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DECEMBER 1987

Report on Workshop

REPAIR AND RETROFIT OF EXISTING STRUCTURES

Los Angeles, California
September 30 - October 1, 1987

Sponsored by
National Science Foundation
Grant No. ECE-8701316

PHIL M. FERGUSON STRUCTURAL ENGINEERING LABORATORY
Department of Civil Engineering / Bureau of Engineering Research
The University of Texas at Austin

Report of Investigations 9205

Subsidence Due to Undermining of Sloping Terrain: A Case Study

By Paul W. Jeran and Vladimir Adamek

UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary

BUREAU OF MINES
T S Ary, Director

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University of Texas at Austin
Phil M. Ferguson Engineering Laboratory
Austin, TX 78712

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16. Abstract (Limit: 200 words)

The workshop was organized to assess current research, design, and regulatory efforts on repair and retrofit of structures in the United States. The objective was to define research that would enable the U.S. earthquake engineering community to address problems related to a reduction of hazards posed by existing structures. Participants discussed research needs in the areas of: (1) reinforced concrete and steel structural systems (frames, walls, foundations, cladding, and bracing); (2) masonry structures; and (3) industrial institutional buildings with emphasis on critical systems within the buildings. Two major general research themes were identified at the Workshop: (1) performance of structural or nonstructural systems in existing buildings, and (2) performance of retrofitting or repair systems. A summary of reports presented at the workshop is included. Appended to the report is a summary report of a similar U.S.-Japan workshop held in Tsukuba, Japan, in May of 1987.

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Maintenance	Buildings	Frames	Concrete structures
Structures	Concretes	Bracing	Earthquake resistant structures
Meetings	Foundations	Industrial buildings	Reinforced concrete
Masonry	Walls	Structural design	

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1.a

PREFACE

The problem of designing repair and retrofit schemes for existing structures is more complex than tha' associated with new construction. There has been a general perception that life safety (protection against injury or loss of life by building collapse or damage) is the major problem. However, other issues are of considerable importance. It may be necessary to prevent or limit damage to allow operational capability of critical structures. There has been very little public awareness of the hazards posed by damage to critical systems within structures that may have relatively low tolerance for building deformations during an earthquake.

The workshop was organized to assess current research, design, and regulatory efforts on repair and retrofit of structures in the United States. The objective was to define research that would enable the U.S. earthquake engineering community to address problems related to a reduction of hazards posed by existing structures.

The Los Angeles workshop followed a similar workshop organized in Japan to bring together a group of 5 U.S. and 35 Japanese engineers for the purpose of assessing the state-of-the-art in the area of repair and retrofitting existing structures.

The time and effort of all the participants was instrumental in permitting the workshops to take place. The National Science Foundation supported the participation of the U.S. group at the workshop in Japan and of many of the participants at the Los Angeles workshop. Special thanks are due Drs. A. J. Eggenberger and J.B. Scalzi of the National Science Foundation and Dr. M. Hirosawa of the Building Research Institute in Japan.

James O. Jirsa
Austin, Texas

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WORKSHOP SUMMARY

Repair and Retrofit of Existing Structures

Los Angeles, California
September 30-October 1, 1987

Background

In connection with the 19th Annual U.S.-Japan Panel on Wind and Seismic Effects (UJNR) meeting at the Building Research Institute (BRI) in Tsukuba, Japan, in May 1987, a special workshop was organized to bring together a group of U.S. and Japanese engineers for the purpose of assessing the state-of-the-art in the area of repair and retrofitting existing structures. Five U.S. and 35 Japanese engineers participated. U.S. participation was supported by the National Science Foundation. A number of papers were presented and included in a report published by BRI. Additional details of the workshop are included in Appendix B.

For the U.S. participants, the workshop provided an opportunity to review the considerable effort in Japan on evaluation, repair, and strengthening of structures. Following the workshop in Japan, it was decided to organize a subsequent meeting to be held in the U.S. At this meeting, current research, design, and regulatory efforts would be discussed. Research that would enable the U.S. earthquake engineering community to address problems related to a reduction of hazards posed by existing structures would be considered and a plan for developing a research program would be proposed.

The agenda for the U.S. workshop was developed as shown in Appendix A1. A group of design engineers, researchers, and building officials was invited to participate. The list of participants is included in Appendix A2.

Format

The Workshop was divided into three half-day sessions. The first half day was devoted to a summary of current activities in the area of research, regulation, and design. Brief reports were presented on (1) the topics and papers related to research and design in Japan, (2) research being supported and encouraged by the National Science Foundation and the Federal Emergency Management Agency, (3) governmental activities in the State of California and in the City of Los Angeles, and (4) activities in design including detailing problems, analytical approaches, masonry structures, and architectural problems, and problems related to contents and equipment in buildings. Brief summaries of the reports are included in Appendix A3.

During the second half-day, the participants were divided into three discussion groups to establish research needs in the areas of

I. Reinforced concrete and steel structural systems - frames, walls, foundations, cladding, bracing

II. Masonry structures

III. Industrial, institutional buildings with emphasis on critical systems within the buildings

Summaries of the task group reports are included in Appendix A4.

The final half-day session began with reports from the task group discussion and was followed by a general discussion during which coordination and priority ordering of research topics was considered. The discussion was overshadowed by the early morning earthquake which occurred in Whittier on October 1. (See Appendix A5.) The event reinforced the need for a major effort in the area of repair and strengthening to reduce hazards.

In the following sections the results of the general discussion are presented. First, the general issues are described, the critical topics are listed, and the research needs are presented. Finally, some suggestions for organizing and coordinating a national effort are given. Since all details and specific items discussed are not summarized in the sections which follow, the material in Appendices A3 and A4 should be carefully reviewed.

General Issues

The problem of designing repair and retrofit schemes for existing structures is more complex than that associated with new construction. The designer must first assess the condition of existing building. In many cases, plans are inaccurate or nonexistent and the material and member properties cannot be reliably determined. Once an assessment has been made that the structure or systems within that structure pose a hazard, a means of reducing the hazard must be designed. While there has been a general perception that life safety (protection against injury or loss of life by building collapse or damage) is the major problem, other issues are of considerable importance. It may be necessary to prevent or limit damage to allow operational capability of critical structures. Institutional buildings (hospitals, control centers, communications centers), defense installations, and critical industrial facilities fall into this category. There has been very little public awareness of the hazards posed by damage to critical systems within structures that may have relatively low tolerance for building deformations during an earthquake. Examples of such systems include piping that is used to transport toxic chemicals or wastes, electrical lines, tanks or lines for explosive gases or chemicals.

