daub, etc.).

2. Research in Support of Implementation Programs. New information is required for vulnerability reduction programs. Extensive research is needed on:

   a. Program models.

   b. Public information dissemination techniques.

   c. Innovative finance programs.

   d. Incentives that can be used to encourage the adoption/acceptance of change in traditional societies.

   e. Innovative "entry" strategies for introducing change and modification techniques.

E. IMPLEMENTATION NEEDS

Housing program agencies must be provided with the following information and tools in order to successfully carry out vulnerability reduction efforts:

1. Building guidelines and standards that can be interpreted by non-technical personnel;

2. Public information materials that can be understood by various target populations;

3. Model program formats that can be followed by implementing agencies;

4. Reference materials for program planners (these should be available at a central information clearinghouse);

5. Increased availability of technical assistance to implementing agencies. This will require the establishment of increased linkages between the research community and the implementing agencies.

F. REFERENCES

1. Frederick C. Cuny, Editor, The OXFAM/World Neighbors Housing Reconstruction Program: Guatemala 1976-77, INTERTECT, Dallas, Texas, 1977.

2. Ian Davis et al, "The Modification of Unsafe Housing Following Disasters", Architectural Design 7/79, pp. 193-198.

3. Duncan MacLean Earle, Roofs of Tin in El Quiché: An Analysis of a Reconstruction Program in the Highlands of Guatemala, State University of New York, Albany, 1978.

4. J. Peter Marion, "Mid-Term Report: Southern Quiché Reconstruction Program, Chiché Region Office", Save the Children Alliance, Guatemala, January 15, 1977.

5. Mary McKay, "The OXFAM/World Neighbors Housing Education Programme in Guatemala", Disasters, Vol. 2, No. 2/3, 1978, pp. 152-157.

6. Robin Julian Biellik et al, Southern Quiché Reconstruction Program, Save the Children Alliance, Guatemala, September 1976.

7. Alcira Kreimer, Reconstruction Planning on Shaky Ground: Learning from Recent Disaster Experience, Prepared for a research project on the provision of emergency shelter and housing following disasters (Ian Davis, Frederick C. Cuny and Frederick Krimgold) undertaken for the U.N. Disaster Relief Office, 1977.

8. Robert M. Carmack, Final Report: Anthropological Analysis of the Earthquake in Western Guatemala, Save the Children Alliance, Guatemala, 1976.

9. Programa COBE, Adobe, Ministerio de Vivienda y Construcción, Lima, Peru, 1979.

ROOFS

A. DESCRIPTION OF THE PROBLEM

1. Weight. In many regions, earthen buildings are covered with roofs made of extremely heavy material. In Africa, the Middle East and Asia, roofs are often made of earthen materials supported by large heavy logs. In Latin America, heavy clay tile roofs are often used on earthen buildings.

   The use of such materials is most often a result of economics, although tradition, climate and lack of alternative roofing materials may also play a major role. Because of these constraints, the use of heavy roof systems must be included in research on earthen buildings in seismic areas.

2. Design. The design of a roof system can play a major part in the overall vulnerability of a building. Simple roof systems, designed to reduce materials and costs, often increase vulnerability. Some common features are illustrated on the accompanying page. Additional research on design and methods for reducing vulnerability from roof systems is required, as well as on methods for retrofitting or modifying existing houses with unsafe roof systems.

B. REFERENCES

1. Frederick C. Cuny, Analysis of the Potential for Housing Improvement in High Risk, Vulnerable Areas of Peru, INTERTECT, Dallas, Texas, 1979.

2. Frederick C. Cuny, Improvement of Adobe Houses in Peru: A Guide to Technical Considerations for Agencies, INTERTECT, Dallas, Texas, 1979.

