International Workshop Earthen Buildings in Seismic Areas

Conference Report
Research Needs and Priorities
Volume III

INTERNATIONAL WORKSHOP · EARTHEN BUILDINGS IN SEISMIC AREAS ·

The University of New Mexico

Intertect

Prepared for
The National Science Foundation

NATIONAL · SCIENCE · FOUNDATION

INTERNATIONAL WORKSHOP

EARTHEN BUILDINGS IN SEISMIC AREAS

Held at the University of New Mexico
Albuquerque, New Mexico
May 24-28, 1981

VOLUME III

CONFERENCE REPORT
RESEARCH NEEDS AND PRIORITIES
BIBLIOGRAPHY

Frederick C. Cuny
INTERTECT

Gerald W. May
University of New Mexico

Sponsored by:

The National Science Foundation
Washington, DC 20550

Appropriate Technology International (ATI)
Washington, DC 20036

Office of Foreign Disaster Assistance (OFDA)
Washington, DC 20523

September 1981

INTERNATIONAL WORKSHOP ON EARTHEN BUILDINGS IN SEISMIC AREAS

CONFERENCE REPORT

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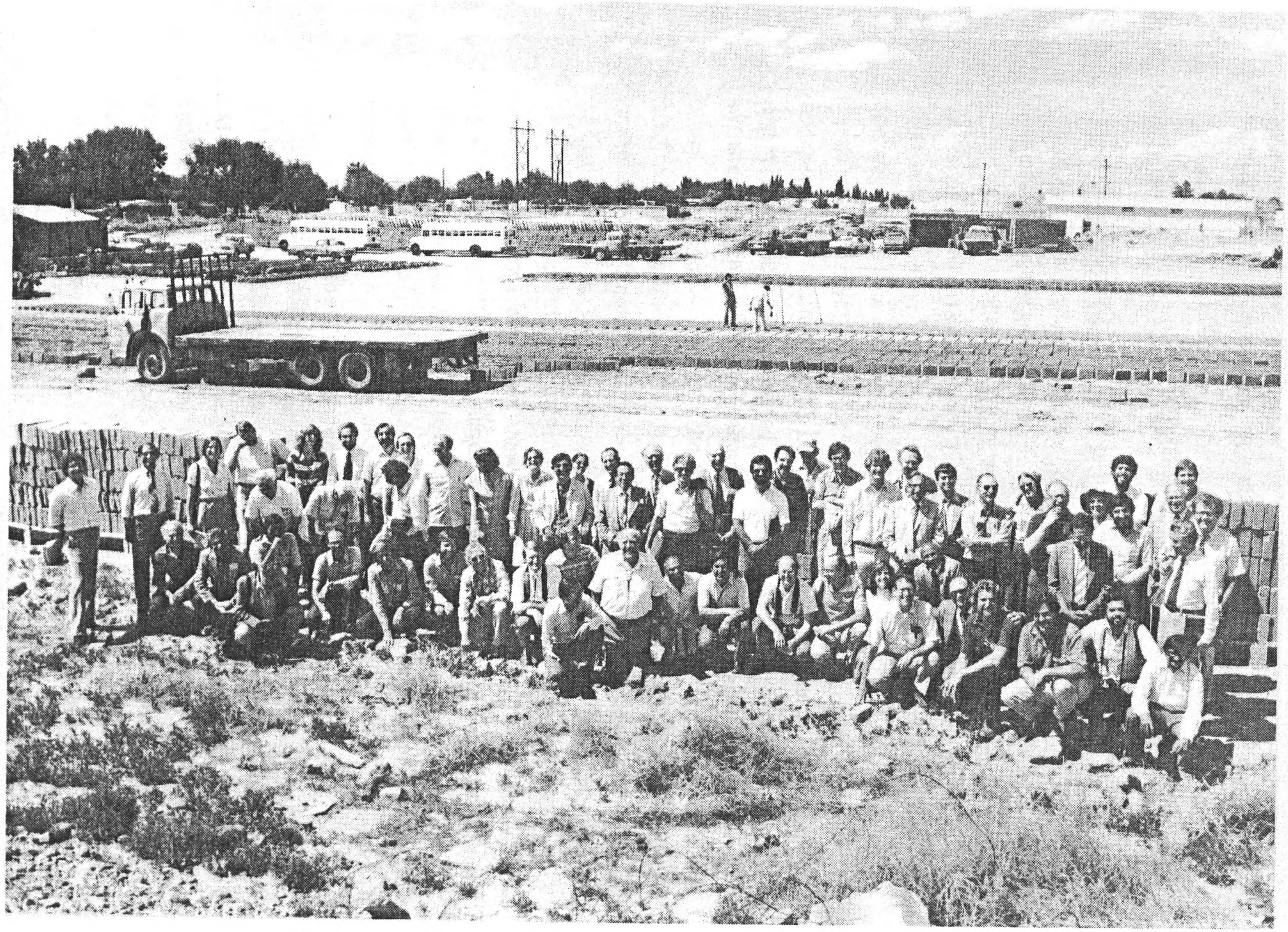

Figure 1. Participants in the International Workshop.

INTERNATIONAL WORKSHOP ON EARTHEN BUILDINGS IN SEISMIC AREAS

CONFERENCE REPORT

I. INTRODUCTION

A. Description of The Conference

1. Background

Although adobe is used as a building material in areas of high seismic risk in the United States and is the predominant building material in many seismically active regions of the developing countries, very little effort has been expended in formulating a systematic body of knowledge of seismic behavior and design of such structures. During this century alone nearly one million people have died in earthquakes, with more than 80% of these deaths occurring in collapsed unreinforced masonry and adobe buildings. Most of the research conducted to date has been applied to engineered structures, typically of reinforced concrete or steel construction. Little has been written about ways of applying existing earthquake engineering knowledge to buildings using traditional materials and methods. Recognizing this problem, the University of New Mexico and INTERTECT jointly hosted a conference to bring together researchers and implementers in order to compile the work to date, so that an international effort could be directed toward reducing one of the major seismic hazards.

2. Goals and Objectives

In May 1981, an International Workshop on Earthen Buildings in Seismic Areas was convened in Albuquerque at the University of New Mexico. The workshop, jointly hosted by the Engineering College of the University and INTERTECT (a Dallas-based consulting firm), was sponsored by the National Science Foundation, the Office of Foreign Disaster Assistance (Agency for International Development), and Appropriate Technology

International. The emphasis of the workshop was on non-engineered adobe houses in seismic areas, although information about related forms of earthen and unreinforced masonry structures was also presented and discussed.

The workshop brought together a select invited group of domestic and foreign researchers and implementers to achieve the following objectives:

a. To develop a clear statement of the problems associated with earthen low-rise buildings in seismic areas;

b. To define the existing state of the art in regard to earthen building materials, design and construction methods in seismic regions;

c. To identify and categorize existing national and international research findings in related areas and seek to establish their applicability to the seismic design and construction of earthen buildings;

d. To identify appropriate channels for technology transfer across international boundaries and to explore social and economic barriers to such transfer;

e. To identify opportunities for cooperative international research;

f. To identify and describe the gaps in the present body of knowledge and to define research needs.

3. Workshop Organization

The primary responsibility for planning and implementing the workshop rested with an executive committee composed of four individuals:

a. Dr. Gerald W. May
Professor of Civil Engineering
Dean of the College of Engineering
University of New Mexico

b. Dr. Golden Lane
Senior Research Engineer
New Mexico Engineering Research Institute
University of New Mexico

c. Mr. Frederick C. Cuny
Executive Chairman
INTERTECT
Dallas, Texas

d. Ms. Jinx Parker
Program Manager
INTERTECT
Dallas, Texas

Working with the Executive committee was an advisory board consisting of leading researchers in the field. The functions of the advisory board were:

a. To help in identifying participants;
b. To help in identifying topic areas and discussion agendas for the work groups;
c. To recommend resource people for discussion groups;
d. To help develop a list of topics for presentations or to identify other contributors; and
e. To comment on the proceedings drawn up by the discussion groups.

The individuals who served on the advisory board were:

a. Dr. John A. Blume
Past President, Earthquake Engineering Research Institute
President, URS/J.A. Blume & Associates

b. Dr. Aybars Gurpinar
Principal Research Associate
D'Appolonia, Inc.
Brussels, Belgium

c. Dr. Julio Vargas Neumann
Department of Engineering
Pontificia Universidad Catolica
Lima, Peru

d. Mr. Roberto Meli
Institute of Engineering
Universidad Autonoma de Mexico
Mexico, D.F.

e. Dr. Mete Sozen
Professor of Civil Engineering
University of Illinois
Urbana, Illinois

f. Dr. Eric Carlson
Deputy, Director, Appraisal
U.N. Centre for Human Settlements (HABITAT)
Nairobi, Kenya

g. Dr. Nicholas Ambrayses
Imperial College of Science and Technology
University of London
London, U.K.

h. Dr. Jai Krishna
Past President, International Association of Earthquake Engineering
Professor Emeritus, University of Roorkee
Roorkee, India

The Executive Committee met with members of the Advisory Board in Istanbul in September 1980 at the 7th World Conference on Earthquake Engineering. During this meeting, the Advisory Board reviewed the plans, suggested a number of topics for discussion and identified a number of candidates to receive invitations to the conference.

4. Inter-disciplinary Participation

It was decided that not only outstanding earthquake engineers and researchers would be invited to participate in the conference, but also building officials and staff from housing agencies and other practitioners involved with the actual implementation of housing improvement. In all, five particular types of candidates were sought. They included:

a. Engineers and architects involved in earthquake engineering research, both in structures and materials;

b. Personnel from governments, voluntary agencies and foreign aid organizations involved in the implementation of modification programs;

c. Experts on social, economic and cultural aspects of the overall problem;

d. Officials experienced with building codes involving earthen buildings and persons from lending institutions familiar with the problem of financing improvements to earthen buidings in seismic areas.

Participants from each of these groups were identified and letters were sent to them. If they indicated interest, and their interests were compatible with the Workshop scope, letters of invitation to participante in the conference were sent. The list of actual participants present at the conference is included in Section B of this chapter. In all, 16 countries were represented by the 87 participants.

5. Topic Areas

The conference scope was organized into five primary topic areas:

a. Subject Area 1: Structures
b. Subject Area 2: Materials
c. Subject Area 3: Social, Economic and Cultural Aspects
d. Subject Area 4: Program Implementation
e. Subject Area 5: Codes, Specifications and Standards

6. Workshop Structure

a. Format of the Workshop

The Workshop was structured so that a maximum of interaction occurred in small discussion groups. It spanned a period of 4 days, with 2-1/2 days of intensive work sessions. During the first two days, morning plenary sessions were conducted wherein keynote presentations were made to provide background and structure for the work sessions that followed in the afternoon. Each participant received a schedule with assignments to a particular session at a specific time (based on pre-workshop selection of preferred topic areas by the participants) and was able to attend three of the five work sessions during the course of the Workshop. At each group session, the participants were asked to review the state-of-the-art, identify research needs, and identify the resource persons actively engaged in the field. Each group was chaired by a respected researcher or practitioner who guided the discussions and, with the assistance of a recorder, prepared a summary of each session. Three of the 15 discussion sessions were conducted in Spanish expecially for the Spanish-speaking participants from Latin America. At the end of the Workshop, the session leaders and recorders from each subject area met to prepare a brief report on the findings of the different groups on that subject area and summarized the findings to the final full plenary session.

b. Briefing Papers

In order to provide the participants with an overview of each subject area and to identify some of the key issues and topics for the work sessions, the Executive Committee elected to prepare a set of briefing papers for conference participants. These briefing papers, which are included in the Appendix, identified areas of concern, described existing research, and provided a list of bibliographic sources for each of the topics.

c. Conference Papers

Each of the invited conference participants was asked to prepare a paper on his or her field of expertise. Some of these papers were printed prior to the conference and distributed so that participants could refer to them throughout the conference. A complete set of these papers are included in the Proceedings.

d. Conference Library

Each of the participants was asked to bring copies of relevant publications on the topic of earthen buildings in seismic areas which could be displayed at the conference and used as a temporary reference library. At the end of the conference, many of the participants elected to leave the publications with the University of New Mexico to form a basis for a library which could be used to facilitate further exchange of information.

e. Field Trips

Two field trips were conducted during the conference. These included a visit to a large adobe brick production yard which produces stabilized adobe for use in the Albuquerque region, and a visit to the construction sites of several modern homes of stabilized adobe in the Albuquerque area. The following day the participants visited the historic Indian Pueblo of Tesuque, New Mexico, about 80 miles north of Albuquerque to observe adobe buildings several centuries old. They also inspected the test site of the Thermal Mass Study, a project sponsored by the Department of Housing and Urban Development and the Department of Energy, which is exploring the thermal properties of adobe buildings.