The owner and the engineer must establish levels of performance (strength and deformation) to reduce, to an appropriate level, hazards to life safety or to operational continuity. It should be noted that there is not a consensus as to performance requirements.

Once the need for retrofitting a system to improve performance is established, the designer must devise a plan for achieving the specified level of performance. A number of techniques for improving the strength, stiffness, or toughness of the structure are available. While some research data are available, there is very little available in the literature or in the codes to guide a designer. The development of new materials, such as epoxies, composites, high strength steels and concretes, offer a wide range of alternatives. What is lacking is data regarding the interaction of "new" systems attached to the structure with the existing structural system. It appears that sophisticated analytical tools are available to address the problems but models representing the behavior of a complex retrofitted system have not yet been developed.

Finally, there appears to be a perception that repair and retrofitting are regional problems associated with relatively small areas of high seismic risk. However, inadequate structures are located in all regions of seismic risk--reduction of hazards from existing buildings is a national problem. In the event of a major earthquake, reconstruction will be of nationwide concern and will represent an economic loss of national importance. Therefore, it is clear that a major effort is needed by the research and design community to develop a coordinated program which ultimately will result in codes, specifications, and design guidelines to reduce hazards from existing buildings. There will also be a need for code writing groups and governmental bodies to establish guidance pertaining to responsibility and liability issues in the area of repairing and retrofitting existing buildings. The role of the owner, engineer, contractor and building official must be clarified.

Critical Topics

In the chart in Fig. 1, the critical stages involved in reducing the hazards from existing structures are outlined. In assessing the hazard (Stage 1), the performance criteria and site characteristics must be established. The area where data are needed is in establishing the performance criteria for damage control and continuity of operations. Of special concern is data establishing response between levels of moderate or early damage and collapse. The analysis of the building to determine the need for retrofitting is dependent on data and models for behavior of the materials, structural elements, and connections, and non-structural systems. Very little is available to the designer for making a rigorous analysis of the system.

In Stage 2, the design and performance of the repair and retrofit scheme must be examined to determine if it will meet established performance criteria. Traditional means of retrofitting by adding walls, braces, or inceasing element size are used, but their performance has not been documented and models to represent their behavior are needed if reasonably reliable analyses are to be made. Even less is known about the response of nonstructural elements. In addition, there is a need for developing new technologies to address the myriad of situations faced in design. Of special importance are new materials (composites, high-strength) and new systems (energy absorbers, isolation).

In Stage 3, the data developed in Stages 1 and 2 will have progressed to the point that standards can be developed for use by designers, owners, and regulatory agencies to target specific types of hazardous buildings and to recommend means of reducing hazards to an acceptable level. The professional community must identify those structures (building types) which represent the greatest hazard and move as rapidly as possible toward Stage 3 goals.

Structures which appear to represent the greatest hazard are:

(a) Unreinforced masonry--bearing or infill walls
(b) Nonductile concrete structures--including tilt-up structures
(c) Nonductile steel structures
(d) High occupancy buildings constructed and/or designed prior to recent codes (pre 1976)
(e) Structures housing critical or toxic systems

Much has already been done in the area of unreinforced masonry bearing walls and in some communities (Los Angeles, Long Beach), programs are already in place to address the problem. California has passed legislation targeting unreinforced masonry structures for inventory. Many structures include unreinforced masonry bearing walls or infill walls in steel or concrete frames. Guidance is needed for the designer to implement hazard reduction techniques for such structures.

<u>Research Needs</u>

Two major general research themes were identified at the Workshop:

1. Performance of structural or nonstructural systems in existing buildings

2. Performance of retrofitting or repair systems

There is a knowledge gap regarding the performance of buildings in the range from damage to collapse. Data are needed to develop models for response of material, elements, connections, infill walls, so that satisfactory analyses can be made. Available data on cyclic response should be collected from all sources and where such data are inadequate, experimental programs should be established to develop information. Of particular interest in this regard is the response of elements and systems not meeting current standards and the problem of infill wall/frame interaction. There is also a need to establish influence of structural response on contents and equipment within the structure. Nondestructive means of establishing the condition of the structure must be developed.

With respect to performance of repair or retrofit systems, the interaction of new and existing elements must be established. Connections for transferring forces between new elements and the existing structure are of special concern. The force-deformation characteristics of the new and existing systems must be "matched" to optimize and control performance.

New materials and new techniques must be studied to determine their applicability to the repair and retrofit problem. Such developments will widen the range of options available to the owner and designer and offer the potential for reducing construction costs.

<u>Specific Research Topics</u>

The following list of topics is offered for guidance but is not in priority order. Some topics may provide substantial short-term benefits and should be initiated quickly while other topics must be considered long-range in that the benefits may not be derived quickly but will have considerable impact. An indication of this categorization is included.

1. Behavior of existing steel or concrete "non-ductile" frames with or without unreinforced masonry walls. It may be desirable to identify existing buildings scheduled for demoliton and conduct appropriate tests. Data from earthquake reconnaisance reports and records from instrumented buildings may be useful. Where laboratory studies are needed, large-scale models should be tested to improve correlation with existing structures. The ultimate objective of this work is the development of analytical models for assessing response and for determining the sensitivity of response to a wide range of material, design, and construction variables. (short range)

2. Connections between elements or details that do not meet current standards for providing continuity, toughness, or strength in existing structures. Specific issues are ties between elements (masonry walls to floors, walls to frames), spacing of ties in concrete beams or columns, connections in steel frames, lack of continuous reinforcement in slab systems, connections between elements in prefabricated or tilt-up construction, connections between different structural systems (concrete walls-steel columns, concrete floors-steel beams), anchorage of cladding or equipment. (short range)

3. Improvement of means for assessing condition of structure. New means of nondestructive evaluation and testing are needed to determine material characteristics, remaining life, and integrity of structure, foundation, or appurtenances. Tomography may be one technique meriting study. (short and long range)

4. Evaluation of performance of "traditional" techniques for retrofitting structures:

Steel structures - adding material to section or element
- adding new systems--walls, braces
- improving connections

Concrete structures - adding materials to section or element
- adding new systems - walls, braces

Masonry - new connections
- in-plane and out-of-plane strengthening techniques

The objective is to develop models for use in analysis. Data should be collected from all available sources before new experimental work is initiated. (short range)

5. Development of techniques for evaluating hazards associated with industrial facilities and for establishing retrofit objectives for critical structures.