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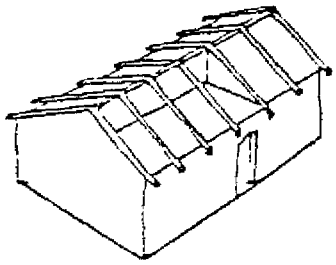
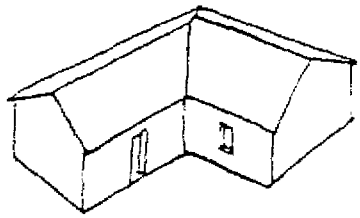
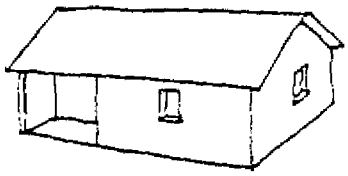
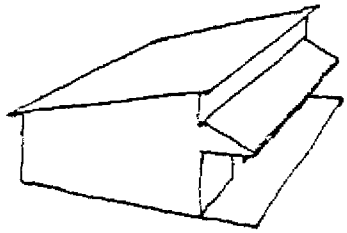
4. A.S. Arya, Teddy Boen et al, Guidelines for Earthquake Resistant Non-Engineered Construction, International Association for Earthquake Engineering, 1980.

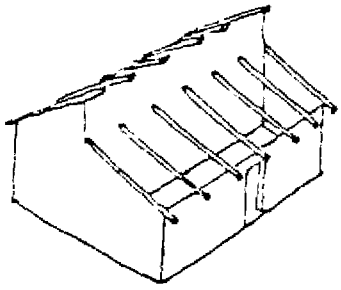
DANGEROUS ROOF CONFIGURATIONS

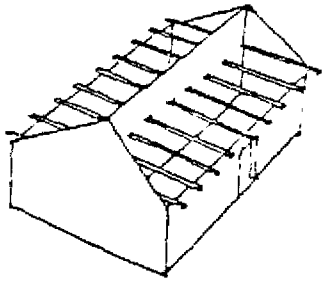












THE PROBLEM OF PARTITIONS AND INTERIOR WALLS

A. DESCRIPTION OF THE PROBLEM

In many earthen buildings, interior walls are built after the primary shell has been erected. Often the interior walls are not properly fastened to the exterior walls and are not reinforced. Thus they are free-standing and pose a major safety hazard in earthquakes. This is especially a problem in older, large houses throughout Latin America.

B. RESEARCH NEEDS

To reduce this hazard, the following activities are needed:

1. Development of a data base concerning the problem.

2. Acquisition and dissemination of data from structural research on related types of buildings (unreinforced low-quality masonry, etc.).

3. Development of low-cost methods for reinforcing interior walls, including:

   a. low-cost alternatives to earthen walls;

   b. low-cost components for reinforcing and fastening walls and partitions;

   c. low-cost methods for strengthening earthen interior walls in both existing and new buildings.

4. Development of practical methods which permit addition and fastening of an interior wall after a house has been constructed (for example, the placement of studs or attachments in exterior walls which will facilitate the attachment of the partition).

C. WORK IN PROGRESS

A research program on the performance of non-structural partitions in buildings has recently been funded by the National Science Foundation (U.S.).

D. REFERENCE

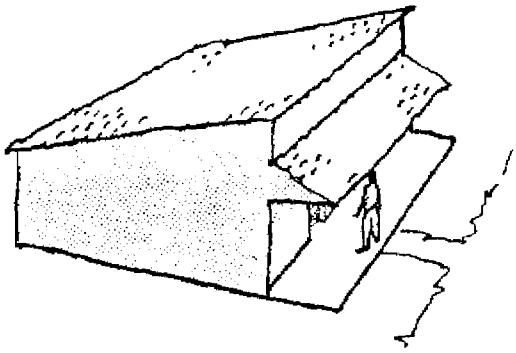
Satwant Rihal, The Behavior of Architectural (Non-Structural) Building Components During Earthquakes: Racking Tests of Non-Structural Building Partitions, California Polytechnic State University, 1980.