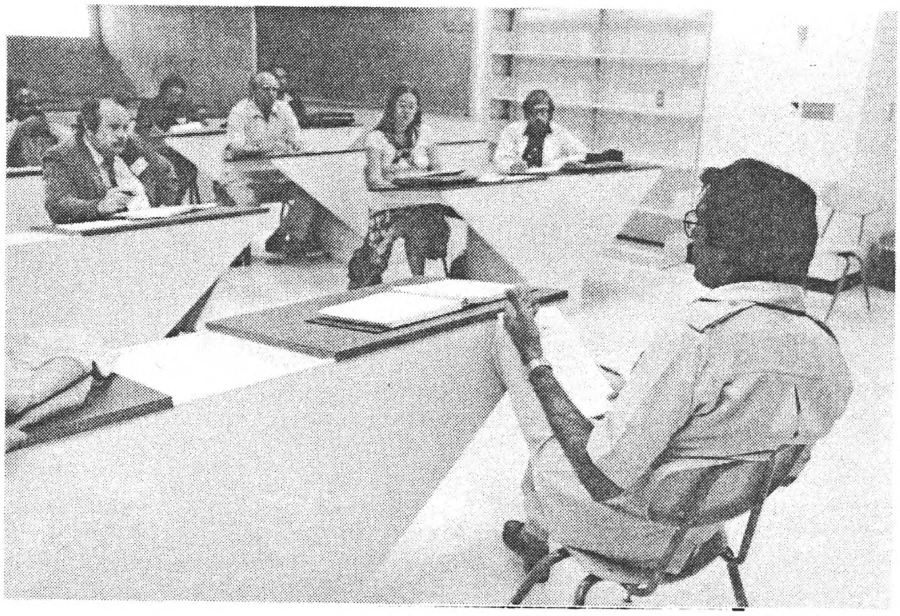

Figure 2. Discussion Group in Session.

Figure 3. Discussion Group in Session.

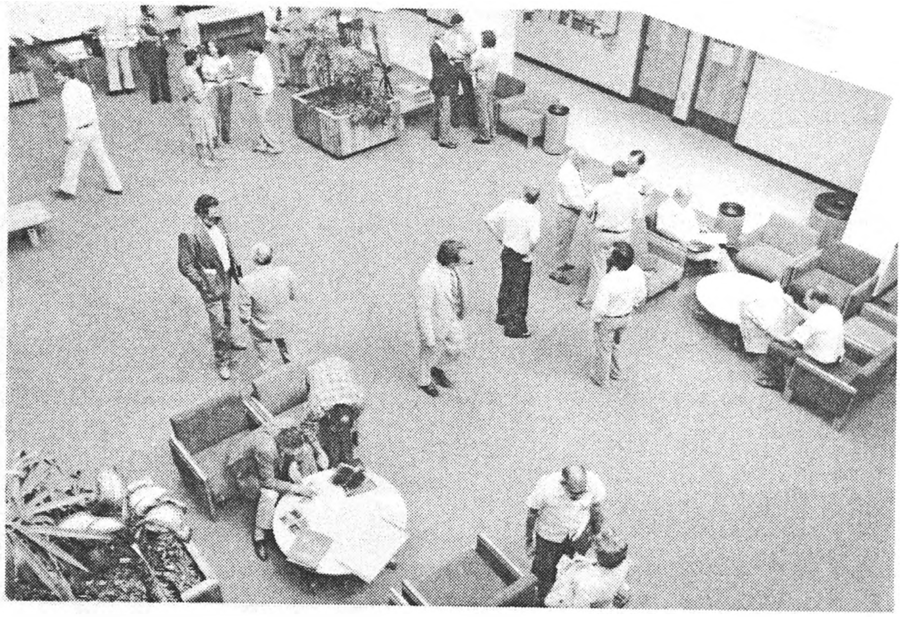

Figure 4. The central atrium, gathering place between sessions.

Figure 5. Jai Krishna and Haresh Shah relax.

Figure 6. Teddy Boen and Frederick Cuny in discussion.

Figure 7. Gerald May, William Haney and John Blume in informal discussion.

B. List of Conference Participants

INTERNATIONAL WORKSHOP

ON

EARTHEN BUILDINGS IN SEISMIC AREAS

List of Participants

Daniel Abrams
Assistant Professor of Civil Engineering
Dept. of Civil & Environmental Engineering
Box 428, University of Colorado
Boulder, Colorado 80302, U.S.A.

Rolando Acosta
Operations Officer
Appropriate Technology International (ATI)
1754 Massachusetts Avenue, N.W.
Washington, D.C. 20036, U.S.A.

Anil Kumar Agarwal
Director, Centre for Science and Environment
B-12 Press Enclave
New Delhi 110017, India

Chris Ahrens
VITA/World Bank Project Officer
1818 H Street, N.W., Rm. E-1036
Washington, D.C. 20433, U.S.A.

A. S. Arya
Professor, Dept. of Earthquake Engineering
University of Roorkee
23/B Civil Lines
Roorkee 247667, U.P., India

José Enrique Asturias R.
Chairman, CEMAT
8a. Calle 6-06, Zona 1
Edificio Elma 6° piso
Guatemala City, Guatemala, C.A.

Mahlon A. Barash
Housing Finance Advisor/Resident Technician
Cooperative Housing Foundation
c/o USAID
Avenida España 386
Lima 1, Peru

Robert E. Barnes
President, Robert E. Barnes & Assoc., Inc.
553 N. 4th Avenue
Tucson, Arizona 85705, U.S.A.

Frederick L. Bates
Professor of Sociology
University of Georgia
Athens, Georgia 30602, U.S.A.

Carlos Batista
Project Director
Tucson Barrio Association
43 West Simpson
Tucson, Arizona 88701, U.S.A.

Dr. Bazan
Universidad Nacional Autónoma de Mexico
Mexico 20, D.F.

Alecio Bejarano A.
Co-Administrator, Proyecto Anallajchi
International Voluntary Services, Inc.
Abdon Saavedra 1966 (Sopocachi)
Cajón 20190
La Paz, Bolivia

Michael Belshaw
Quinta el Santuario
Camp Wood Route
Prescott, Arizona 86301, U.S.A.

Stephen O. Bender
Chief of Project
OAS/Program of Regional Development
OEA/Casilla de Correo 320
Montevideo, Uruguay

John A. Blume
Chairman and Senior Consultant
URS/John A. Blume & Associates
130 Jessie Street
San Francisco, California 94105, U.S.A.

Teddy Boen
Director, International Association
for Earthquake Engineering
Kompleks BDN, 0.12, Letjen S. Parman
Slipi, Jakarta Barat, Indonesia

Gordon E. Bosl
Farmers Home Administration
517 Gold Avenue, S.W., Rm. 3414
Albuquerque, New Mexico 87102, U.S.A.

William E. Burk III
Burk & Burk Architects, AIA
1805 Indiana, N.E.
Albuquerque, New Mexico 87110, U.S.A.

Mark H. Butler
Architect/Housing Consultant
c/o 120 Grover Avenue
Princeton, New Jersey 08540, U.S.A.

Eric Carlson
Deputy Director, Appraisal
U.N. Centre for Human Settlements
(HABITAT)
P.O. Box 67553
Nairobi, Kenya

John Carney
Southwest Adobe Association
P.O. Box 10506
Alameda, New Mexico 87114, U.S.A.

Panayotis Gr. Carydis
Professor of Earthquake Engineering
National Technical University
42 Patission Street
Athens 147, Greece

Dan J. Cash
Deputy Group Leader
Los Alamos Scientific Laboratory
MS 978, Group G-2
Los Alamos, New Mexico 87545, U.S.A.

Luis Crisosto A.
Professor of Structural Engineering
Escuela de Ingeniería
Pontificia Universidad Católica de Chile
Casilla 114-D
Santiago, Chile

Chris Cuny
INTERTECT
P.O. Box 10502
Dallas, Texas 75207, U.S.A.

Frederick C. Cuny
Executive Chairman, INTERTECT
P.O. Box 10502
Dallas, Texas 75207, U.S.A.

Ian R. Davis
Principal Lecturer, Disasters &
Settlements Unit, Dept. of
Architecture
Oxford Polytechnic
Headington Oxford OX3 OBP, U.K.

Carolyn Dry
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550, U.S.A.

Mustafa Erdik
Associate Professor of Civil
Engineering
Earthquake Engineering Research Institute
Middle East Technical University
Ankara, Turkey

Amilcar Galindo
Tajín 280 B
Mexico 12, D.F.

Perry Joseph Gibbs
Director, Centro de Arquitectura/
Urbanismo para la Comunidad
P.O. Box 1870
Tucson, Arizona 85701, U.S.A.

Hugo Giuliani
Professor, Universidad Nacional de
San Juan
Avda. Lib. Gral. San Martín 1290, Oeste
5400 San Juan, República Argentina

Aybars Gürpinar
Staff Consultant
D'Appolonia S.A.
Boulevard du Souverain 100
B-1170 Brussels, Belgium

William Thomas Haney
Mimbres, Inc., Planners & Architects
P.O. Box 2672
Santa Fe, New Mexico 87501, U.S.A.

Thomas J. Harley
Vice President and General Manager
Hans Sumpf Company, Inc.
40101 Avenue 10
Madera, California 93637, U.S.A.

Volker Hartkopf
Associate Director
Institute of Building Sciences
Carnegie-Mellon University
Dept. of Architecture, Doherty Hall 1319
Pittsburgh, Pennsylvania 15213, U.S.A.

José Herrera Cano
Professor, Universidad Nacional de San Juan
Avda. Lib. Gral. San Martín 1290, Oeste
5400 San Juan, República Argentina

Rick Homans
Adobe Today Magazine
P.O. Box 1178
Belen, New Mexico 87002, U.S.A.

Gudrun H. Huden
Disaster Preparedness Officer
Office of U.S. Foreign Disaster Assistance (OFDA), Rm. 1262-A
Agency for International Development
Washington, D.C. 20523, U.S.A.

Vladimir C. Kalevras
Professor, Chair of Reinforced Concrete
School of Engineering
Democritus University of Thrace
Xanthi, Greece

W. O. Keightley
Professor of Civil Engineering
Dept. of Civil Engineering & Engineering Mechanics
Montana State University
Bozeman, Montana 59717, U.S.A.

Frederick Krimgold
Program Director, Earthquake Hazards Mitigation Program
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550, U.S.A.

Jai Krishna
Professor Emeritus
University of Roorkee
61, Civil Lines
Roorkee 247667, U.P., India

Robert W. Lamson
Program Manager
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550, U.S.A.

Golden Lane, Jr.
Eric H. Wang Civil Engineering Research Facility (CERF)
University of New Mexico
P.O. Box 25, Campus Post Office
Albuquerque, New Mexico 87131, U.S.A.

David Scott Luther
Fundación para el Desarrollo Comunitario
56 Max H. Ureña
Santo Domingo, Dominican Republic

Fortunato J. Maiolo
General Engineer
Agency for International Development
Rm. 206-E, SA-18
Washington, D.C. 20523, U.S.A.

G. C. Mathur
Director, National Buildings Organisation
"G" Wing, Nirman Bhawan
Maulana Azad Road
New Delhi 110011, India

Gerald W. May
Dean, College of Engineering
University of New Mexico
Albuquerque, New Mexico 87131, U.S.A.

Paul G. McHenry, Jr.
McHenry & Co.
P.O. Drawer 706
Corrales, New Mexico 87048, U.S.A.

Mary E. McKay
Consultant, Applied Technology Assoc.
2035 Rockingham Street
McLean, Virginia 22101, U.S.A.

John F. Meehan
Principal Structural Engineer
Office of the State Architect, Structural Safety
1500 5th Street, Rm. 101
Sacramento, California 95814, U.S.A.

Roberto Meli
Instituto de Ingeniería
Universidad Nacional Autónoma de Mexico
Mexico 20, D.F.

Claudio C. Merrifield
SAHOP
Mar Blanco 89-8
Mexico 17, D.F.

Naser Mostaghel
Professor, Civil Engineering Dept.
University of Utah
3012 Merrill Engineering Building
Salt Lake City, Utah 84112, U.S.A.

Babar Khan Mumtaz
Deputy Director, Development Planning Unit
University College, London
9 Endsleigh Gardens
London WC1H OED, U.K.

Lynn Nelson
HABITAT
Walnut Grove, California

David J. Oakley
Vice President, PADCO Inc.
7 Netherfield Road
Harpenden Hertfordshire AL5 2AF, U.K.

Paul Oliver
Associate Head, Dept. of Architecture
Oxford Polytechnic
Headington Oxford OX3 OBP, U.K.

Marco Tulio Ordóñez C.
Director, Dept. of Construction and Supervision
Consejo Nacional para la Protección de la Antigua Guatemala (C.N.P.A.G.)
Convento de Capuchinas
La Antigua Guatemala, Guatemala, C.A.