6. Development of new techniques for retrofitting structures, including

Isolation of the structure, or its contents
Passive or energy absorbing systems
Materials - composites, epoxies, high strength steel and concrete

(short and long range)

7. Techniques for retrofitting foundations for increased loads from retrofitted structure. (long range)

8. Development of expert systems. Much of the "art" of retrofitting resides with a relatively small fraction of the profession. Expert systems provide a means to disseminate specialized information to a broad range of users. (long range)

9. Organization of international exchanges of information with professionals in other countries where seismic hazard reduction is being addressed, including but not limited to Japan, China, New Zealand, Italy. (short range)

10. Studies of cost-effectiveness of various retrofit techniques and assessment of cost to reduce hazard to different levels of acceptability. (long range)

Development of Research Effort

The Workshop participants expressed strong support for the development of a coordinated research effort to address the issues discussed. While some research is already underway, a rapid expansion of that effort is needed to develop technical information for reducing the risk represented by the most hazardous buildings. There is a critical mass of designers, researchers, building officials, and owners that recognizes the problem and has the capability to develop the necessary technical data. This group needs to be mobilized quickly so that the momentum already developed is not lost. The work of communities such as Long Beach and Los Angeles must be encouraged and expanded to include other municipalities in zones of appreciable seismic risk and with an inventory of hazardous buildings.

For the research program to be effective, it must be organized to include all segments of the community responsible for structural safety--owners, designers, researchers, building officials. The development of a program involving all interests will insure that a wide variety of views is considered and that information generated will be quickly disseminated and utilized.

Information such as the results of this or other workshops should be disseminated to let individuals or groups develop proposals for the needed research.

As indicated in the section on Specific Research Topics, the range of topics to be studied is quite varied. Therefore, it is important that some structure to the research program be developed. Some coordination, especially of items such as, 1, 2, or 4 in the list of specific research topics, is needed if progress is to be made toward developing standards for use in reducing hazards. It is suggested that there be an effort toward assembling a group or groups of individuals to lay out a coordinated effort in selected high-priority areas. For example, the reduction of hazards posed by non-ductile frames with unreinforced masonry walls. Such a team should include designers to work with researchers to provide practical advice, to conduct design studies, and to help disseminate data to the profession. Contractors and material suppliers may be included to offer advice related to costs and planning of projects. Funding must be at a level and for a duration sufficient to ensure continuity of work and to lead to a useful product--the development of design standards and guidelines.