PROBLEMS OF DECORATIVE FEATURES

A. DESCRIPTION OF THE PROBLEM

Decorative features such as ornamental facades, large overhanging porches and split-level roofs (see illustrations) are often major contributors to the vulnerability of earthen buildings in seismic areas. The usual approach in vulnerability reduction has been to discourage the use of such features, but in practice this approach has had little result. Thus additional research on the effect of these features on a building's performance is required, and methods should be developed to strengthen the buildings so that these features can be safely incorporated.

B. TYPICAL FEATURES



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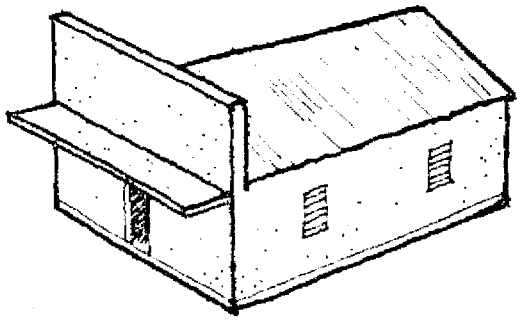

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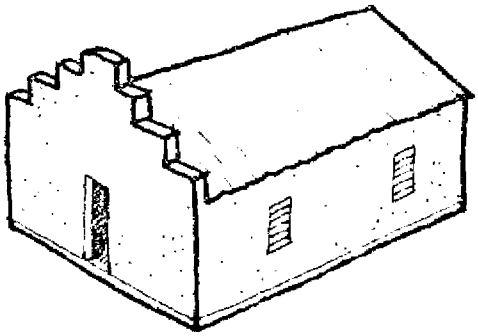

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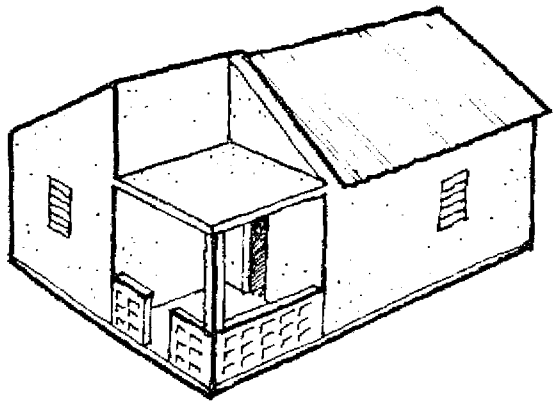

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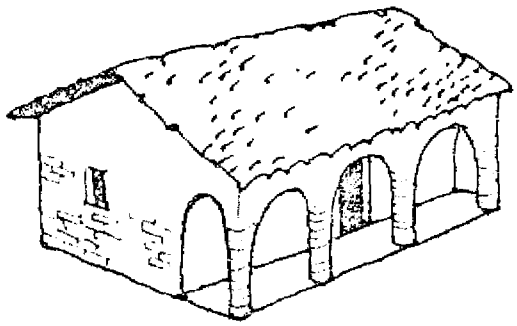

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C. REFERENCES

1. INTERTECT, Improvement of Rural Housing in the Dominican Republic to Withstand Hurricanes and Earthquakes, Office of Housing, Agency for International Development, Washington, D.C., 1981.

2. Frederick C. Cuny, Improvement of Adobe Houses in Peru: A Guide to Technical Considerations for Agencies, INTERTECT, Dallas, Texas, 1979.

WOOD PRESERVATION

A. DESCRIPTION OF THE PROBLEM

In many regions, earthen buildings derive a degree of strength and earthquake resistance from a wooden frame placed in the walls. Popular examples include:

1. Wattle-and-daub
2. Bajareque
3. Certain types of rammed earth buildings

In addition, many roof systems commonly used with earthen buildings rely on wooden supports.