Ronald Parker
Program Director
Vecinos Mundiales (World Neighbors)
Apartado Postal #1, Villa de Etla
Oaxaca, Mexico

Kathy Parker
Coordinator for Production of Educational Materials
Vecinos Mundiales (World Neighbors)
Apartado Postal #1, Villa de Etla
Oaxaca, Mexico

Celina U. Penalba
Director of Research
Ministry of Housing & Human Settlements
Reparto Belmonte No. 21, Km. 6½
Carretera Sur
Managua, Nicaragua

Juan Manuel Perdomo R.
Gerente Administrativo-Financiero
Fundación Servicio de Vivienda Popular (SERVIVIENDA)
Calle 48 No. 14-61
P.O. Box 51681
Bogotá, Colombia

Eduardo A. Perez
Field Representative
Sister Cities International
1625 Eye Street, N.W., Suite 424
Washington, D.C. 20003, U.S.A.

Joseph M. Plecnik
Associate Professor, Structural Mechanics & Materials
Civil Engineering Dept.
California State University
Long Beach, California 90840, U.S.A.

Reza Razani
Professor of Civil Engineering
Shiraz University, Iran
c/o 21851 Fuller Avenue
Euclid, Ohio 44123, U.S.A.

Satwant S. Rihal
Professor, School of Architecture & Environmental Design
California Polytechnic State University
San Luis Obispo, California 93407, U.S.A.

James H. Rockwell
Technical Director
International Institute of Housing Technology
California State University
Fresno, California 93740, U.S.A.

Roberto Samanez A.
Director del Instituto Nacional de Cultura, Cusco
Apartado Postal No. 289
Cusco, Peru

Charles Scawthorn
Dames & Moore
500 Sansome Street
San Francisco, California 94111, U.S.A.

Janet Schnorr
Northern Arizona University
C.U. Box 1570
Flagstaff, Arizona 86011, U.S.A.

Haresh C. Shah
Professor of Structural Engineering
Director, J.A. Blume Earthquake
Engineering Center
Stanford University
Stanford, California 94305, U.S.A.

Lois Sherman
Freelance Journalist
Santa Fe, New Mexico 87501, U.S.A.

D. Neil Snarr
Chairman & Professor, Dept. of Sociology
Wilmington College
Wilmington, Ohio 45177, U.S.A.

Robin J. S. Spence
Dept. of Architecture
Cambridge University
1 Scroope Terrace
Cambridge CB2 1PX, U.K.

Urbano Tejada Schmidt
Director General (Encargado)
Oficina de Investigación y Normalización
Ministerio de Vivienda y Construcción
Copernico 207
Lima 32, Peru

Paul Thompson
INTERTECT
Thompson Architects
20½ East Mifflin Street
Madison, Wisconsin 53711, U.S.A.

Joseph M. Tibbets
Publisher, Adobe Today Magazine
P.O. Box 1178
Belen, New Mexico 87002, U.S.A.

Jerry Tobias
Department of Housing & Urban Development
(HUD)
Washington, D.C. 20410, U.S.A.

Rafael E. Torres
Professor, Depto. de Estructuras y
Construcción
Universidad Nacional de Ingeniería
Casilla 2812
Lima, Peru

Julio Vargas Neumann
Director de Investigación
Depto. de Ingeniería
Pontificia Universidad Católica del Perú
Apartado 12534
Lima 21, Peru

Joseph Vaughan
Adobe Today Magazine
P.O. Box 1178
Belen, New Mexico 87002, U.S.A.

A. James Viets
INTERTECT
P.O. Box 10502
Dallas, Texas 75207, U.S.A.

Frederick A. Webster
Consulting Engineer
Jamk R. Benjamin & Associates, Inc.
260 Sheridan Avenue, Suite 205
Palo Alto, California 94306, U.S.A.

Charles W. White
Robert E. Barnes & Associates, Inc.
553 N. 4th Avenue
Tucson, Arizona 85705, U.S.A.

Müfit Yorulmaz
Professor, Technical University of
Istanbul
Faculty of Architecture
Teknik Üniversite
Maçka, Istanbul, Turkey

C. Conference Schedule and Workshop Session Assignments

DATE	TIME/PLACE	
Sunday, May 24	7:30-9:30 p.m. Cabaret Room Hilton Inn	Reception and Registration
Monday, May 25	7:15 and 8:15 a.m. Hilton, AMF, Holiday Inn, Dollar Inn	Buses from Hotels to Campus
	8:00-9:00 a.m.	Late Registration (ME Bldg)
	9:00-9:15 a.m. Plenary Rm. 218 ME Bldg	Welcome: Gerald W. May Dean, College of Engineering University of New Mexico
	9:15-9:45 a.m. Plenary Rm. 218 ME Bldg	Opening Address: John A. Blume President, URS/J.A. Blume & Associates Past Pres. Earthquake Engineering Research Institute (EERI)
	9:45-10:15 a.m. Plenary Rm. 218 ME Bldg	Keynote Paper: W. O. Keightley Professor, Dept. of Civil Engineering Montana State University
	10:15-10:45 a.m. Plenary Rm. 218 ME Bldg	Keynote Paper: Ian Davis Disasters & Settlements Unit Dept. of Architecture Oxford Polytechnic
	10:45-11:00 a.m. Lobby, ME Bldg	Break
	11:00-11:45 a.m. Plenary Rm. 218 ME Bldg	Keynote Paper: Aybars Gurpinar Staff Consultant, D'Appolonia S.A.
	12:00-1:15 p.m. Patio, ME Bldg	Lunch
	1:30-2:00 p.m. Plenary Rm. 218 ME Bldg	NSF Programmatic Perspectives Frederick Krimgold Earthquake Hazard Mitigation Program Robert W. Lawson Appropriate Technology Program

DATE	TIME/PLACE	
Monday, May 25	1:30-4:30 p.m. Rms. 206, 208, 210, 214, 220, ME Bldg	Work Sessions: I, II, IV, V (English) III (Spanish)
	4:45 p.m.	Buses to Hotels
	Evening Open	
Tuesday, May 26	8:00 and 8:35 a.m. Hilton, AMF, Holiday Inn, Dollar Inn	Buses from Hotels to Campus
	9:00-9:15 a.m. Plenary Rm. 218 ME Bldg	Introduction: Frederick C. Cuny Executive Director, INTERTECT
	9:15-9:45 a.m. Plenary Rm. 218 ME Bldg	Keynote Paper: Eric Carlson U.N. Centre for Human Settlements (HABITAT)
	9:45-10:15 a.m. Plenary Rm. 218 ME Bldg.	Keynote Paper: Haresh Shah Prof. of Structural Engineering Stanford University
	10:15-10:30 a.m. Lobby, ME Bldg.	Break
	10:30-11:00 a.m. Plenary Rm. 218 ME Bldg	Keynote Paper: Roberto Meli Instituto de Ingenieria Universidad Autonoma de Mexico
	11:00-11:30 a.m. Plenary Rm. 218 ME Bldg	Keynote Paper: P. G. McHenry McHenry and Company, Albuquerque
	11:30-12:00 Noon Plenary Rm. 218 ME Bldg	Keynote Paper: Julio Vargas Neumann Director de Investigacion Departamento de Ingenieria Pontificia Universidad Catolica del Peru
	12:00-1:15 p.m. Patio, ME Bldg	Lunch
	1:30-4:30 p.m. Rms. 206, 208, 210, 214, 220, ME Bldg	Work Sessions: I, III, IV, V (English) II (Spanish)

DATE	TIME/PLACE	
Tuesday, May 26	4:45 p.m.	Buses to Hotels
	7:30 p.m. Hilton Inn	International Case Studies
Wednesday, May 27	8:00 and 8:35 a.m. Hilton, AMF, Holiday Inn, Dollar Inn	Buses from Hotels to Campus
	9:00-12:00 Noon Rms. 206, 208, 210, 214, 220, ME Bldg	Work Sessions: II, III (English) I, IV, V (Spanish)
	12:00-1:15 p.m. Patio, ME Bldg	Lunch
	1:30-4:30 p.m. Buses leave from ME Bldg; return to hotels	Corrales Tour Adobe yard, construction site
	6:00 p.m. Hilton, AMF, Holiday Inn, Dollar Inn	Buses to Old Town
	7:30 p.m. La Placita Restaurant Old Town, Albuquerque	Banquet Speaker: P. G. McHenry Buses return to hotels after Banquet.
Thursday, May 28	9:30 a.m. Hilton Inn only	Bus for Santa Fe Tour (Optional)
	5:00 p.m. Hilton Inn only	Bus returns from Santa Fe

SUGGESTED WORKSHOP ASSIGNMENTS

TUESDAY, May 26, 1981

SUBJECT AREA 1: SOCIAL, ECONOMIC & CULTURAL ASPECTS (English)

Bates
Bender
Cash
Davis
Gerbrandt (P)
Huden
Krimgold
Mathur (P)
McHenry
McKay
Murtz
Oakley
Scawthorn
Snarr (P)
Ural
Vargas

SUBJECT AREA 2: MATERIALS (Spanish)

Acosta
Crisosto
Giuliana
Ordonez
Penalba
Perdomo
Razani
Samanez Argumedo
Tejado (P)
*Torres

SUBJECT AREA 3: STRUCTURES (English)

Abrams (P)
Aytun
Barash
Bosl
Butler
Crosby
Kalevras (P)
*Keightly
Luther (P)
Maiola
Mostaghel (P)
K. K. Mumtaz
R. Parker
Rihal (P)
Shaw
Ural
Webster (P)
White
Yorulmaz

SUBJECT AREA 4: IMPLEMENTATION (English)

Agarwal
Arya
Asturias
Boen
Burk
Carlson
Haney
Hartkopf
*B. Mumtaz (P)
Oakley (P)
Oliver
K. Parker
Rockwell
Spence
Webster

SUBJECT AREA 5: CODES, SPECIFICATIONS AND STANDARDS (English)

Abrams
Agarwal
Aytun (P)
Barnes (P)
Burk
Erdik
Gurpinar
*Haney (P)
Jain
Kalevras
Meehan (P)
Webster
Yorulmaz (P)

* Session Leader

(P) Presenting a Paper

SUGGESTED WORKSHOP ASSIGNMENTS

MONDAY, May 25, 1981

SUBJECT AREA 1: SOCIAL, ECONOMIC & CULTURAL ASPECTS (English)

Agarwal
Asturias
Barash (P)
Butler
Carlson
Crosby
Harthopf
Jain
Luther
Maiola
B. Mumtaz
K. K. Mumtaz (P)
Oakley
*Oliver (P)
K. Parker

SUBJECT AREA 2: MATERIALS (English)

Bender
Boen
Burk
Kalevras
Meehan
Mostaghel
K. K. Mumtaz
Murty
*Plecnic (P)
Scawthorn
Spence
Yorulmaz

SUBJECT AREA 3: STRUCTURES (Spanish)

Acosta
Bejarano
Crisosto (P)
Giuliani (P)
Herrera
Meli
Ordonez
R. Parker
Penalba (P)
Perez
Tejada
Torres (P)
Vargas

SUBJECT AREA 4: IMPLEMENTATION (English)

Abrams
Aytun
Barnes
Bates (P)
Butler (P)
Davis
Erdik (P)
Gurpinar
Huden
*McKay
Snarr
White

SUBJECT AREA 5: CODES, SPECIFICATIONS AND STANDARDS (English)

Arya
Boen
Bosl
Cash
Krimgold
*McHenry
Razani
Rihal
Rockwell
Ural
Webster

*Session Leader

(P) Presenting a Paper

SUGGESTED WORKSHOP ASSIGNMENTS

WEDNESDAY, May 27, 1981

SUBJECT AREA 1: SOCIAL, ECONOMIC & CULTURAL ASPECTS (Spanish)

Acosta
Bejarano
*Ordonez
K. Parker
Peradomo
Perez
Samanez Argumedo (P)

SUBJECT AREA 2: MATERIALS (English)

Abrams
Crosby
Hartkopf
Huden
Keightley
Maiola
B. Mumtaz
Rihal
Rockwell (P)
Shaw
Webster
White

SUBJECT AREA 3: STRUCTURES (English)

Arya (P)
Aytun
Barnes
*Boen (P)
Burk
Cash
Davis
Erdik
Gurpinar
Jain
Krimgold
McHenry
McKay
Mostaghel
Murtz
Oakley
Oliver
Plecnic
Meehan
Rezani
Rihal
Scawthorn (P)
Snarr
Spence (P)
Webster

SUBJECT AREA 4: IMPLEMENTATION (Spanish)

*Bender (P)
Bejarano
R. Parker
Perdomo
Perez
Samanez Argumedo
Tejada

SUBJECT AREA 5: CODES, SPECIFICATIONS AND STANDARDS (Spanish)

Bates
Barash
Carlson
Crisosto
Giuliani
Herrera
Torres
*Vargas

*Session Leader

(P) Presenting a Paper

D. Products of the Conference

1. Documents

There are three documents which describe the work of the conference and present the papers prepared as a result of the conference. They are:

a. The Proceedings of the conference (papers submitted by invited participants as well as others who could not attend)

b. The Research Needs and Priorities

c. An annotated bibliography on earthen buildings in seismic areas and related topics.