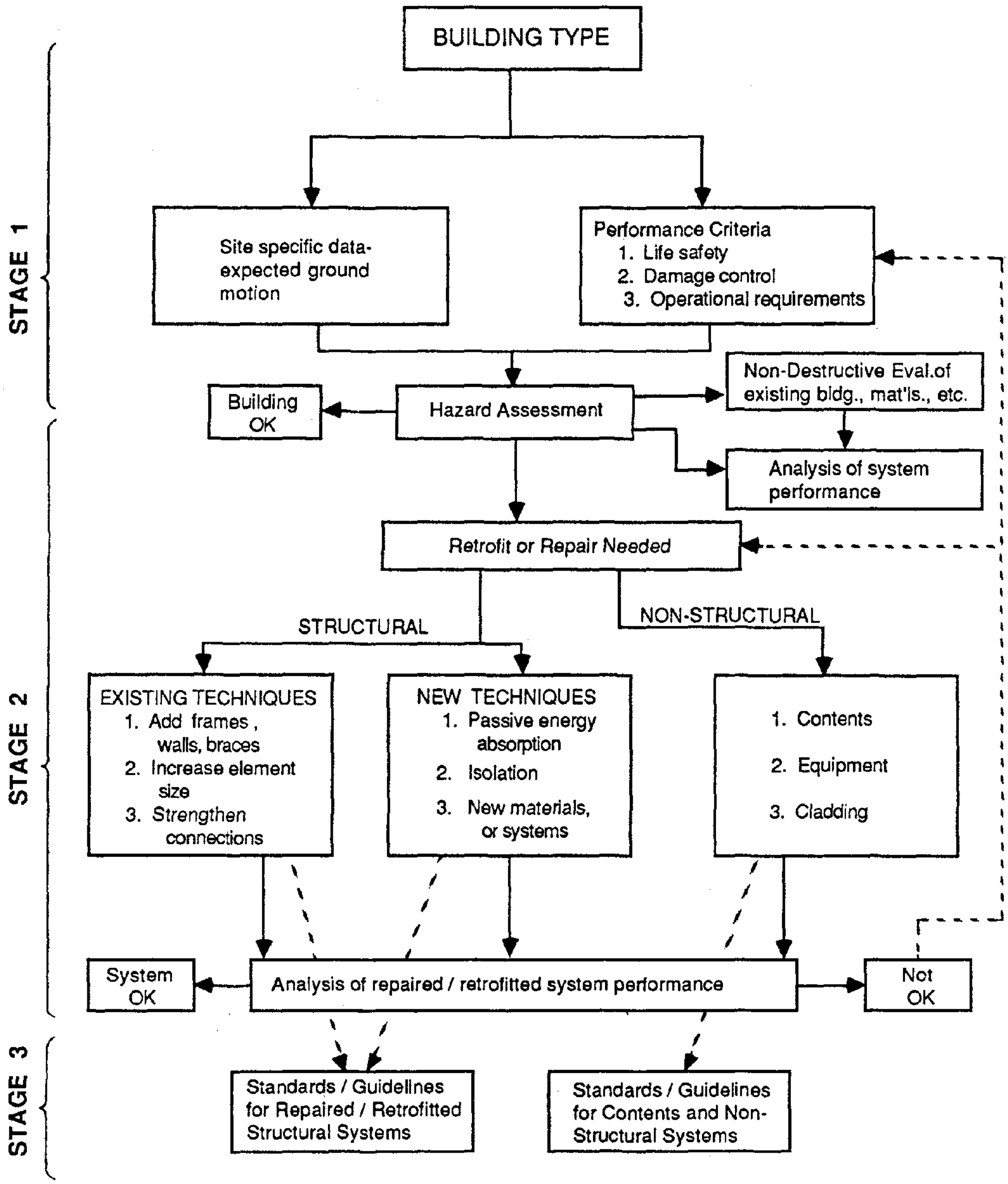

Fig. 1. Stages in Hazard Reduction of Existing Buildings

APPENDIX A

U.S. WORKSHOP

Los Angeles, Sept. 30-Oct. 1, 1987

APPENDIX A1

SCHEDULE FOR WORKSHOP

Repair and Retrofit of Existing Structures
Los Angeles, California

<u>Wednesday, September 30, 1987</u>

8:30	Introduction to Workshop - J. O. Jirsa
9:00	Review of Workshop in Japan, May 1987 L. A. Wyllie, Jr. N. F. Forell J. P. Moehle
9:45	Break
10:15	Research Sponsored by NSF - A. J. Eggenberger
10:25	Research Sponsored by FEMA - U. Morelli
10:35	Regulatory Activities P. F. Fratessa - California Seismic Safety Commission A. Asakura - City of Los Angeles
10:55	Design Activities W. T. Holmes - Detailing Problems G. C. Hart - Analysis of Retrofitted Structures J. Kariotis - Masonry Structures M. Green - Architectural Elements and Cladding
11:35	Overview of ATC-14 - J. O. Malley
11:45	Additional Comments by Participants--time permitting
12:00	Lunch
1:00-5:00	Task Group Discussions on Research Needs (See attached sheet for Group Assignments) Each group should focus on both short-term and long-term needs to advance the state-of-the-art. The product of the group discussion should be a listing, in priority order, of the problems to be studied with a brief commentary to justify the need. We need to develop a coordinated program which will provide information useful to designers, builders, and regulatory groups to fill the gaps in our knowledge in the area of repair and retrofit.
3:00	Break

<u>Thursday, October 1, 1987</u>

8:30	Presentation and Discussion of Task Group Reports I. L. A. Wyllie, Jr., and R. D. Hanson II. D. P. Abrams and J. M. Plecnik III. N. F. Forell and J. P. Moehle
10:00	Break
10:30	Suggestions for Short-term and Long-term Research Needs (Path Forward) Moderator, J. O. Jirsa Recorder, J. O. Malley
12:00	Lunch
1:00	Comments and Suggestions for Workshop Report
2:00	Reflections on Workshop

Adjournment

TASK GROUPS

Repair and Retrofit of Existing Structures
Los Angeles, California
September 30-October 1, 1987

I. Reinforced Concrete and Steel Structural Systems--Frames, Walls, Foundations, Cladding, Bracing

L. A. Wyllie, Jr., Moderator
R. D. Hanson, Recorder
R. Burkett
P. F. Fratessa
M. Green
H. S. Lew
N. Youssef
J. Warner

II. Masonry Structures

D. P. Abrams, Moderator
J. M. Plecnik, Recorder
A. Asakura
J. Kariotis
S. P. Prawel
L. T. Tobin

III. Industrial, Institutional Buildings with emphasis on systems within the structure (such as, toxic chemical lines, computers, manufacturing equipment, etc.) which may require special retrofitting techniques or may impose special requirements on the structural system retrofitting

N. F. Forell, Moderator
J. P. Moehle, Recorder
I. Buckle
W. T. Holmes
J. O. Malley

APPENDIX A2

PARTICIPANTS

Repair and Retrofit of Existing Structures
Los Angeles, California
September 30-October 1, 1987

Daniel P. Abrams
3148 NCEL
208 N. Romine St.
University of Illinois
Urbana IL 61801
217/333-0565

Allen Asakura
City of L.A.-Bldg. Dept.
200 N. Spring St, Rm. 460-Y
Los Angeles CA 90012
213/485-7837

Ian Buckle
Computech Engr. Serv. Inc.
2855 Telegraph Ave, St. 410
Berkeley CA 94705
415/843-3576

R. Burkett, LT CEC USNR
Dept. of the Air Force
Air Force Engr. and Serv. Ctr.
Tyndall AFB FL 32403-6001
904/283-6237

A. J. Eggenberger
Program Director
Earthquake Hazard Mitigation
National Science Foundation
Washington DC 20550
202/357-9500

Nicholas E. Forell
Forell/Elsesser Engrs. Inc.
539 Bryant Street
San Francisco CA 94107
415/896-0966

Paul F. Fratessa
Paul F. Fratessa Associates
11881 Skyline Blvd.
Oakland CA 94619
415/482-3341

Melvyn Green
Melvyn Green & Associates
1145 Artesia Blvd., St. 204
Manhattan Beach CA 90266
213/374-6424

Robert D. Hanson
2370 G. G. Brown Bldg.
University of Michigan
Ann Arbor MI 48109-2125
313/764-5617

Gary C. Hart
Univ. of Calif. at L.A. &
Englekirk & Hart Const.
Engrs. Inc.
2116 Arlington Ave.
Los Angeles CA 90018
213/733-2640

William T. Holmes
Rutherford and Chekene
487 Bryant Street
San Francisco CA 94107
415/391-3990

James O. Jirsa
Ferguson Struc. Engr. Lab.
10100 Burnet Rd, #24
Austin TX 78758
512/471-4582

John Kariotis
Kariotis & Associates
711 Mission St, Suite D
South Pasadena CA 91030
213/682-2871

H. S. Lew
Structures Division
National Bureau of
Standards
Gaitherburg MD 20899
301/975-6061

Jack P. Moehle
EERC
714 Davis Hall
University of California
Berkeley CA 94720
415/642-0697

Ugo Morelli
FEMA
500 C Street, SW
Washington DC 20472
202/646-2810

J. Plecnik
Dept. of Civil Engineering
California State University
of Long Beach
Long Beach CA 90801
213/498-4406

James O. Malley
H J Degenkolb Associates
350 Sansome St, #900
San Francisco CA 94104
415/392-6952

S. P. Prawel
NCEER
State Univ. of Buffalo
Buffalo NY 14260
716/636-2311

L. Thomas Tobin
Calif. Seismic Safety Comm.
1900 K St, Suite 100
Sacramento CA 95814
916/322-4917

L. A. Wyllie, Jr.
H J Degenkolb Associates
350 Sansome St, #900
San Francisco CA 94104
415/392-6952

Nabih Youssef
A C Martin & Associates
811 W. 7th Street
Los Angeles CA 90017
213/683-1900

James Warner
P.O. Box 1208
Mariposa CA 95338

APPENDIX A3

SUMMARY OF REPORTS PRESENTED AT WORKSHOP

Repair and Retrofit of Existing Structures
Los Angeles, California
September 30-October 1, 1987

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EARTHQUAKE MITIGATION IN FEMA

Ugo Morelli

Federal Emergency Management Agency

The Seismic Design Segment of the FEMA Earthquake Program funds the preparation of materials intended to increase the seismic safety of new and existing buildings and new and existing lifeline systems for both the federal and non-federal sectors.