Earthen materials often facilitate the rapid deterioration of wooden components. Insects may have easy access to the wood, and wood rot caused by both moisture and dryness can be enhanced by enclosing wooden posts in earthen materials. With few exceptions, the wood preservation techniques commonly used in traditional societies do not adequately protect the wood from deterioration. As durable hardwoods are depleted worldwide, softer woods are used in construction that are even more susceptible to deterioration, thus increasing the vulnerability of earthen buildings.

B. RESEARCH NEEDS

Research on low-cost methods of preserving wood used structurally in earthen buildings should be encouraged as part of comprehensive research efforts on earthen buildings in seismic areas. Research should also explore methods for local production of preservatives from extracts of indigenous materials commonly found in areas with a high proportion of earthen buildings.

C. PAST RESEARCH AND EXPERIENCE

Following the 1976 Guatemalan earthquake, a number of reconstruction agencies were confronted with the problem of wood preservation. Many of the earthen buildings (bajareque and adobe de canto) in Guatemala utilize wood posts structurally, and the agencies developed methods for strengthening these traditional systems. A variety of wood preservation techniques were explored, although great difficulty was experienced because the cost of using many of these methods was extremely high. Some of the methods used were:

1. Distribution of pressure-treated timber;
2. Distribution of creosote and pentachlorophenol for home builders to "paint" onto wood surfaces;
3. Provision of facilities where families could bring their wood to be soaked in a preservative under the supervision of trained personnel;

4. Distribution of technical information to homebuilders on low-cost methods of preserving wood (including charring the wood, and making "homemade" preservatives from used crankcase oil and industrial pesticides).

Methods that were suggested but not tried included the use of lime baths, the use of portable pressure-treating devices, and conversion to other types of structural elements (e.g., reinforced concrete posts).

D. REFERENCES

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2. J. Jenners, "Applying Wood Preservative to Green Lumber", VITA, Mt. Rainier, Maryland, 1962.

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7. Prolonging the Life of Wood in Houses, Ideas & Methods Exchange No. 47, Department of Housing & Urban Development, Office of International Affairs, Washington, D.C., 1971.

PROBLEM OF ADDITIONS

A. DESCRIPTION OF THE PROBLEM

Earthen houses are often evolutionary, i.e., a one- or two-room building is erected followed by the addition of other rooms or enclosed areas at a later date. These additions often abut, or are attached to, the main structure in such a way that the overall configuration and balance becomes unsafe. The problem can be a result of space restrictions and/or the layout of the building site which may force construction in this manner.

Most housing programs focus on the construction of a safe basic unit only, and no provisions are made so that additions can be made safely. Furthermore, most research programs have focused only on the basic structures and have not yet addressed the problems caused by these additions.

B. PAST EXPERIENCE

1. No research programs investigating the problem were identified. Methods for addressing the problem thoroughly are discussed briefly in an A.I.D. Disaster Assistance Manual, Vol. I: Transition Housing for Victims of Disasters.

2. Most efforts to address the problem have focused on revising land planning techniques. This approach has been used in several reconstruction programs in Chile, Peru and Guatemala. The problem has also been addressed in the layout of controlled squatter settlements in Peru by the Ministry of Housing and Construction.

3. A number of researchers have proposed the construction of in-house shelters as a means of providing limited protection to occupants of buildings with these safety problems.

C. RESEARCH NEEDS

Various aspects of the problem should be addressed in a comprehensive research program. The research agenda should include:

1. Practical, low-cost methods for adding rooms safely.

2. Designs for expanding the buildings safely.

3. Land planning techniques that facilitate safe expansion.

4. Methods for determining vulnerability of existing buildings.

5. Practical, low-cost methods for providing protection to occupants of unsafe buildings.

D. IMPLEMENTATION NEEDS

In order to successfully address the problem in the field, implementing agencies will require:

1. Guidelines for land planning;

2. Guidelines for reinforcing primary structures of houses likely to be expanded in this manner.

E. REFERENCE

PADCO, Inc., Transition Housing for Victims of Disaster (Disaster Assistance Manual Volume I), Office of Housing/Office of U.S. Foreign Disaster Assistance, Agency for International Development, Washington, D.C., April 1981.