The Proceedings will be published as two separate volumes, and the Research Agenda and Bibliography will be combined in a third volume.

2. Establishment of An International Working Group

During the last plenary session of the workshop, the participants elected to hold a meeting to discuss follow-up activities, to continue the work and spirit of the workshop. At a meeting on the final day, a group composed of more than one third of the participants voted to formally establish an international working group to work towards the goal of reducing vulnerability of earthen buildings in seismic areas. The group asked the conference organizers to serve as a focal point for the working group and to carry out the following activities:

a. To prepare a draft declaration describing the scope of the problem as established by the conference and citing the need for further research in order to reduce the problem. The purpose of this declaration is to bring the scope of the problem and need for more work in this critical area to the attention of the earthquake engineering community and the implementing agencies.

b. To establish the framework for an international effort to address the problem. The participants elected to formally establish an International Working Group on the Improvement of Earthen Buildings in Seismic Areas. This working group is to serve as a vehicle for information exchange among researchers and practitioners, and to sponsor follow-up activities to the conference.

c. To establish an information center. The participants asked the conference organizers to establish a center for the compilation and dissemination of information on earthen buildings in seismic areas and to provide a focal point for the exchange and translation of key documents in the subject area.

d. To prepare and publish a newsletter.

e. To organize immediate follow-up activities to facilitate coordination of research and standardization of reconnaissance, research and implementation activities.

II. STATE-OF-THE-ART AND RESEARCH NEEDS AND PRIORITIES

The research agenda is divided into five topic areas which coincide with the work groups that were established during the conference. They are:

A. Structures
B. Materials
C. Social, Economic and Cultural Aspects
D. Program Implementation
E. Building Codes, Specifications and Standards

The research agenda for each topic area is preceded by a description of the state-of-the-art as identified by the participants. The research topics are then identified and organized according to either priority or a logical progression of activity.

Each research need is presented with a descriptive statement, a description of the specific tasks and action required, and recommendations for implementation and support. This material was compiled from the notes of each of the discussion groups.

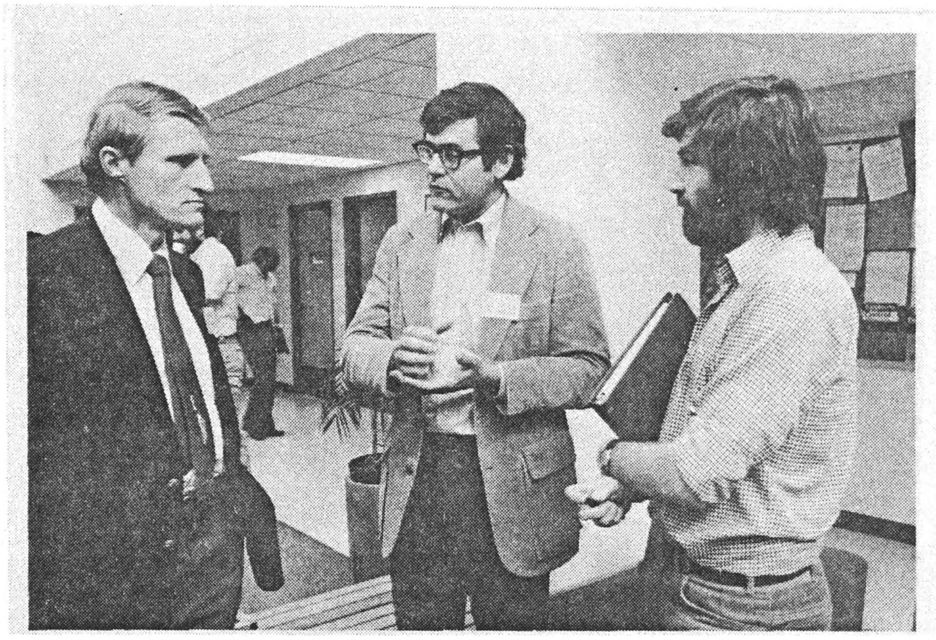

Figure 8. Gerald May, Frederick Krimgold and Robin Spence converse.

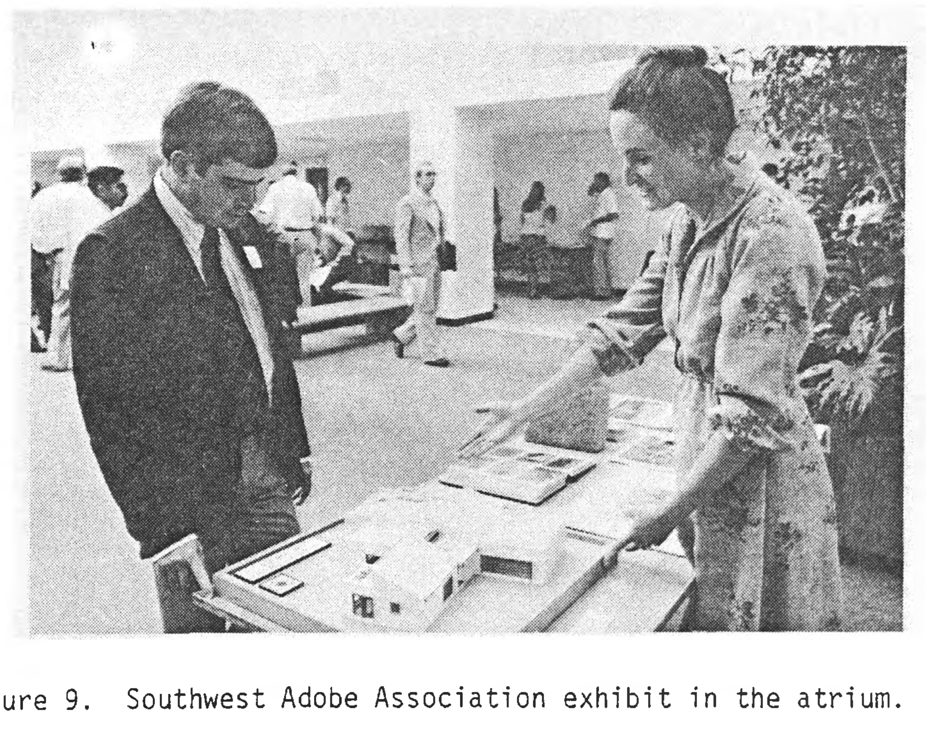

Figure 9. Southwest Adobe Association exhibit in the atrium.

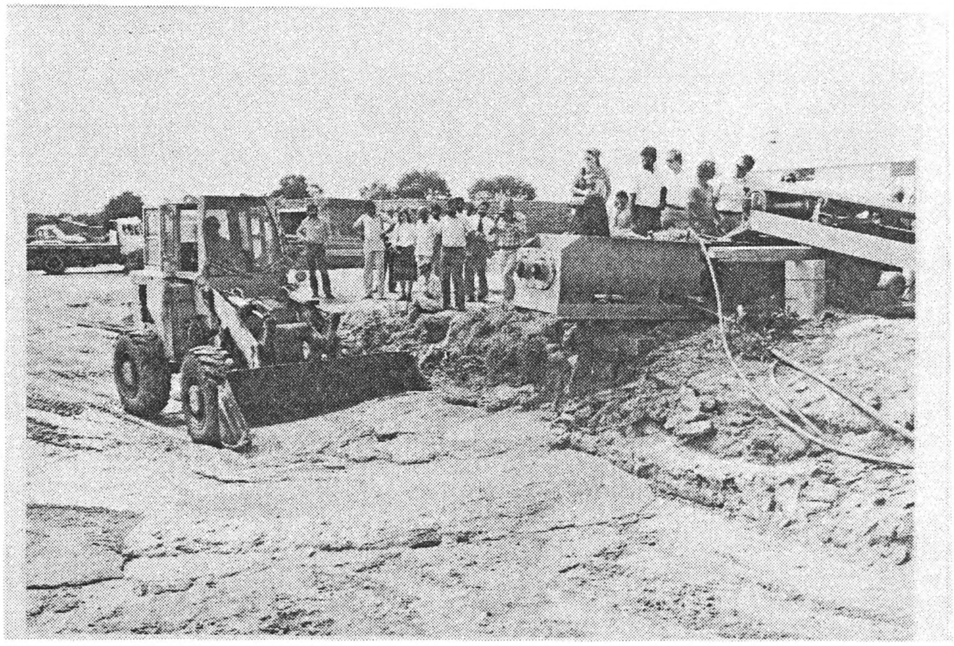

Figure 10. Field trip: a visit to an adobe manufacturing yard.

Figure 11. Mixing in the straw at the adobe yard.

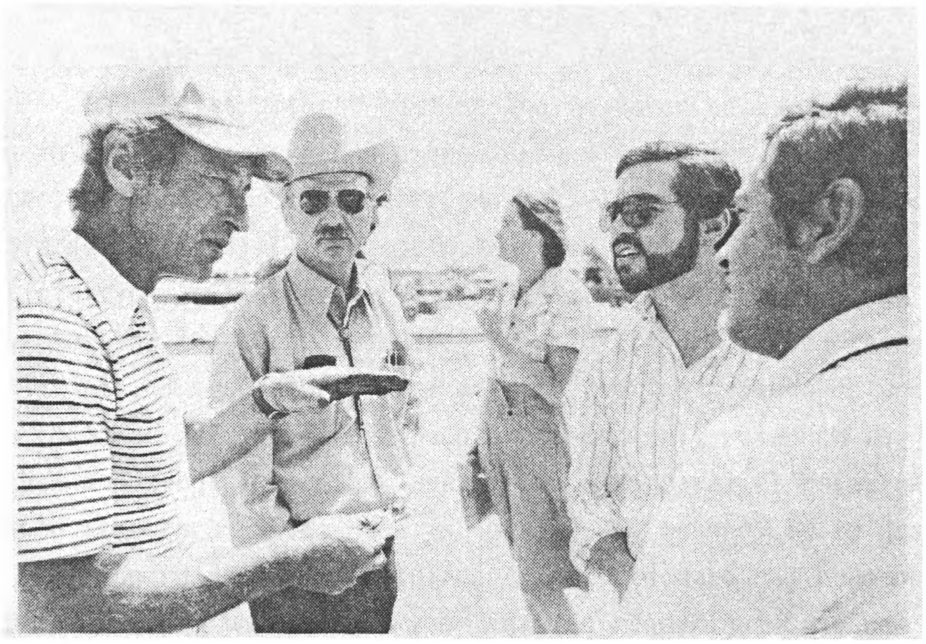

Figure 12. In discussion with the owner of the adobe yard.

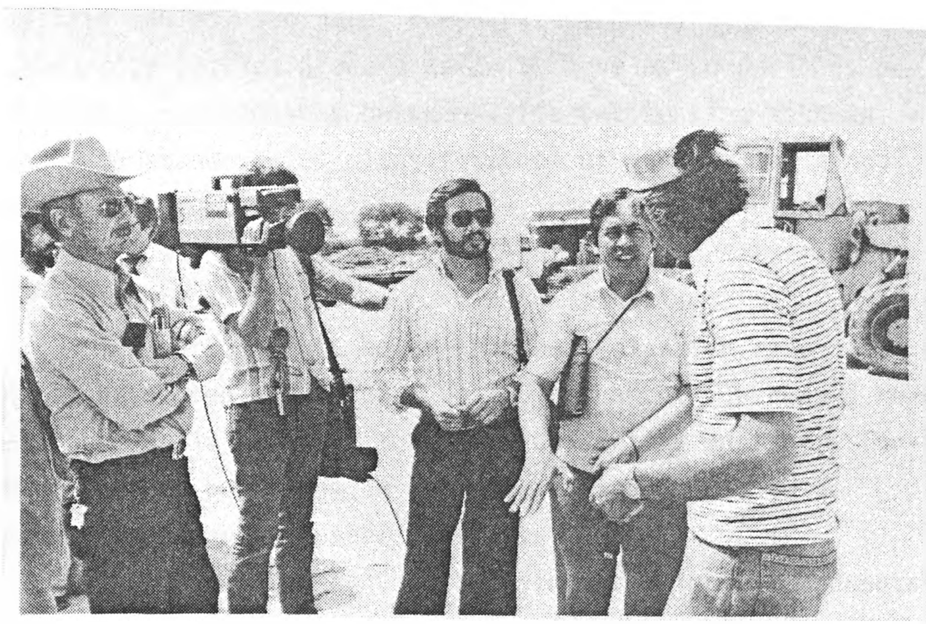

Figure 13. An interview with TV reporters.

SUBJECT AREA 1: STRUCTURES

A. State of The Art

While structural testing and research on earthen buildings in seismic areas has not been extensive in the United States, major research projects and activities have been conducted overseas, especially in Latin America. It was felt that U.S. participation in this area could benefit both the developing countries and the United States. By committing American research facilities and equipment to the effort, testing procedures and data could be developed which could aid not only research on earthen buildings in seismic areas, but also parallel research on related structural types such as low-quality masonry buildings.