1. ACTIVITIES UNDERWAY RELATING TO EXISTING HAZARDOUS BUILDINGS

A. Typical Costs for Seismic Rehabilitation of Buildings.

The objective of this project is to collect and collate data and information on typical costs to reduce the seismic hazard to life safety that they pose. "Typical" in this context should be understood to mean "best available data" on different types of buildings and occupancies in different seismic areas, with reasonable extension of these data to other parts of the country. The data are not expected to be statistically valid, but rather provide a coherent data set with national applicability. The project will result in a basic concise report directed at design professionals (architects and engineers), academicians and other researchers, building regulatory personnel and other elected and appointed officials, model code and standards writers, and interested citizens. A companion complementary publication will contain all necessary supporting materials. This 15-month effort is expected to be completed by the end of December 1987 and is being conducted by the Los Angeles firm of Englekirk and Hart, Consulting Engineers, Inc. It is proceeding as planned, and all indications are that a useful product--the first of its kind on the topic of costs of seismic rehabilitation--will be forthcoming.

B. Two Related Handbooks.

The Applied Technology Council was awarded a contract in April 1987, to prepare two closely related handbooks.

1) The Handbook on Rapid Visual Screening of Hazards Buildings will develop and present a standard method to conduct a rapid, visual, on-site screening of the existing buildings of all types and occupancies in a locality to identify those that pose a potentially serious risk to loss of life and injury or of severe curtailment of community services in case of a damaging earthquake. The screening will be capable of

being conducted very quickly and inexpensively by a qualified person. The handbook is intended mainly for the use of local building officials, the architectural and engineering professions, the building and building-owners communities, emergency managers, and interested citizens throughout the country. It will not be used to prescribe how to reduce the risks posed by hazardous buildings, but rather to identify those buildings that might require a more elaborate evaluation. It will have an annex that identifies buildings the characteristics of which make them capable of generating very heavy rubble after a severe ground shaking. The annex is intended to alert local emergency managers to the need for a heavy urban rescue capability to be brought to bear immediately after a damaging earthquake. The handbook will be reviewed by an advisory committee representing all components of the intended audience and is expected to be completed a year after award.

2) The Handbook on Seismic Evaluation of Hazardous Buildings will provide a nationally applicable, consensus-backed methodology on how to conduct an evaluation of the seismic resistance of buildings of different types and occupancies in areas of different seismicity. This evaluation process will be applied to those existing buildings which have undergone a prior rapid screening and have been identified as posing a potentially serious risk of loss of life and injury or of severe curtailment of community services in case of a damaging earthquake. The evaluation will cover both structural and non-structural elements and require the review of construction documents (e.g., "as-built" plans), the general condition of the building, and simple calculations. It will be written specifically for design professionals and local building officials.

The handbook will have a companion publication containing all the necessary supporting documentation. Both will be reviewed by an advisory committee representing the intended audience before being submitted to the BSSC for a formal consensus approval process identical to that used for the NEHRP Provisions. This material is expected to be completed two years after award with an additional year required for the BSSC consensus process.

2. PLANNED ACTIVITIES

A. Methodology for Establishing Cost of Seismic Rehabilitation of Buildings.

The objective of this project is two-fold: (1) to identify generally accepted strengthening and other rehabilitation approaches for the seismic retrofitting of existing hazardous buildings; (2) to develop a nationally applicable methodology for estimating the construction costs of such approaches. The strengthening approaches will be of both a structural and non-structural nature and are intended to remove or abate life-threatening risks only. They will also be nationally applicable and appropriate to the seismicity of the area in which they are expected to be used, as depicted in the maps of the NEHRP Provisions.

The engineering report on strengthening techniques is expected to be ready for the consensus approval process 18 months after award, or about the end of March 1989, at which time it will also be forwarded to BSSC for balloting and consensus approval.

The approved document will then be put into final form. A methodology on how to estimate the cost of the strengthening techniques identified in the engineering report will then be developed in the ensuing 12 months, for a total project elapsed duration of 42 months. Completion of this project, therefore, is expected about the end of March 1991. The competition is in process and a successful offeror will be selected during the summer of 1987.

B. Handbook and Supporting Report on Priorities for Seismic Retrofitting of Existing Hazardous Buildings.

This is the first truly interdisciplinary effort related to the abatement of seismic risks posed by existing buildings. Its specific objective is to develop a nationally applicable handbook for the use of a local jurisdiction in making an informed decision on retrofitting hazardous existing buildings. The handbook will provide to the decisionmakers guidelines for setting priorities in this activity. The guidelines will be based on the most significant factors that would impinge on a retrofitting decision, and the multiple and complex impacts that these factors might have. Factors and impacts are both technical and societal/public policy in nature; hence the interdisciplinary approach of this effort.

The handbook and supporting report are intended as tools in the consideration and adoption of public policy in regard to setting priorities in a retrofitting program. The intended audience consists principally of local elected and appointed officials who have building regulatory and related responsibilities. Design professionals, researchers, and interested citizens will also be able to profit from the information contained in the final products of this effort.

A competition is underway for this project and the successful offeror is expected to be announced before the end of the summer of 1987. The effort is scheduled to last 15 months and should therefore be completed by the end of 1988.

C. Financial Incentives for Seismic Rehabilitation of Existing Hazardous Buildings.

The objective of this study is to identify and describe in detail the financial mechanisms and incentives in place at the federal, state, and county/local levels that can be used to encourage the seismic rehabilitation of hazardous buildings. A small sample of states and counties/municipalities representative of different geographic and seismic environments and of different socioeconomic conditions will be used as a basis for drawing conclusions as to what mechanisms can be effectively used to institute a local seismic rehabilitation effort. If funding permits, a few actual case studies will also be included. The intended audience for this report is the elected and appointed local officialdom, with particular emphasis on the building regulatory, community and housing development, planning, and financial management departments of a local jurisdiction. The effort is expected to be competitively procured during fiscal year 1988, if funding becomes available, and to last about 24 months.