REPAIRS TO EARTHEN BUILDINGS

A. DESCRIPTION OF THE PROBLEM

Practical, low-cost methods for repairing earthen buildings are not generally available.

B. PAST RESEARCH AND EXPERIENCE

Most research on repair of earthen buildings has focused on the preservation and repair of historic buildings. In the preservation and protection of such buildings, high costs may be justified but the methods used are usually too expensive for use by low-income families.

During the 1970's, several programs addressed the problem of repairing low-rise earthen housing damaged by earthquakes, and a number of publications and reports resulted. Two such efforts were:

1. A joint project by the United Nations Center for Housing, Building & Planning (now the U.N. Centre for Human Settlements/HABITAT) and UNESCO to compile and publish information on low-cost construction resistant to hurricanes and earthquakes. A manual was produced which included some limited recommendations on repair of earthen buildings (Repair of Buildings Damaged by Earthquakes).

2. A special reconstruction program conducted by Save the Children Alliance in Southern Quiché, Guatemala, in 1976-77 focused on repair and reconstruction of adobe houses. Several reports on the difficulties experienced are available from this agency, and a brief illustrated manual for homeowners was produced ("Como Inspeccionar y Reparar las Casa Dañadas por Terremotos").

C. WORK IN PROGRESS

No current program specifically examining the repair of earthen buildings was identified.

D. RESEARCH NEEDS

Research needs include:

1. Practical, low-cost methods of repair using indigenous materials and skills.

2. Research on the practicality of using synthetic materials (e.g. epoxies) in the repair of earthen housing.

E. IMPLEMENTATION NEEDS

Housing and reconstruction agencies require:

1. Practical methods for determining the relative safety of a damaged structure and what is required to repair the building safely and economically.

2. Practical methods and tools for repairing houses.

3. Illustrated manuals providing information on the correct procedures for repairing houses safely and economically for both implementing agencies and the general public.

F. REFERENCES

1. Hernan Ayarza E., Sergio Rojas I, and Luis Crisosto A., Repair of Buildings Damaged by Earthquakes, ST/ESA/60, United Nations, New York, 1977.

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PROBLEMS OF URBAN LOT SIZES

A. DESCRIPTION OF THE PROBLEM

Urban lots are often small and narrow. This is to reduce costs and make more lots available for low-income families. Small, narrow sites increase vulnerability because:

1. The narrow configuration virtually ensures that the houses will be attached or abut one another.

2. The homeowner will be forced to expand on the site in an unsafe manner.

This problem is a result of tradition as well as of poor urban planning and is usually seen with rectangular grid-type layouts and subdivision plans.

B. PAST EXPERIENCE

To date, the problem has not been identified as a major consideration for urban planners or reconstruction agencies, and little connection between site planning in seismic areas and building safety has been practiced.

C. RESEARCH NEEDS

A data base concerning this problem and the special requirements of siting for earthen buildings should be developed.

D. IMPLEMENTATION NEEDS

1. Recommended standards for urban sites for earthen housing should be developed.

2. A guide for site planning for earthen buildings or urban sites in seismic areas should be prepared for housing agencies and urban planning authorities.

E. REFERENCES

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THE PROBLEM OF ATTACHED HOUSING IN URBAN AREAS

A. DESCRIPTION OF THE PROBLEM

Due to space restrictions and land costs, earthen buildings on urban sites often cover an entire lot and are attached to (or abut) an adjacent building. These are often the most vulnerable earthen houses in seismic areas. Under seismic conditions, forces can be transferred from one house to the other, increasing the load on the adjacent structure. Current research has focused on low-rise detached housing, which is most likely to be found in rural settings or in peri-urban areas. Research should be conducted on the problem of reinforcing houses in an urban environment.