Coordination of research efforts to date has been on an informal basis with the most coordination occurring among researchers in Latin America. A wide variety of testing methods and procedures have been developed to simulate earthquake loading conditions ranging from high technology shake tables to low technology tilt tables. To date, however, there has been no attempt to standardize testing procedures or to develop comparisons or establish the relationship between different testing methods.

No standardized classification of earthen buildings, materials or structures exists. This, combined with language difficulties, was seen as a major obstacle to coordination of research efforts.

The participants noted that post-disaster reconnaissance has developed little data to aid research. Increased reconnaissance activities and more data collection on the performance of earthen buildings in earthquakes was deemed to be essential for expanded research efforts.

The testing of earthen buildings and their components was seen to be at an early stage. Participants noted a need to establish priorities for the next decade of research and to identify opportunities for comprehensive cooperative research using the various laboratory facilities that are currently engaged in this work.

Before international cooperative efforts can be established, however, it was felt that certain activities to standardize testing practice sould be initiated. Among the activities listed were:

1. Development of testing standards.
2. Defining the intent of testing.
3. Establishing valid scaling laws for experimental tests.
4. Establishing the relationship of different testing procedures and methods.

It was noted that more research to date has concentrated on adobe buildings. While it was recommended that adobe should retain a high priority, other types of earthen buildings are also found in large numbers in the seismic regions. Participants noted the need to especially examine rammed earth and wattle-and-daub construction commonly found throughout Latin America.

Participants also noted a need for closer liaison with related earthquake engineering research, especially in low-quality, unreinforced masonry construction. It was felt that much of the work on earthen buildings could be related to research on low-quality masonry, especially the development of testing procedures, terminologies, etc.

The difficulties of instrumentation of earthen buidings under actual seismic loading conditions were also noted. Instrumentation is difficult due to the nature of the materials and variations in construction techniques and workmanship. Thus, most information to date has been limited to "before and after" comparisons and studies of buildings damaged in earthquakes. New methods for instrumenting and/or observing earthen buildings under seismic conditions was deemed a high priority.

B. Research Agenda

The structures research agenda is divided into four parts: Standardization and coordination of research, documentation, testing, and priorities.

1. Standardization and Coordination

a. Coordination of Research Efforts

(1) Statement

Due to the limited number of researchers and institutions involved in research on earthen buildings in seismic areas, research efforts sould be more coordinated and cooperative research programs should be instigated.

(2) Action

To provide cordination and stimulation of cooperative research, an international network of researchers and institutions engaged in the field should be established. To be effective, this network should have a central information clearing house and should publish periodic newsletters and organize periodic meetings, both in the regions and at an international level, to encourage further exchange of information among researchers.

(3) Implementation

As a result of the workshop, a group of the participants agreed to formally establish an International Working Group on the Improvement of Earthen Buildings in Seismic Areas. The objectives of this group are to promote continued research into all aspects of the problems of earthen building in seismic areas to stimulate cooperative research; to provide a focal point for the exchange of information; and to work with the existing earthquake engineering research organizations to stimulate new interest in this topic.

It is hoped that the sponsors of this conference and other organizations will support the working group and its activities.

b. Standardization

(1) Statement

In order to facilitate coordination and to encourage cooperative research, standard classification and nomenclature must be established.

(2) Action

It is recommended that an international committee of researchers be convened to establish common classifications and nomenclature required for international research. Standardization should cover:

(a) Materials

(b) Building systems

(c) Building forms

(d) Damage descriptions

It is recommended that the classifications be in both English and Spanish.

(3) Implementation

It is the intent of the newly formed International Working Group to convene within one year an international meeting of experts to define common terminology and classifications. It is hoped that the sponsors of the workshop will continue to support this activity and provide assistance to enable members of the committee to attend the meeting.

2. Documentation

a. Reconnaissance

(1) Statement

Increased post-disaster reconnaissance efforts are required in order to develop a base of data for structural research.

(2) Action

In order to improve the quality of the data developed by reconnaissance surveys, the adoption of standard evaluation procedures and forms is required.

In order to provide the needed data, increased reconnaissance missions should be supported. Reconnaissance teams now responding to earthquakes should be expanded to include specialists in earthen construction. Regional researchers in this field should be supported to participate in international efforts.

Reconnaissance should not only examine buildings which failed but also those that survived. The surveys should also seek to identify traditional forms of architecture and construction which are effective against earthquakes but which have fallen into disuse.

(3) Implementation

The international committee established to develop standards (mentioned above) should develop and adopt standard reconnaissance procedures and formats.

It is recommended that NSF encourage the Earthquake Engineering Research Institute and other organizations engaged in reconnaissance activities to include specialists on earthen buildings in the reconnaissance teams where applicable.

It is recommended that the International Working Group identify a number of researchers in various regions who could participate in reconnaissance efforts. This list should be provided to EERI and other organizations engaged in reconnaissance activities.

b. Defining the Scope of the Structural Research Agenda

(1) Statement

Research to date has concentrated on the types of buildings found in those countries where the research efforts have been undertaken. It is recognized that a wide variety of other types of architectural forms, construction techniques, and uses of earthen materials exist. It is, therefore, necessary to undertake a broad examination of the use of earthen buildings in seismic areas and to identify the various structural systems now in use.

(2) Action

Coordinated research efforts to identify the principal and most critical structural aspects of earthen buildings should be undertaken on both macro and micro levels. Using the standard classification recommended earlier, efforts should be supported to identify the various structural systems in use and to determine the prevalence of various non-structural components and features (such as partitions, stairs, parapets and ornamental features).

(3) Implementation

The collection of the data at a macro level will require support from numerous organizations. Some of the data may in fact, already exist from other sources. Efforts, therefore, should be focused on supporting research, compiling existing data, and supporting efforts to identify and classify structures where data is not now available.

c. Compilation of Data

(1) Statement

The compilation and dissemination of data concerning structural aspects of traditional housing should be centralized.

(2) Implementation

This activity sould be a function of the International Working Group established as a result of the workshop.

3. Testing

a. Standardization of Testing Procedures

(1) Statement

Various methods have been developed to test earthen buildings under simulated earthquake loading conditions. The relationship between the various methods utilized however, has not been established. Comparative data needs to be developed in order to be able to equate the different systems.

(2) Action

Four activities are required in order to establish the relationship between various testing methods:

(a) Identical structures should be tested dynamically at full scale and at several smaller scales to establish reliable scaling laws.

(b) Tests on the large scale test platforms (tilt table, and rolling stock test bed) should be conducted to determine the relationship between the various testing methods.

(c) Blast tests on full scale buildings should be conducted and equated with both the large-scale and small-scale tests.

(d) The relationship between the full-scale tests and small-scale tests should be established.

(3) Implementation

Establishment of the relationship between the various testing procedures and methods will require an international cooperative effort. Unique testing facilities have been developed in India (the rolling stock test facility) and Peru (tilt table) which could be equated and compared to various-sized shake tables in the United States.

Cooperative research could be supported under a number of funding programs within the National Science Foundation and through monies from other interested organizations such as A.I.D., UNESCO, and Andean Pact.

b. Instrumentation

(1) Statement

The instrumentation of earthen buildings under actual or simulated seismic loading conditions is difficult due to the nature of the materials and variations in construction techniques and workmanship. New methods for instrumenting and/or observing earthen buildings under various seismic conditions is required.

(2) Action

New methods and equipment for instrumenting and observing earthen buildings should be developed. Instrumentation techniques developed for research on unreinforced, low-quality masonry may be applicable for use in earthen buildings.

c. Implementation

NSF is encouraged to support research on new methods of instrumenting and observing earthen buildings during seismic events.

4. Repair and Strengthening of Earthen Buildings

a. Statement

To date, little research on the repair and strengthening of earthen buildings in seismic areas has been conducted.

b. Action

Increased research on repair and strengthening of earthen buildings should be conducted. Especially important is research on surface coating which would increase seismic resistance, epoxy injection, and retrofitting strategies.

c. Implementation

It is recommended that current research on the use of surface coatings and epoxies be broadened to include the potential for the application of these materials to earthen buildings.

5. Research Priorities

The following is a list of research priorities identified by the workshop participants:

a. Architectual forms and structural systems which will result in more uniform stress distribution to minimize reinforcement requirements should be identified.

b. Research on different types of reinforcing systems including wood and steel should be expanded.

c. Research on alternative lightweight roofing systems that are culturally acceptable should be conducted.

d. Studies on reinforced concrete or other frames using adobe as an infill material should be conducted.

e. Research on the effects of non-structural components on the earthquake resistance of adobe structures should be conducted. Research should include:

(1) Interior partitions

(2) Stairs

(3) Parapets

(4) Ornamental features

(5) Verandas and porches

f. Research to determine the behavior of poured adobe should be initiated.

g. Research on the behavior of rammed each structure should be expanded.

h. Research on the causes of understress should be conducted.

i. In situ testing of full size structures should be conducted.

j. Blast tests to determine the dynamic resistance and response of earthen structures should be conducted.

k. Research on strengthening and repair of earthen buildings should be initiated.

l. Simple analytical methods for design application should be developed.

m. The effect of soil/foundation interaction should be investigated.

n. Simple methods of field testing for use by building officials and local builders should be developed.

SUBJECT AREA 2: MATERIALS

A. State of The Art

Most research on earthen materials used in houses in seismic areas has concentrated on examinations of various types of adobe buildings. Extensive research on adobe was conducted at three different periods. At the turn of the century, extensive research on adobe was carried out by the Department of Agriculture and several universities in the Land Grant system. The research focused on means of improving individual adobe blocks. Little of this research addressed seismic issues.

In the 1930's and 1940's, earthen building materials were again examined in some detail. During this time, asphalt was introduced and promoted as a stabilizer for adobe. Some limited research was conducted on the properties of adobe buildings and their seismic resistance.

In the 1970's, an extensive international research effort was begun in response to the widespread damage that was observed in the 1970 Peruvian earthquake. Research efforts to develop low-cost, stabilized adobe were conducted under a joint effort of the National Bureau of Standards, Fresno State University and several private companies in conjunction with several Latin American counterparts. In Peru, a major program of research on earthen buildings and adobe was conducted by the government of Peru and several participating universities.

Until the late 1970's , the majority of efforts focused on improving the quality of the adobe block through the addition of asphalt and other synthetic stabilizers. However, as petroleum costs increased during the 70's, the asphalt materials most favored have become too costly for use in building in the Third World. In the United States, the materials are still relatively affordable, though here too rising costs are beginning to have an effect. Thus, in materials research, a plateau of sorts has been reached. It was felt by the participants that alternative means of stabilizing earthen materials need to be examined and newer low-cost methods, especially those which utilize local materials which can be obtained at little or no cost, should be explored. The types of materials which should be examined include natural resins and fibers found in the plants of many developing countries, as well as low-cost industrial products.

The participants also identified the need to conduct research on other types of earthen construction methods found in seismic areas. While it was agreed that adobe should continue to receive a high priority, more work should be directed toward rammed earth structures and other types of earthen buildings.

Alternative means of providing protection for earthen buildings was also felt to be a high priority. It was noted that there has been some research on the use of exterior coatings for prolonging the life of earthen materials as well as limited research on surface bonding. It was felt that both areas required further research and that priorities should be given first to developing surface treatment for low-cost housing in areas of high rainfall and second, to developing treatments for preserving historic buildings.

While participants noted that there were a number of notable research efforts and recent publications on material-related topics, international exchange of information has been relatively limited due to both linguistic barriers and lack of a central coordinated network among those working in this field. It was felt that the existing earthquake engineering organizations should be encouraged to give more attention to this area and that a formal network of researchers engaged in work on earthen materials should be established.

B. Research Agenda

1. Establishment of a Data Bank

a. Statement

A considerable amount of both experimental and performance data about various types of earthen buildings in seismic areas has already been developed. Hence, the first priority should be the creation of a data bank on all existing information available on earthen materials and earthen construction.

b. Action

As an outgrowth of this workshop, a number of the participants voted to formally establish an international network of researchers and practicioners to coordinate and exchange information on activities related to earthen buildings in seismic areas. As a part of this effort, the participants asked the conference organizers to establish a center for the collection and dissemination of information related to this effort.

c. Implementation

The conference organizers are currently working to establish the network and information center as recommended by the conference participants. It is hoped that the sponsors of the conference and other interested organizations can help provide resources and support for these activities.

2. Standardization of Terminology and Testing Procedures

a. Statement

It was found that variations in the terminology relating to earthen buildings and the non-standardization of tests often hamper international exchanges of information on materials research related to earthen buildings in seismic areas.

b. Action

It is recommended that classification, nomenclature and testing procedures be standardized. An international committee of the principal researchers in the field should be established to define common terminology and to establish common testing procedures.

c. Implementation

The international committee recommended above should accomplish its tasks through regional meetings of experts coordinated under the direction of the International Working Group established at this workshop. The first meetings of the committee should coincide with other international meetings which numbers of the committee would normally attend, thereby reducing costs.