REGULATORY ACTIVITIES - CITY OF LOS ANGELES

Allen Asakura

Chief, Earthquake Division
City of Los Angeles

The City of Los Angeles has been enforcing its Earthquake Hazard Reduction Program since the adoption of an ordinance on February 13, 1981. The program, when completed will mitigate the seismic hazards in some 8,000 unreinforced masonry bearing wall buildings located in the City. The program is scheduled for completion in 1991. To date, all compliance orders have been issued. The order requires that all structural upgrading work be completed within 3 or 4 years of the issuance date of the order. Of the 8,000 buildings, work has been completed for 1,000 to meet "full" compliance, and "wall anchors only" have been installed in 800 buildings. There have been over 3,700 plans submitted for full compliance work and over 2,300 building permits issued. Approximately 700 buildings have been demolished.

There were many factors that led up to the eventual passage of the ordinance. None was more important than the cost involved to perform the necessary structural upgrading work. Because of the research work accomplished by a joint venture of Agababian, Barnes, and Kariotis (under a National Science Foundation grant), the technical standards adopted under the ordinance allowed the necessary structural upgrading work to be done at reasonable costs. The results of the research work recognized that existing materials have structural strength and stability and could be used to help resist earthquake forces. It balanced out the greatest concern of those that opposed the passage of the ordinance whose contentions were that the cost of upgrading would lead to a demolition derby and result in the elimination of low-income housing stock. The program, to date, has shown that the cost of upgrading is economically feasible, and that a demolition derby has not occurred. The research work gave sound creditable background from which reasonable structural standards could be developed.

The City of Los Angeles is studying the repair and retrofit of "other" existing hazardous structures. Of immediate concern are those buildings designed and constructed prior to the adoption of a seismic ordinance and containing unreinforced masonry infill walls. These "other" unreinforced masonry buildings fall within the scope of California S.B. #547. The City of Los Angeles plans to survey and identify such buildings commencing July 1988. The successful implementation of a mitigation program will depend heavily on the costs associated with performing the necessary structural upgrading. Research work and testing need to be performed so that reasonable structural standards could be developed. These standards must incorporate the contribution of an existing structural system (acting alone or in combination with a new system) in the total seismic resistance of a structure. In California because of the seismic hazards associated with this class of buildings and the mandate of S.B. #547, it is important that the necessary work be accomplished as soon as possible and disseminated in a format that is usable to practicing engineers and governmental agencies.

ANALYSIS AND RETROFITTING OF EXISTING BUILDINGS

A PERSPECTIVE FROM A MEMBER OF THE CALIFORNIA SEISMIC SAFETY COMMISSION

Paul F. Fratessa

Paul F. Fratessa Associates

This outline is not an official report but a perspective on what is perceived as the Commission's view toward the hazardous building problem in the State of California.

1. BACKGROUND OF THE COMMISSION

   A. Commission formed by legislation to mitigate seismic hazard in the state.

   B. Reports to the Governor and the State Legislature.

   C. Made up of 17 members from varying interests including legislators, insurance, fire protection, local government, seismologists, geo-technical, structural engineering, volunteer organizations, utilities, emergency services and architecture.

2. COMMISSION ACTIVITIES

   A. Meets generally once per month in Sacramento or other locations.

   B. Holds public hearings.

   C. Develops reports to the Governor and Legislature.

   D. Publishes documents related to seismic hazard mitigation:

      1) Potentially Hazardous Buildings SSC 85-04.

      2) The Commission's Role in Seismic Research SSC 86-01.

      3) Rehabilitating Hazardous Masonry Buildings, a Draft Model Ordinance SSC 85-06.

      4) Costs and Housing Impacts of Unreinforced Masonry Building Rehabilation..Edited Transcripts of Hearings.

      5) SB 547 Guidebook for Local Governments.

   E. Sponsors and/or supports legislation.

F. Developed and published the 5-year plan California at Risk. Reducing earthquake hazards 1987 to 1992.

3. INFORMATION RELATING TO THIS WORKSHOP

A. Public hearings have exposed the Commission to the technical and social problems faced with seismic mitigation measures. The engineering solution is only part of the issue.

B. Social impacts: Rehabing can cause displacement of low-cost living individuals and families. Rehabed building comes back on market at more expensive rent thus removing some low-cost inventory.

C. Financial impacts: What is the financial incentive to rehab, or more importantly to provide financing for rehab if the value of the building is not improved?

D. A question of liability?

1) To what seismic safety standard is the rehab to be accomplished?

2) If less than the modern code, what is the justification?

3) If the justification is merely the protection of life and not property then buildings could be unusable after an earthquake.

4) How would a lender look at this issue?

5) How sure is the engineering profession about this threshold of design?

6) Who is liable for the design at less than the modern code?

4. WORKSHOP FOCUS

Workshop should focus on improving the confidence level in our ability to evaluate and retrofit structures so that the projection of life safety is sound.

A. Eventually a document (code or ordinance) will result.

B. Prior to the development of the code the gathering and dissemination of available data will upgrade the state of the art.

C. Areas of PFF concerns

1) Wall anchors in masonry and concrete.

2) Unreinforced masonry retrofitted using wall strong backs or other out-of-plane reinforcing techniques.

3) Correlation of cyclic shear and bending tests to field observable parameters for URM.

4) Infilled performance with steel or concrete forms.

5. COMMISSION SUPPORT

The Commission can support efforts if appropriate information is made available.

DESIGN ACTIVITIES - ANALYSIS OF RETROFITTED STRUCTURES

Gary C. Hart

University of California, Los Angeles
and Englekirk and Hart, Inc.

1. INTRODUCTION.

During approximately the last decade I have been involved in the analysis of numerous existing buildings to evaluate their earthquake safety and possible retrofit. As the engineer of record the degree of analysis required has been my responsibility. Since 1978 my activities in this area were very limited and almost totally analytical. It should not be surprising to some to note that my ideas on the type and role of analysis have changed and it is only in the last few years that they seem to have stabilized. Therefore, the intent of this talk and paper is to share some insight on this role of analysis.

2. THE ROLAIDS FEELING.

The bottomline I now believe is that enough analysis must be performed by the structural engineer of record to insure that his/her "feeling" is one of comfort that the structure does not pose a life-safety hazard. I call this the Rolaids feeling because only the engineer of record knows when the feeling of R-E-L-I-E-F exists and he or she feels comfortable. This position is unsettling to the "academic" side of those of us educated in the early 1960's. However, it is not unsettling to many excellent engineers educated prior to the "enlightened space age." Structural engineering is an art in the purest definition of art wherein thought and reason are applied to result in a final product.