B. PAST EXPERIENCE

To date, this problem has been seen as a land planning issue. Methods employed have included:

1. Increasing the size of the lots;

2. Consolidating land during post-earthquake demolition and reconstruction activities;

3. Strict enforcement of building codes requiring separation between buildings.

Examples of land consolidation and replatting can be found in numerous programs including Skopje, Yugoslavia, and Managua, Nicaragua.

The Save the Children Alliance, working with the Department of Quiché, Guatemala, in 1976-77, developed several programs designed to encourage separation of housing in urban areas and built several demonstration structures. Their reports identify many of the problems encountered.

C. WORK IN PROGRESS

None identified.

D. RESEARCH NEEDS

Research on this problem will require the development of a data base derived from field studies, especially post-earthquake reconnaissance, and may require new techniques in modelling and instrumentation. Research efforts should be aimed at providing:

1. Practical, low-cost methods for reinforcing existing buildings.

2. Practical, low-cost methods for reinforcing new buildings.

3. Practical methods of demolishing and replacing buildings within a block without affecting the overall structural performance of the other houses in the same block.

4. Implementable codes and specifications to control the problem in new construction.

E. REFERENCE

PADCO, Inc., Transition Housing for Victims of Disasters (Disaster Assistance Manual Volume I), Office of Housing/Office of U.S. Foreign Disaster Assistance, Agency for International Development, Washington, D.C., April 1981.

BUILDING CODES FOR EARTHEN BUILDINGS

A. DESCRIPTION OF THE PROBLEM

Many building codes which permit earthen buildings in seismic areas are impractical or unenforceable for many reasons including:

1. The cost of producing materials and building structures in accordance with the codes may make the cost of construction comparable to other, more expensive types of buildings (e.g., stabilized adobe often costs more than fired clay brick).

2. The materials required to improve the quality of earthen materials (e.g., asphalt for stabilized adobe) may not be available in commercial markets or an alternative distribution system.

3. Information about how to meet the codes is not widely distributed in a form comprehensible to and usable by local building craftsmen.

4. Codes may require design changes that result in non-traditional forms which do not meet cultural standards or needs for housing.

5. Governmental agencies charged with enforcement are often modelled after western agencies whose roles are passive and restrictive rather than active (giving advice and assistance).

B. PAST EXPERIENCE AND RESEARCH

Codes for adobe buildings and materials have been prepared and adopted in the following countries:

1. Costa Rica
2. Mexico
3. Peru
4. Turkey
5. United States (California, Arizona, New Mexico)

C. WORK IN PROGRESS

Research related to development or revision of building codes for earthen structures is being conducted in the following countries:

1. Argentina
2. China
3. Dominican Republic
4. Guatemala
5. India
6. Mexico
7. Nicaragua
8. Peru
9. Turkey

In the Dominican Republic and Peru, work is in progress on the development of innovative methods for disseminating information on building code requirements.

D. RESEARCH NEEDS

1. To date, most research has concentrated on adobe buildings. Research efforts should be expanded to other types of earthen structures (rammed earth, wattle-and-daub, etc.)

2. Research should be expanded concerning the possibilities of using products easily derived from indigenous materials to stabilize and strengthen earthen materials. Such research could include agents developed from distillation of plants and fibrous materials.

E. IMPLEMENTATION NEEDS

1. Public information aids describing methods of building according to the codes, which present the information clearly and in a manner comprehensible to local craftsmen who may be illiterate or semi-literate, should be developed for use by housing agencies.

2. A full complement of audio-visual materials (especially films) should be developed for use by housing agencies.

3. Housing agencies should develop a range of incentives to encourage people to comply with the earthen building codes. Possible incentives might include:

   a. Priority for housing loans

   b. Reduced taxation

   c. Government subsidies

F. REFERENCES

1. "Recommended Building Standards for Joyabaj, Guatemala", INTERTECT, Dallas, Texas, 1977.