It is recommended that American participation in these committees be supported by NSF and that foreign participation in these standardization efforts be supported by A.I.D., HABITAT, Appropriate Technology International and UNESCO.

3. Material Properties

a. Statement

Further research on the key factors and properties of adobe blocks and their influence on seismic resistance of earthen buildings is required.

b. Action

It was recommended that further research should be conducted to determine the effect of material properties of adobe blocks on seismic resistance of structures. The following research topics were identified:

(1) The effect of soil gradation and type.

(2) The effect of water impurities (such as salinity).

(3) The effect of water content on fabrication and strength.

(4) The identification of alternative types of stabilizers.

(5) The relative effectiveness of various types of stabilizers commonly used (example: straw, cement, lime, asphalt, etc.) and their relative effectiveness in increasing strength and durability.

(6) Research on the optimum size and shape of adobe blocks for purposes of seismic resistance in different sizes of structures.

c. Implementation

It was recognized that substantial progress in this research has already been made in several foreign laboratories. Thus, it was recommended that the majority of the research effort be continued in these locations and that American researchers be supported to participate in these efforts.

It is recommended that NSF continue to support American participation in these activities through programs such as Science in the Developing Countries and through cooperative U.S. and foreign projects.

It is recommended that U.S. institutions which have extensive experience or recent work in stabilization and materials research be encouraged to expand these efforts and that their work be supported by NSF.

It is recommended that A.I.D continue to support international research efforts and foreign national research in this field.

It was felt that both A.I.D. and NSF could play a central role in coordinating research efforts and the exchange of information simply through the use of their good offices and awareness of activities in both the foreign and domestic sectors. Thus, the participants urged that NSF and A.I.D. establish an informal liaison group to keep each organization apprised of developments in this field.

4. Mortar Joints

a. Statement

Analyses of adobe structures following recent earthquakes suggest that the majority of failures occur at the brick-mortar interface.

b. Action

Research studies on the development of greater bond strength between the adobe block and mortar joints should be conducted.

c. Implementation

It was felt that the international organizations and institutions which have already conducted extensive research on earthen material should be supported for research on bonding. It is recognized however, that recent developments and research from related fields (such as unreinforced, low-quality masonry) may play a significant role in this task. A study should be made to determine the applicability of this information to adobe masonry. Therefore, increased interchange between U.S. and foreign research institutions is encouraged, and support for joint U.S. and foreign cooperative research should be supported by a variety of institutions including NSF, A.I.D., UNESCO and HABITAT.

5. Field Test Procedures

a. Statement

Standardized experimental tests which can be readily performed, even in remote locations, to determine the properties of earthen materials and what is needed to effectively prepare and strengthen the materials for use in construction should be developed.

b. Action

Research should be conducted to develop simplified field methods for soil sampling and testing for earthen materials to be used in construction of housing. These construction aids should be designed to:

(1) Assist local builders in determining the best soils for use in preparing earthen materials.

(2) Provide guidance on the best types of stabilizing materials to use with the soils.

(3) Provide guidance on the best types of mortar to use with the blocks.

(4) Provide information on the related construction aspects such as recommended reinforcing systems, maximum size and width of walls, and general data relating to the configuration of the building.

This data should be standardized to the greatest extens possible and should include only those tests which can be readily performed with minimum scientific knowledge.

c. Implementation

It is recommended that Appropriate Technology International and other appropriate technology groups support the development of these construction aids.

Since construction aids of this type would be beneficial in any locale where earthen buildings are used, cooperative research and development should be encouraged.

6. Research on Non-Earthen Materials Commonly Used in Conjunction With Earthen Buildings

a. Statement

Research on non-earthen materials commonly used in construction of earthen buildings (such as wood, cane, straw, etc.) and their properties and performance when used in earthen buildings under seismic loading conditions is not presently adequate.

b. Action

First, research is needed to define the durability and performance of wood and other non-earthen materials in adobe construction. Especially important is an analysis of the interaction between earthen materials and reinforcement under seismic loading conditions. Both full-scale and small-scale testing is required.

Second, research is needed on durability of wood and other structural elements commonly used. Priority should be given to simple, lowcost methods of prolonging the life of wood in earthen buildings.

c. Implementation

It is recommended that NSF support research in this area. Bracing systems of wood, concrete, etc., using earthen materials as an infill, were seen as a research objective which could benefit from U.S. testing facilities.

7. Effect of Climatic Conditions on Earthen Buildings

a. Statement

Little information exists concerning the effects of extreme climatic conditions on the seismic performance of earthen buildings.

b. Action

Research should be carried out to improve earthen materials under varying climatic conditions, including rain, freeze/thaw cycles and various wind and erosion conditions. Research should include:

(1) Development of information on the changes to the material properties under various climatic conditions.

(2) Development of recommendations for reducing adverse climatic effects (such as the use of coatings and sealants).

c. Implementation

It is recommended that research in this field be carried out in two parallel programs. First, foreign research institutions with extensive earthen materials research capabilities and experience should be supported for further research on the changes in material properties due to climatic exposure. Second, it is recommended that NSF support domestic research related to development of coatings, sealants, and stabilizing materials which could strengthen the materials under varying conditions.

The overall research should be coordinated through periodic meetings of the researchers involved and an exchange of researchers during parts of the program.

It is recommended that NSF support the domestic research component under a joint U.S. and foreign cooperative research program.

8. Effect of Material Properties on Structural Behavior

a. Statement

The interaction betwen structural design and material characteristics of earthen buildings under seismic loading conditions is not fully known.

b. Action

The interaction between structural design and material characteristics should be investigated by means of both full-scale and small-scale tests.

c. Implementation

Joint U.S. and foreign cooperative research should be supported on this topic with full-scale tests being conducted internationally and small-scale tets being conducted at U.S. facilities. It is recommended that NSF support the small-scale testing components as part of a comprehensive U.S. and foreign research program and that A.I.D. participate in the support of the foreign research institutions.

SUBJECT AREA 3: SOCIAL, ECONOMIC, AND CULTURAL ASPECTS

A. State of The Art

The participants noted that there is a need for more information about the inter-relationship of the social, economic and cultural aspects of indigeneous buildings in seismic areas. The failure to develop this data was cited as the principal reason why vulnerability reduction efforts have not been more successful. The participants felt that researchers and engineers have not been sensitive to this complex balance and thus many structural modifications have not been accepted by the people they were designed to help.

A number of both engineers and social scientists present felt that the technology for safe construction of earthen housing in seismic areas has been growing faster than the actual application of the various techniques. The reasons cited for this were summarized as follows:

1. A lack of understanding of the social, economic and cultural aspects of the problem.

2. A lack of cumulative and comprehensive collection of information existing about the topic.

3. A lack of interaction between social scientists and earthquake engineers.

4. Insufficient communication between all levels of a program, from the engineer/designer to the occupant.

5. A lack of understanding of the techniques of successful technology transfer and the cultural and economic obstacles which must be overcome.

It was noted that actual vulnerability reduction efforts to date have been fairly limited; thus, the existing state-of-the-art is not well defined. If adequate research is carried out within the next few years, vulnerability reduction efforts can be influenced substantially.

B. Research Agenda

1. Standardized Terminology

a. Statement

In order to facilitate coordination, research and implementation, standardized terminologies, definitions, and classifications are required.

b. Action

An international committee of the principal researchers in the field should be established to define the common terms, etc. This committee should:

(1) Establish the nature and variety of earthen buildings in worldwide use. This should be presentd as a taxonomy of building forms, types and materials.

(2) Establish the cultural context in which earthen buildings are used.

(3) Establish the social and economic relationship between earthen buildings and disaster vulnerability.

c. Implementation

These objectives should be accomplished through regional meetings of experts coordinated by a central project manager. Terminologies should be in English and Spanish.

2. Cultural Mapping

a. Statement

Detailed cultural mapping on both a macro and micro scale is required in order to further identify and define the scope of the problem.

b. Action

Research projects on a regional and country-by-country basis should be supported. Mapping should include:

(1) Popular building features which affect seismic resistance of a building.

(2) Traditional forms and their influence on seismic resistance.

(3) Cultural influences, preferences, customs, etc., which affect building construction.

(4) Legal or governmental regulations which affect building construction.

Specific topics which should be examined are:

(a) Urban building patterns

(b) Rural building patterns

(c) Local building skills

(d) Perceptions of risk and vulnerability and how they affect design and construction of housing.

c. Implementation

These objectives should be carried out in two ways. First, U.S.A.I.D., HABITAT Center and the World Bank should be encouraged to support local research and mapping efforts in countries with a high number of earthen buildings. To facilitate this work, a standardized format for such efforts should be adopted (this should be a task of the committee described in paragraph 1(b) above).

Second, NSF, U.S.A.I.D, HABITAT and the World Bank should support regional mapping efforts, compiling the work accomplished at the country level into regional and worldwide atlases.

3. Economic Factors

a. Statement

Research is required to collect data related to the economic factors involving earthen building systems.

b. Action

Research is required to determine the economic aspects and implications of earthen buildings, focusing on:

(1) An evaluation of construction costs/ maintenance costs correlated to the anticipated life of buildings in both existing and proposed earthen building types.

(2) An analysis of the relative cost benefits of improvements to earthen buildings in comparison to complete relocation of alternative methods of construction.

(3) The development of a comprehensive data base describing construction techniques which provide maximum earthquake tolerance at minimum costs.

c. Implementation

It is recommended that NSF support further research on economic factors related to housing modification and vulnerability reduction.

It is recognized that much of the needed data also pertains to other types of structures both in the U.S. and abroad. Therefore, portions of the necessary research can be non-specific to earthen buidings and earthquakes. Thus, NSF is encouraged to support a broad range of research on societal and economic factors to develop the required data. It is recommended that existing societal research be expanded to include those issues specific to earthen buildings in seismic areas.

Such studies as A.I.D., A.T.I., and HABITAT can assist in these efforts by supporting in-country efforts to develop social-economic data relating to program implementation.

It is recommended that NSF, A.I.D. and A.T.I. establish an informal liaison group to encourage broader interchange between U.S. and foreign scientists and researchers engaged in these efforts. Programs such as NSF's Science in Developing Countries (SDC), A.I.D's Invitational Travel Funds, and various foreign currency programs can provide much needed support for international interchange.

4. Defining the Urban Versus Rural Context

a. Statement

The social and economic differences between the use of earthen buildings in urban and rural settings and their influences on construction and safety should be defined.

b. Action

Research is required to determine the essential social, cultural and economic differences and similarities when earthen buildings are used in urban and rural areas. Specifically, comparative research is required on:

(1) Investment levels

(2) Differences in building costs

(3) Differences in construction and maintenance practices.

(4) Changes in the building process dictated by a change from rural to urban settings.

(5) Changes in site selection and development necessitated by changing from a rural to an urban context.

c. Implementation

It is recommended that research on these topics should be supported by the National Science Foundation, the World Bank, and HABITAT Center.

5. Psychological and Social Aspects of Intervention

a. Statement

The impetus to modify earthen buildings is normally a result of planned housing improvement programs. Little information exists concerning the psychological and social factors related to this type of intervention and the impact of such interventions on both families and the society in which they occur.

b. Action

New research on the psychological and social aspects of intervention should be conducted. In particular, research should be directed towards:

(1) Identification of the psychological and social impact of various intervention strategies.

(2) The relationship of the psycho-social impact of intervention in relation to the benefits of vulnerability reduction.

(3) The impact of the introduction of new materials and/or new or adapted technologies. This should also be viewed in terms of the impact on rising aspirations for social and economic development.

(4) The social implications and factors affecting acceptance or rejection of building codes.

c. Implementation

The impact of intervention and various intervention strategies is a vital concern not only to U.S. hazard mitigation efforts but also to foreign aid programs. Thus, research in this area should be supported by many different types of institutions. NSF can support these efforts through research on societal aspects of earthquake hazard mitigation.

Implementing agencies such as U.S.A.I.D., the World Bank and various non-governmental organizations involved in housing mitigation and vulnerability reduction efforts should be encouraged to support these efforts through evaluations and assessments of past intervention programs.

6. Longitudinal studies

a. Statement

Often a project's post-documentation and evaluation are conducted immediately after implementation. Therefore, the long-range effects of a program are not fully known.

b. Action

Longitudinal studies should be conducted to document and evaluate various implementation approaches over extended periods of time following implementation. Studies should especially identify the specific aspects of a program which are continued without support at the end of the intervention.

c. Implementation

It is recommended that an increased number of longitudinal studies be supported by NSF. It is recommended, however, that the longitudinal studies focus on various aspects of modification efforts rather than on comprehensive assessments of all aspects of a particular disaster.