It is clear to me that building codes for seismic retrofit must be very broad in scope and only identify basic considerations which must be addressed by the engineer of record in the design. Therefore, what must be done is to document the tools, or analysis options which currently exist, and to then let the structural engineer of record select from among the options.

3. DESIGN CRITERIA CONSIDERATIONS.

The following considerations should be addressed as part of a seismic retrofit.

A. Seismic Environment.

1) Design life
2) Probability of exceedance
3) Site specific response spectra
4) Time histories

B. Component Strength and Ductility.

1) Beam and column component moment and deformation capacities, plus shear capacities
2) Joint component performance

C. Response of Existing System.

1) Life safety deformation limit
2) Deformation compatibility of multiple material systems

D. Response of Strengthened Structure.

1) Retrofit system alternatives
2) Deformation compatibility of composite system

DESIGN ACTIVITIES - DETAILING ISSUES

William T. Holmes

Rutherford & Chekene

In "An Action Plan for Reducing Earthquake Hazards of Existing Buildings" (ABE Joint Venture, FEMA, 1985), types of buildings considered seismically hazardous were listed as follows:

- Concrete frame buildings without special reinforcing
- Precast concrete buildings, including pre-1973 tilt-up structures and more recent tilt-up and precast-composite buildings
- "Soft-story" buildings (those with the lower story lacking adequate strength or toughness)
- Buildings with prestressed concrete elements and/or post-tensioned concrete slabs
- Steel frame or concrete frame buildings with unreinforced masonry walls
- Reinforced concrete wall buildings with no special detailing or reinforcement
- Unreinforced masonry-wall buildings with no special detailing or reinforcement
- Unreinforced masonry-wall buildings with wood or precast concrete floors
- Theaters and auditoriums having long-span roof structures
- Large, unengineered wood-frame buildings
- Buildings with inadequately anchored exterior cladding and glazing
- Buildings with poorly anchored parapets and appendages

Although these are more building characteristics than building types, it is interesting to compare this list with actual strengthening activities. Although our work is in no way a random, representative sample, Rutherford & Chekene is reasonably active in seismic strengthening, and a cross section of activity can therefore be obtained by summarizing our experiences. Buildings actually strengthened (not including evaluations, cost studies, etc.) over the last 20 years included:

Tilt ups	12
URM parapet mitigation	10
Concrete framing (all types)	8
URM bearing wall	6
Steel	2
Wood (not including repair)	1

The reasons that buildings are strengthened vary; often the inherent seismic hazard is not the primary cause for work on the building. The generators of strengthening activities can be broadly categorized:

1. RETROACTIVE REQUIREMENTS (e.g. LA, SF parapets, LA, Long Beach, Santa Rosa URM, etc.).

2. TRIGGERED REQUIREMENTS (e.g. San Francisco).

   A. Increase in Occupancy.

   B. Significant Change to Structure.

   C. Significant Remodeling.

3. VOLUNTARY ACTION.

   A. Conditions.

      1) Associated renovation
      2) Required evaluation (e.g. Palo Alto)
      3) Prepurchase evaluation
      4) Concern evaluation

   B. Motives.

      1) Protection of life safety
      2) Avoidance of property damage
      3) Maintenance of property values
      4) Avoidance of loss of business
      5) Maintenance of ability to perform
      6) Protection of image
      7) Fear of personal injury or other tort liability
      8) Maintenance of fiduciary responsibility
      9) Tax incentives

Very few elements of seismic strengthening are straightforward, but certain design issues seem to appear frequently. Although many of the issues listed below have been partially addressed in one way or another, none would seem settled in the same sense as in the design of new buildings.

1. LACK OF CRITERIA.

   A. When to Strengthen.

B. Level of Strengthening.

1) Force level
2) Mitigation of specific deficiencies
3) Spot strengthening
   a) priorities
   b) liabilities (the prudent man: the imprudent engineer?)

2. OVERTURNING AT FOUNDATIONS (not unlike problem with new buildings except more difficult to solve).

A. Rationalization of Rocking.

B. Determination of Dynamic Characteristics of Soils.

3. DISTORTION CAPACITY OF EXISTING STRUCTURAL ELEMENTS.

A. Concrete.

1) Inadequately or incorrectly reinforced concrete
2) Inadequate bond or splices
3) Beam column joints

B. URM In-Plane.

C. Dynamic P-delta Limits.

4. CLAY TILE (similar to 3 but so pervasive is to be listed separately).

A. Effect on Structural Response.

B. Level of Hazard.

1) In-plane distortion
2) Out-of-plane failure
3) Furring

C. Reasonable Methods of Mitigation.

5. NEW CONCRETE TO OLD.

A. Vertical Faces.

1) Dowel requirements
2) 2x (square root) shear limitation on single layer reinforcing
3) Shotcrete quality control

B. Horizontal Faces.

1) Shear transfer at new wall-existing floors

C. Methods of Effectively Trimming New Openings in Walls.

6. ALL MANNER OF DOWELS/BOLTS TO EXISTING WORK.

A. Materials.

1) Concrete
2) URM
3) Clay tile, block, etc.

B. Types.

1) Expansion
2) Epoxy
3) Grout

C. Positions.

1) Downhand
2) Horizontal
3) Overhead

7. CROSS BUILDING TIES IN EXISTING PLYWOOD DIAPHRAGMS.

A. Diaphragm Tension Capabilities.

B. Point-Load Distribution Capabilities.

8. BEHAVIOR OF STRENGTHENED BUILDINGS.

A. Performance.

B. Instrumental Records.

C. Mexico City Experiences 1957-1985.

DESIGN ACTIVITIES - MASONRY STRUCTURES

John Kariotis

Kariotis & Associates

Existing masonry structures that may pose earthquake hazards fall into two categories. The first category is the unreinforced masonry structures that exist throughout the United States in seismic zones. The second category is reinforced masonry structures that were constructed in conformance with codes that did not incorporate standards for the design of in-plane shear.