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FINANCING EARTHEN BUILDINGS

A. DESCRIPTION OF THE PROBLEM

Families often experience difficulties in obtaining financial assistance for new construction, modification or repair of earthen buildings in seismic areas. Among the reasons identified are:

1. Earthen buildings are not regarded as a desirable building type by the financial institutions.

2. Earthen buildings are generally not insurable (or reinsurable).

3. The families who reside in earthen buildings may represent the lowest economic strata in many societies and therefore may not qualify for loans even under normal conditions.

4. Financing (and insurance) may only be available to families who build according to a building code. These codes often do not permit earthen buildings, or may require methods of construction that substantially increase building costs.

Most loan programs for earthen housing are provided after earthquakes, rather than during normal periods. When loans are available, it has been found:

1. That loans are usually for adobe rather than for other types of earthen buildings;

2. That few agencies providing the loans require that safer construction methods be used;

3. That few agencies providing loans also provide technical assistance during construction. (It was found, however, that non-governmental agencies providing loans are more likely to encourage the use of safer construction methods and provide technical assistance than are governmental agencies.)

B. PAST EXPERIENCE AND RESEARCH

Financial institutions have usually preferred not to provide financial assistance for construction of earthen buildings unless certain minimum standards could be met. In those countries where loan programs have been linked to codes, participation has been minimal, usually because of the increased costs of construction. One country where this approach has been tried and where data exists about the program is Peru.

Innovative loan programs for the modification of earthen housing as a mitigation measure have not been developed and implemented.

C. RESEARCH NEEDS

1. A data base about innovative financing mechanisms for low-income housing should be developed. Programs applicable to the financing of earthen housing in seismic areas, especially those which encourage safer construction, should be identified and disseminated to agencies active in housing programs in seismic areas.

2. Pilot financial assistance programs should be developed and conducted on a demonstration basis. The results of such efforts should be disseminated widely.

3. As housing modifications may be dependent upon introduction of new materials or components not commonly available in local markets, finance programs may be required to enable local suppliers to purchase and stock these elements.

4. Other means of supplying necessary components for housing modification, at a reduced cost, should be explored.

D. IMPLEMENTATION NEEDS

Information on innovative housing finance mechanisms should be provided to program planners and implementing agencies in the form of easy-to-follow guides for establishing such programs. Information provided should include a description of the program, sample forms, and a critical assessment of the performance of such programs based on previous experience.

E. REFERENCES

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2. PADCO, Inc., "Financing Systems: The Experience of the Assisted", Annex III, Transition Housing for Victims of Disaster (Disaster Assistance Manual Volume I), Office of Housing/Office of U.S. Foreign Disaster Assistance, Agency for International Development, Washington, D.C., April 1981.

INSURANCE

A. DESCRIPTION OF THE PROBLEM

Insurance for earthen buildings in seismic areas is not currently available to low-income families at an affordable cost. Often, because buildings are not insured, they cannot be financed. Therefore, innovative insurance schemes are required. Such insurance programs should be tied to vulnerability reduction efforts.

B. PAST EXPERIENCE AND RESEARCH

1. Comprehensive disaster insurance for all houses has been researched in Australia. Many of the suggestions (such as insurance pools, all-risk insurance, etc.) could become the basis for a program of insurance for earthen buildings in earthquake-prone areas.

2. An innovative insurance scheme for low-cost housing in seismic areas, designed to permit participation of low-income families, has been developed and is in operation in Japan.

C. WORK IN PROGRESS

1. Comprehensive, all-risk insurance for disasters is currently under study by the Federal Emergency Management Agency in the United States. Additional research in support of this effort has been funded by the National Science Foundation.

2. An innovative natural disaster insurance program has been developed by the Texas Insurance Development Corporation to offer earthquake insurance for earthen buildings in seismic regions of developing countries. This program will be available to insurance companies under licensing agreements.

D. RESEARCH NEEDS

1. Earthquake insurance for earthen buildings will not be feasible until the actuarial data required has been compiled. Most of the information required is not now available, primarily because the families who require the insurance do not normally participate in financial programs from which the actuarial data is derived. To encourage insurance companies to move into this market, financial support may be required to develop the data and demonstrate the feasibility of insuring these buildings.