7. Cost-Benefit of Various Hazard Mitigation Strategies

a. Statement

Little information is known about the comparative cost-benefit relationship between various alternative strategies to reduce vulnerability of earthen buildings in seismic areas.

b. Action

Research should be conducted to define the trade-offs between risk reduction strategies including an examination of the potential social and economic consequences of the various alternatives. In particular, a comparative analysis should be made of:

(1) Relocation from vulnerable sites versus structural modification to reduce vulnerability.

(2) The comparative advantages and disadvantages of changing from earthen buildings to other types of materials and the social and economic consequences of such changes.

c. Implementation

Relocation is a strategy often proposed as a vulnerability reduction alternative. Several relocation programs have been attempted in the developing countries. Thus, NSF is encouraged to support research on these programs. The information can be useful to U.S. program planners for comparative purposes, and to Third World program officials for immediate application in post-earthquake reconstruction programs.

8. Social Input in Structural Research

a. Statement

Many of the techniques which have been developed to modify and strengthen earthen buildings in seismic areas have proven to be too expensive or too sophisticated to use. It is believed that much of this reserch could have resulted in more practical applications had adequate social-science inputs been made early in the research and development process.

b. Action

When dealing with low-cost, non-engineered buildings normally built without the influence of building codes or specifications, it is imperative that social factors be considered from the very beginning of any structural or material research program. Increased interaction between social scientists, housing program implementers and structural and material researchers is required.

c. Implementation

Increased interaction between social scientists, program implementers and earthquake engineers can be effected in two ways:

(1) NSF should encourage increased participation by social scientists in earthquake engineering research programs directed at non-engineered buildings.

(2) The inter-disciplinary network which has been formed as a result of this workshop should be further supported by the sponsors of the workshop. A preliminary activity that should be encouraged is the development of a roster of qualified and experienced social scientists and program implementation personnel who can assist earthquake engineering research.

9. Perceptions of Risk

a. Statement

Information concerning people's perception of risk and the relative priority that risk and vulnerability reduction play in the lives of persons living in earthen buildings in seismic areas is generally lacking.

b. Action

Research on the concept of risk and perceptions of vulnerability is necessary in order to facilitate the planning of vulnerability reduction efforts. Research sould be directed towards:

(1) Developing definitions of risk and vulnerability in both real and relative terms.

(2) Determining how perceptions of risk and vulnerability affect community lives.

(3) Identifying cultural adaptations to vulnerability in the local, indigineous architecture.

(4) Identifying societal and organization coping mechanisms which have developed in response to risk and vulnerability.

c. Implementation

Research on perceptions of risk and societal adaptations to risk and vulnerability should be carried out in both the United States and overseas. International efforts should be supported as lessons and information developed from abroad may provide information useful to hazard mitigation programs in this country.

SUBJECT AREA 4: PROGRAM IMPLEMENTATION

A. State of The Art

Much of the discussion about efforts to reduce vulnerability and improve earthen buildings in seismic areas focused on the lack of information about past experience and highlighted the fact that extensive program implementation activities have not yet been conducted on a large scale. With a few notable exceptions (such as efforts in Turkey and recent efforts in Guatemala by OXFAM, World Neighbors, Save the Children, and U.S.A.I.D.), few programs have been evaluated or observed over any length of time. The participants recognized that the techniques for modifying and improving earthen buildings have only been developed in the last decade; thus, information necessarily will be fragmented and minimal. However, the general lack of data and research on approaches and implementation strategies further frustrates the development of workable implementation programs in this field.

The overall scarcity of information was attributed to a lack of comprehensive research on program implementation; a failure of the operating agencies to evaluate existing projects; and a lack of long-operating agencies to evaluate existing projects; and a lack of longitudinal studies on the long-term impact and results of programs which have been carried out. Where information is available, it has tended to be compartmentalized and not disseminated widely to other practitioners.

The participants also noted that there has been little interaction between researchers and program implementers. Therefore, many of the techniques which have been developed to date to improve buildings are often impractical in actual field use. The participants noted that increased interaction between researchers and implementors needs to be effected and that linkages between the two groups should be well established prior to a disaster response.

The participants noted that most research on improving earthen buildings has concentrated on engineering solutions, and the social and cultural aspects and constraints have often been overlooked and are not fully understood by the research community. To overcome these problems, increased involvement of the engineering researchers in field level activities was urged.

Each of the work sessions on implementation noted the need for increased emphasis on developing local solutions to the problems. Several methods were proposed to bring research and implementation closer to the grassroots level. Several groups recommended that efforts should be initiated to train an intermediate group of technicians (somewhat along the "barefoot doctor" concept employed successfully in public health in China). These intermediate technician groups would serve as problem-solvers at the local level and would aid families in developing acceptable local solutions to specific vulnerability problems.

Several of the experienced practitioners noted the problems of quality control in vulnerability reduction programs. It was noted that as soon as a formal housing program ended, the application of the structural modification techniques often became irregular, and improper construction methods became widespread. To overcome this problem, participants suggested the need for increased emphasis on the trainin of local building technicians and cited quality control as an appropriate role for the "intermediate engineering group" mentioned above.

A number of discussions focused on both the need for increased public awareness and the difficulties in disseminating information about vulnerability reduction. The participants agreed that increased emphasis should be placed on documenting effective public information and housing education techniques, and that additional support is needed to develop effective communication tools and training aids for use in program implementation.

The participants discussed a number of obstacles to vulnerability reduction. It was noted that most vulnerability reduction efforts have occurred after an earthquake and had been directed towards improving the design and construction of new housing, not reduction of vulnerability of existing housing. The difficulty of intervention, except in disasters, was discussed at some length. The participants agreed that in order to carry out disaster mitigation efforts, local governments' capacities to conduct mitigation programs must be strengthened. It was also felt that research on different kinds of incentives which could be used to encourage home owners to utilize earthquake resistant construction techniques should be carried out. Among the incentives that should be explored are: financial incentives (such as loans, subsidies, etc.); material incentives (example: light-weight roofing, bracing, cement, etc.); and legal incentives (such as codes, tax reductions, etc.).

It was found that most research on reduction of vulnerability to earthen buildings has focused on the modification and strengthening of new construction. For overall vulnerability efforts to be successful, new methods for modification and strengthening of existing buildings need to be explored.

B. Research Agenda

The following topics were identified as the highest priority for future research related to program implementation and vulnerability reduction.

1. Implementation Approaches

a. Statement

More data on program implementation is needed in order to provide housing agencies with the necessary tools for vulnerability reduction efforts.

b. Action

New information must be developed about program implementation. This data should be acquired from two sources:

research and evaluation of projects. The criteria for such studies should be established and methodologies developed for general use.

c. Implementation

Research on strategies and approaches for vulnerability reduction programs should be funded by the National Science Foundation as a part of its overall hazards mitigation program. In support of this research NSF should also fund longitudinal studies of current and past programs to develop data upon which program models can be developed.

It is recognized that the majority of information on program implementation strategies may be found in the developing countries. In order to assist U.S. vulnerability reduction efforts, increased linkages between foreign and domestic researchers and program implementation personnel should be encouraged. It is recommended that joint U.S. and foreign research projects be encouraged and that U.S.A.I.D. and NSF establish a joint working group to explore ways in which research and evaluations can be complementary.

U.S.A.I.D. can support this effort by promoting evaluation and assessment of operational programs that receive support from the agency.

2. Techniques for Improving Low-Cost Housing

a. Statement

Often the techniques for anti-seismic modification of low-cost, non-engineered buidings are too costly and complicated for home builders to implement without extensive technical assistance. Recognizing cost as a major obstacle to housing modification and recognizing that only two or three modifications may be carried out by a homeowner, the most effective means of increasing seismic resistance should be identified for each particular type of structure and truly low-cost means of utilizing these techniques should be developed.

b. Action

In order to implement this approach, several activities must be carried out simultaneously. First, research is needed to develop simplified procedures for assessing a particular building and determining what the most cost-effective methods would be to strengthen that particular building. The procedure should enable the assessor to recommend a plan for modification or retrofitting taking into account the various trade-offs of time, labor, materials, etc.

The actions which are available for strengthening a house should be prioritized according to which method most reduces the relative vulnerability.

The results of this research must be presented in a non-technical form for use by implementing agencies and builders.

c. Implementation

It is recommended that the National Science Foundation should support research on:

(1) The priorization of modification techniques.

(2) The determination of which modification methods and which building features most affect or reduce vulnerability in a non-engineered structure.

(3) The development of a simple assessment procedure for field use.

(4) The development of step-by-step approaches to modification of housing which will allow homeowners/builders an opportunity to progressively upgrade housing.

It is further recommended that the National Science Foundation and the Agency for International Development continue to support joing U.S./foreign interchange and research on these topics.

It is recognized that research in related fields (such as unreinforced, low-quality masonry) could also benefit from these procedures; therefore, it is recommended that this research be carried out in conjunction with other on-going efforts.

3. Communication and Education

a. Statement

Little information exists on the process of technology transfer or means of encouraging homeowners to utilize earthquake resistant building techniques.

b. Action

Research is required to develop more information on the overall process of technology transfer, especially communication techniques and housing education. Research topics include:

(1) Identification of th most critical concepts and techniques which need to be transferred and methods for presenting the information in such a manner as not to overwhelm or confuse the audience. Especially needed is theidentification of the critical and priority structural details to be presented and methods for presenting these ideas in a non-technical manner.

(2) Information about the techniques of teaching and communicating, especially methods of presenting technical issues as well as methods for encouraging cultural acceptance of the methods being presented.

(3) Research is needed to identify what materials should be presented to each different audience, i.e., the best points of intervention for successful program implementation.

(4) Research is required on how to determine the most effective type of communicator/teacher for different situations and appropriate roles for different types of professionals and technicians in the overall vulnerability reduction efforts.

4. Special Problems of the Urban Environment

a. Statement

It is recognized that dense urban development creates unique aspects and problems for the reduction of seismic vulnerability. Most research to date has been on detached buildings which are most likely to be found in a rural environment. The special aspects of earthen buildings in urban areas and the problems in implementation of vulnerability reduction require new study.

b. Action

Research on non-structural methods of reducing vulnerability during program implementation is required. Of special concern is research on appropriate methods of siting and sub-division development in urban settings.

Structural methods of providing safety in urban settings are also required. Methods which should be explored are: in-house shelters, safe cores, and other methods of realistically addressing the problem on a cost-effective basis.

c. Implementation

It is recommended that the National Science Foundation encourage and support research on non-structural methods of reducing vulnerability in urban areas.

It is further recommended that NSF and A.I.D. place increased emphasis on research to develop methods of providing basic, minimal safety to urban dwellers living in non-engineered structures. Research in related fields (such as high wind engineering) and on related types of structures (such as low-quality, unreinforced masonry buildings) can provide useful information applicable to earthen buildings in seismic areas.

5. Acceptance of Change

a. Statement

The conditions under which familites will modify or except modification to their housing are not fully understood. The available literature on this topic is minimal.

b. Action

Increased research is required in order to determine the conditions under which modification of earthen buildings will be accepted. It is recognized that in the developing countries many of the people living 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. Research should be supported to identify the conditions under which change or modification would be accepted.

c. Implementation

This information is needed not only for modification of earthen buildings in seismic areas but for modification of all types of non-engineered structures vulnerable to earthquakes and/or windstorms. Thus, it is recommended that NSF encourage comprehensive research on societal and cultural attitudes towards housing modification as part of the current research efforts on societal response to earthquakes.

It is recommended that A.I.D. be encouraged to support parallel research on this topic by local researchers in countries with large numbers of non-engineered structures, vulnerable to either earthquakes or windstorms.

It is recommended that both NSF and A.I.D. and other organizations involved in disaster mitigation encourage further international interchange between social scientists and housing and building officials engaged in program implementation.

SUBJECT AREA 5: BUILDING CODES, SPECIFICATIONS AND STANDARDS

A. State of the Art

It was found that the problems of codes and specifications in the United States differed from the experience of the developing countries. Therefore, discussions tended to differentiate between the U.S. and international use.

The following specific observations were made:

1. Only a relatively few number of codes which permit the use of adobe or other earthen materials in residential construction have been passed in the United States. Conference participants noted that these are generally restrictive in nature and have usually been formulated in response to specific requests from builders or commercial manufacturers or adobe blocks. One notable U.S. code which permits adobe construction is the New Mexico building code and it has been recommended in the past that adobe bricks which meet its criteria be approved under the Uniform Building Code (see Report No. 1801, Nov. 1970, and Report No. 2366.1, Dec., 1968, International Conference of Building Officials). It was found that most codes only specify the quality of the adobe block and do not address structural aspects of building construction.

2. The participants noted that most comprehensive work on preparation and adoption of building codes for earthen buildings has been in the developing countries. Especially notable is recent work in Turkey and Peru.

3. Building codes were generally seen as too restrictive. In the United States, building codes were seen to be too sophisticated for use in low-cost construction as the requirements of the codes usually resulted in making the building costs too high; thus, the codes are unenforceable.