2. The increase in data concerning risk and vulnerability will enable insurance companies to develop the required insurance programs. Increased emphasis should be placed on developing this data in a manner compatible with insurance program information requirements.

E. REFERENCES

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PRESERVATION OF HISTORIC EARTHEN BUILDINGS IN SEISMIC AREAS

A. DESCRIPTION OF THE PROBLEM

Each year, earthquakes damage or destroy a substantial number of historically or culturally significant earthen buildings in the developing countries and many more are unintentionally demolished during clearance activities. Only those buildings considered to be of great historical significance are modified or strengthened to protect them from earthquakes. The types of structures often demolished include:

1. Cathedrals and mosques
2. Public buildings
3. Private homes of lesser historical/cultural/architectural significance

Earthquake destruction and post-disaster demolition activities may result in the following problems:

1. Loss of cultural/architectural heritage;
2. Disruption of cultural identity within an affected community;
3. Declining land values.

B. PAST RESEARCH AND EXPERIENCE

Most of the work on the protection and restoration of historic buildings in seismic areas has concentrated on the preservation of structures of major importance, and few efforts have been made to identify and preserve buildings of lesser historical and cultural significance.

UNESCO has been the major international sponsor of historical and cultural preservation efforts to date and has developed much of the literature. Within the United States the Bureau of Historic Monuments, Department of the Interior and the National Park Service have also played a significant role in developing and implementing historic preservation programs for earthen buildings.

Efforts to protect historic earthen buildings have also been conducted in Guatemala, Mexico and Peru. Many of the techniques utilized in these projects deserve special recognition and can form a base for similar efforts in other regions.

In the Islamic world, the Aga Khan Award for Architecture has stimulated interest in the preservation of historic Islamic buildings, although research and specialized work in earthen buildings in seismic areas has not yet begun.

Much of the actual preservation work has concentrated on reducing deterioration and weathering of earthen buildings, replacement and repair of materials, and strengthening of deteriorated earthen walls. The cost for such work has been relatively high, although justifiable for important structures.

C. RESEARCH NEEDS

1. Expanded research on means of preserving earthen materials.

2. Expanded research on bonding.

3. Expanded research on methods of reinforcing large buildings such as cathedrals, mosques and public buildings.

In order to extend historic preservation to buildings of lesser national and cultural significance, the following activities are required:

1. Development of broadened criteria for designation of historic structures. Emphasis should also be placed on designating historic communities so that the character and atmosphere of certain areas can be preserved. (An excellent example is Antigua, Guatemala.)

   Suggested expanded criteria for buildings are:

   a. Buildings of major national significance;

   b. Buildings of major local significance;

   c. Important buildings;

   d. Buildings of architectural interest.

2. The identification of structures of historical or cultural significance in each community should be expanded, and buildings so designated should be identified with a plaque displayed in a prominent location on the buildings.

3. Establishment of a register of historic structures in each country. A copy of the register should be kept in the disaster management agency of each country so that buildings will not be inadvertently destroyed during post-disaster clearance activities.

4. National and state housing ministries and housing banks should be encouraged to develop special loan and grant programs to assist private homeowners in the modification and strengthening of historic buildings prior to earthquakes, and a special international repair and reconstruction fund should be established to provide assistance to homeowners of significant buildings.

D. REFERENCES

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5. Roberto A. Samanez, "Los Monumentos de Adobe en el Perú y los Casos de Restauración Efectuados en la Zona de Cusco", Third International Symposium on Mud Brick (Adobe) Preservation, Ankara, 1980.

6. Patrick de Sutter, Des Preuves sur la Brique Crue Traditionelle et Stabilisée avec Asfalte Appliquée dans la Restauration des Monuments dans les Andes en Amerique du Sud (Perou).

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