4. It was felt that building codes permitting earthen construction did not address related concerns such as energy use, social or cultural aspects of housing construction, and cost constraints in both the U.S. and the developing countries.

B. Research Agenda

The following research and activities are recommended in order to produce more effective earthen building codes, standards and specifications:

1. Review of Codes

a. Statement

A thorough compilation and review of existing building codes pertaining to earthen buildings in seismic areas needs to be undertaken.

b. Action

A panel of experts should be convened to systematically review the existing codes pertaining to earthen buildings in seismic areas the describe a common approach to developing more workable codes and standards for earthen buildings. This panel of experts should define common terminologies and approaches so that basic minimal codes and standards can become recognized on an international level.

c. Implementation

This international panel of experts should meet under the aegis of an existing earthquake engineering organization (such as the International Association of Earthquake Engineers or the Earthquake Engineering Research Institute). Meetings could be held in conjunction with recognized international conferences in order to reduce the cost. Support for this activity could be provided by NSF, UNESCO, and/or HABITAT Center.

2. Alternatives to Traditional Codes

a. Statement

Existing building codes have proved largely unworkable and overly restrictive.

b. Action

Additional research on alternative approaches to traditional codes should be explored. Priorities should be given to exploring:

(1) The feasibility of using performance standards as an alternative to traditional restrictive codes.

(2) The development of equivalencies and equivalency concept in support of (1) above.

c. Implementation

NSF and the National Bureau of Standards should host a technical meeting between code personnel, researchers and practitioners to examine existing codes and possible changes for the United States.

NSF should support research in support of the development of equivalencies.

3. Code Enforcement

a. Statement

Building code enforcement has proven difficult to put into effect in both the industrialized and developing countries.

b. Action

Additional research on implementation of building codes and standards should be undertaken. Research is needed on:

(1) Effective building inspection and code enforcement practices.

(2) Permit systems

(3) Financing mechanisms which encourage compliance with building codes.

(4) Methods of promoting public awareness and acceptance of building codes, including public information, education and training, and promotional approaches and techniques.

(5) Altenative methods of achieving basic minimum compliance with building codes and standards.

c. Implementation

NSF should encourage and support research activities on effective code enforcement as part of its ongoing program on research on societal response to natural hazards and earthquake mitigation.

4. Dissemination of Existing Information

a. Statement

Much of the research on the building codes for earthen buildings in seismic areas has been conducted internationally. In the United States, little of this information is known to code officials.

b. Action

An effort should be made to compile and disseminate the existing data relating to earthen codes to U.S. code officials. Of special interest would be data relating to standards for earthen materials and structural research in support of the establishment of building codes.

Because much of the data overseas is in foreign languages, support may be necessary in order to translate the codes into English for use in the U.S.

c. Implementation

It is recommended that the activities of the International Working Group on Improvement of Earthen Buildings in Seismic Areas be supported so that an information exchange between codes officials in the U.S. and overseas can be further encouraged.

A.I.D. should be encouraged to support the translation of foreign codes into English.

5. Redefinition of Intent of Codes

a. Statement

In the United States, it has been found that the intent of most building codes relating to building in seismic areas has been to restrict the use of earthen materials rather than to encourage safety when earthen materials are used.

b. Action

In order to more effectively utilize earthen materials, a consensus on the intent of building codes should be developed. Additional research should be conducted to define the acceptable levels of damage in differing earthquake risk zones and codes should be designed to take into account reginal variances and different levels of seismic risk.

c. Implementation

NSF should continue to support research to determine acceptable levels of damage in earthen buildings. This research could be combined with related research on low quality, unreinforced masonry.

6. Priority Areas for Structural Research Relating to Codes

a. Statement

To support the development of earthen building codes, immediate research is necessary to define minimum structural parameters.

b. Action

Research should be conducted to describe acceptable methods for transferring static loads to dynamic loads and to establish minimum reinforcing and ductility standards for earthen buildings.

c. Implementation

NSF should support the required research on a priority basis.

III. PRIORITIES AND A RECOMMENDED WORK PLAN FOR IMMEDIATE ACTION

The following items present a recommended work plan for immediate action to continue the efforts established at the workshop. This work plan draws from each of the topic areas described in the research agenda and places the highest priority activities in a logical, progressive order for commencing research in this field.

A. Establish common terminology for all aspects of earthen building research.

B. Establish common classification for:

1. Structures
2. Materials
3. Reinforcing methods
4. Damage assessment and reconnaissance

C. Identify the range of materials commonly used in earthen buildings and methods in which they are employed.

D. Identify the range of earthen building structures commonly in use and the various materials and structural systems used to reinforce the buildings in seismic areas.

E. Establish common testing terminology.

F. Establish the relationship between various testing methods commonly used to test earthen buildings.

G. Establish the relationship between full-scale testing and model testing of earthen buildings.

H. Establish the relationship between earthen buildings and other low quality masonry under seismic loading conditions.

I. Establish common testing procedures.

J. Establish the relationship between various soils used in earthen structures and their performance under different loading conditions.

APPENDIX A

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BIBLIOGRAPHY

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APPENDIX B

WORKSHOP BRIEFING PAPERS

BRIEFING PAPERS

In order to provide participants with an overview of the issues prominent in research on earthen buildings in seismic areas, the Workshop staff has developed this series of briefing papers. Workshop participants are encouraged to use the papers as a basis for discussions in the work sessions and to expand the list of research needs and references cited in each briefing paper.

TABLE OF CONTENTS

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.

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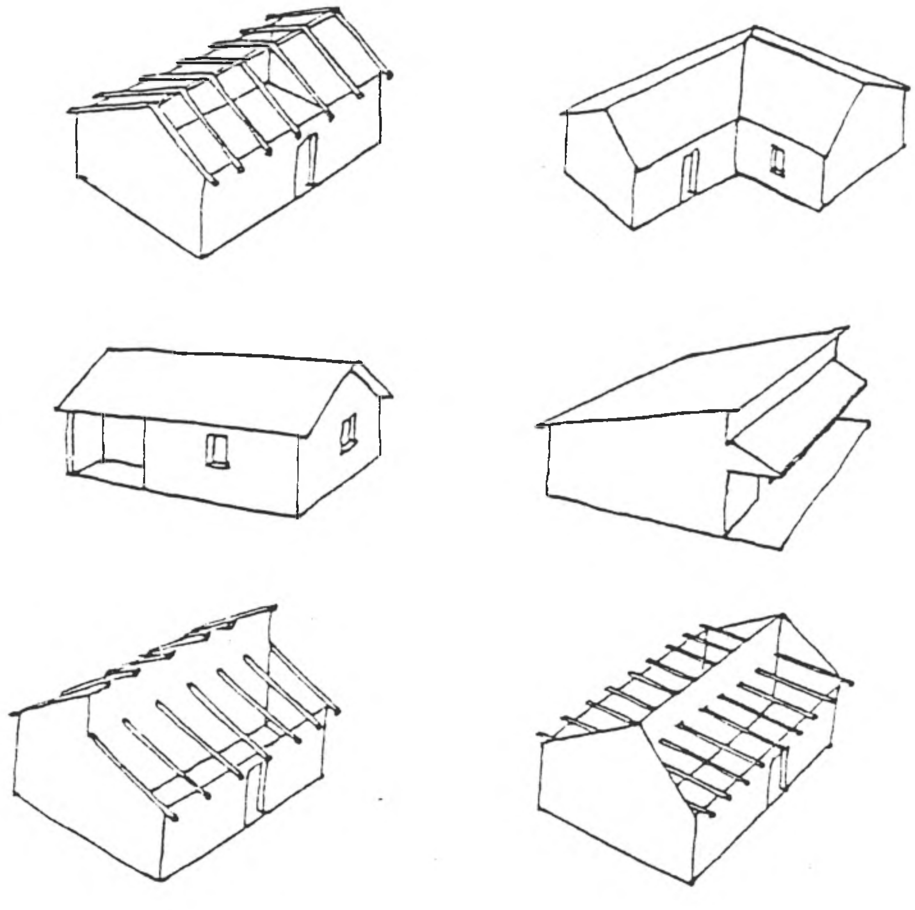
3. Robert Gersony, Tony Jackson, Jo Froman, "Selection of Building Materials", A Contrastive Analysis of Alternative Reconstruction Models After the February 1976 Guatemalan Earthquake, U.S.A.I.D. Mission, Guatemala, 1977.

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

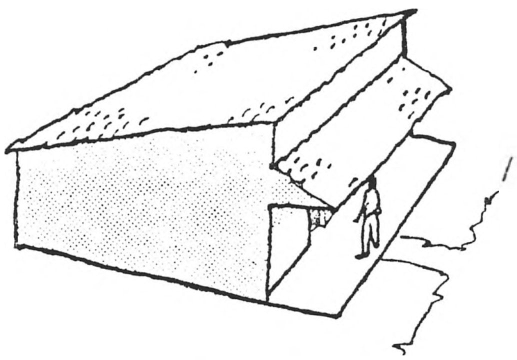
Satwant Rihal, The Behavior of Architectural (Non-Structural) Building Components During Earthquakes: Racking Tests of Non-Structural Building Partitions, California Polytechnic State University, 1980.

PROBLEMS OF DECORATIVE FEATURES

A. <u>DESCRIPTION OF THE PROBLEM</u>

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. <u>TYPICAL FEATURES</u>



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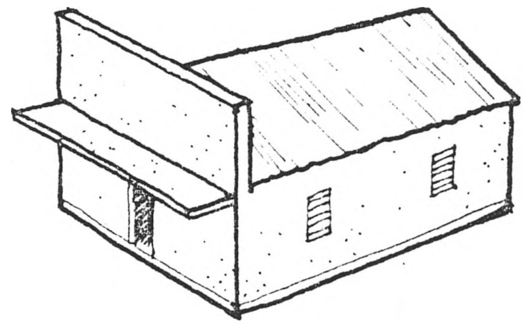

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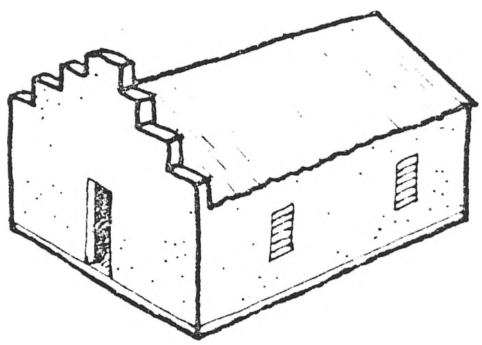

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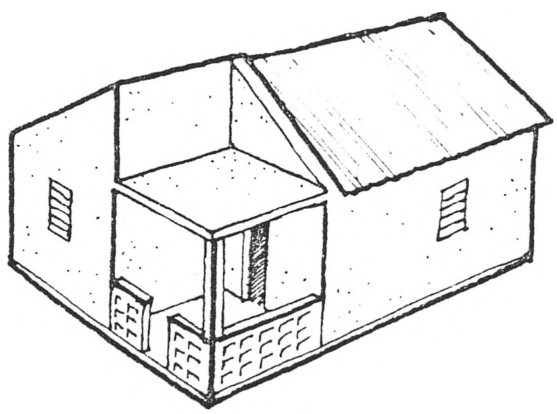

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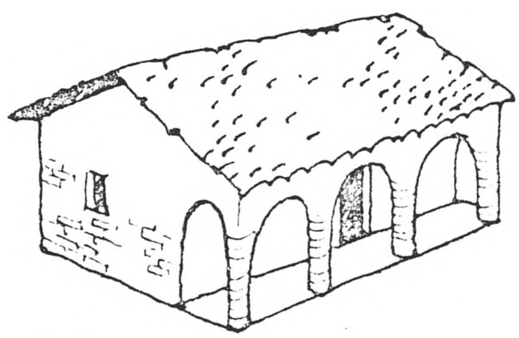

E

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

1. Preservación de Madera por Inmersion, Save the Children Alliance, Guatemala, 1977.

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

3. P.F. Purslow, Methods of Applying Wood Preservatives, Building Research Establishment, Dept. of the Environment, London, 1974

4. "Wood Treatment", INTERTECT, Dallas, Texas.

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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

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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

1. 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.

2. Nebahat Tokatli, "Town Planning as a Tool for Mitigating Earthquake Damage: An Evaluation of the Bolu Case in Turkey", Proceedings of the Seventh World Conference on Earthquake Engineering, Istanbul, 1980.

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.

2. 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.

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

1. William F. Reps, "Economic Factors Which Influence the Advancement of Housing Technology", Design, Siting, and Construction of Low-Cost Housing and Community Buildings to Better Withstand Earthquakes and Windstorms, National Bureau of Standards, U.S. Dept. of Commerce, Washington, D.C., 1974.

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

1. A Natural Disaster Insurance Scheme for Australia, Technical Committee of the Australian Government upon Technical Aspects of a National Scheme for Natural Disaster Insurance, 1978.

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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.

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