Repair and retrofit of existing structures is a much more difficult engineering task than the design of a new structure. The process involves several critical decisions that do not strongly influence the design decision for new structures. These decisions are briefly summarized as follows:

- Determine seismic hazard at the site by a probabilistic or similar process

- Decide on degree of hazard reduction that is appropriate

- Analyze the building to determine hazards and the probable consequences of an unmodified hazard

- Design a repair and retrofit plan

Practicing engineers are familiar with the last take, but generally have a limited working knowledge of the first three tasks. However, the first three tasks have the most significant influence on the cost-effectiveness of the last task. In many instances, the engineer assumes the first three decisions are made by design codes written for the construction of new buildings. Seismic hazard mapping in some U.S. codes has a relationship to probabilistic maps, but the use of zoning rather than coutours limits the use of these maps. The recently adopted hazard maps for the seismic design requirments used in the western United States combines zones that are sometimes based on assumptions of maximum probable ground motion, or uniform risk probabilistic contours, or data with a wide variation in consistency. The zones generally include a doubling of seismic intensity across the zone and in some cases may have a range to 3 or 4 times the lowest value of intensity.

Decisions as to the degree of hazard reduction is totally different than that anticipated for design of new buildings. Damage control is the key element for shaping reocmmendations for seismic design of new buildings. Hazard determined by analysis of existing buildings may either be a significant threat to life safety or may indicate mainly possible damage. Relating possible damage to life-safety threats or property damage and also to a variable annual probability of occurrence may be an effective method for estimating the cost effectiveness of proposed repair and retrofit plans. Analysis of an existing building to determine probable hazard is an absolute necessity. Non-compliance with current design codes should not be a criteria for recommending retrofit. Analysis of existing buildings is not a parallel method to design of a new building. The key element in analysis of an existing building is understanding of its response to ground motions, its existing strength and the behavior of the combination of the retrofit and existing structural materials.

As of today, analytical techniques exist for the unreinforced masonry buildings. These are the ABK TR-08, Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings, January 1984, and another ABK report, Guidelines for the Evaluation of Historic Unreinforced Brick Masonry Buildings in Earthquake Hazard Zones, January 1986. These documents address all four elements of decision making. However, determination of the behavior and strength of existing materials by non-destructive testing methods need additional research effort.

Analytical techniques for reinforced masonry buildings is now limited to the analysis of experimental specimens. Analytical techniques developed for reinforced concrete probably are generally applicable to reinforced masonry systems. The techniques used for analytical and experimental research are not widely published. The information must be obtained by review of many research reports and adjusted to the realities of the existing building by the engineer.

Design of repair and retrofit plans generally is related to current design recommendations. However, in many instances, the engineer must alter the code strength values to be compatible with the existing strength values used.

In summary, the available information for the repair and retrofit of unreinforced masonry building exceeds the available information that is related to reinforced masonry systems. Code requirements based on ABK TR-08 are now in use in southern California. Seminars to increase the use of these analyses and design techniques have aided in the spread of information. However, the currently used codes were only written for the seismic zone of EPA = 0.4 g. The Ad Hoc Hazardous Building Committee of the Southern California Structural Engineers Association is now writing a similar model ordinance for the California State Seismic Safety Commission. Upon completion of this task, the committee's agenda will be the development of an appendix to the Uniform Code for Building Conservation (ICBO) that addresses all seismic zones. However, these future documents will not address the degree of hazard reduction that is appropriate or the separation of possible damage into life-safety threat and property damage categories.

The Technical Coordinating Committee on Masonry Research (TCCMAR) is now developing appropriate earthquake response models and analyses techniques for reinforced masonry building systems. These low and moderate rise buildings are unique and better fit the response model used for unreinforced masonry buildings rather than current code response models.

Unreinforced masonry used as infills in structural frame buildings has only been addressed by past research. This structural system is not related to the building system that uses unreinforced masonry or reinforced masonry walls. This infilled system is considered as a critical earthquake hazard in California, and design activities for the modification of that hazard will require a substantial and coordinated research effort.

DESIGN ACTIVITIES - ARCHITECTURAL ELEMENTS AND CLADDING

Melvyn Green

Melvyn Green and Associates, Structural Engineers

1. OVERVIEW.

Architectural elements and building cladding have generally been neglected in discussions of building seismic retrofit, perhaps because most concern has been directed toward limitation of structural damage. Little time, energy, or money has been left over for consideration of cladding and ornamentation. Only one nonstructural element, the parapet, has received widespread attention, probably because parapet failures are common even in moderate earthquakes.

Seismic failure of other nonstructural elements is highly probable, however. All that is required is that enough seismic shaking take place in buildings with enough deterioration that the connections between structural and architectural elements are broken. We know that, in seismic areas, the occurrence of an earthquake of sufficient size is only a matter of time. The only variable is deterioration.

How deteriorated are attachments of nonstructural elements? How many buildings are affected? No survey exists, but a few facts are available:

A. Buildings with veneers and attached ornamentation have been built in the United States since about 1800. The great majority in most cities probably are "commercial style" buildings dating from about 1890-1915, as well as later ornamented styles such as art deco.

B. In severe-climate areas such as New York and Chicago, veneers and ornamentation are becoming a problem because the freeze-thaw cycles have caused attachments to deteriorate, resulting in spontaneous failure of nonstructural elements. A few people have been killed by falling veneers and ornamentation resulting in local inspect-and-repair laws in these areas.

C. Most seismically active areas in the United States are along the west coast, temperate-climate areas. Thus, no spontaneous failures of veneers and ornamentation have occurred in any seismically active area. As a result, veneers and ornamentation have not been subjected to compulsory inspection.

D. While freeze-thaw stress accelerates deterioration of attachments, lack of such stress does not mean that no deterioration is taking place. It has been our experience that all stone veneers, terra-cotta, and other ornamentation that we have examined have been more or less deteriorated by water incursion. Air pollution also is sometimes a factor.

Our conclusion is that many aging and weakened veneers and architectural attachments exist in seismic areas. Because the mild climate of these areas has slowed the rate of deterioration of attachments, the instability of these elements has not yet been recognized as it has in areas with a harsher climate. However, it is not unlikely that moderately deteriorated attachments, under the stress of a major earthquake, may suddenly fail. As the consequences of such a failure could be catastrophic, examination and strengthening of attachments of non-structural elements of buildings in seismic areas are needed.

2. WORK TO DATE.

The EERI Task Group on Nonstructural Building Elements discussed issues relative to cladding and attachments, mostly in regard to new construction. Melvyn Green and Associates has a grant from the National Science Foundation to identify some of the issues of existing architectural elements and attachments to historic structures.

To date, the only retroactive ordinances regulating veneers and architectural elements in seismic areas are concerned only with parapets. Palo Alto, California has adopted an ordinance requiring investigation of existing buildings including ornamentation.

Several communities have ordinances requiring mitigation of a common hazardous architectural element, the parapet. Frequently parapets have been removed rather than strengthened. Little attention has been directed towards other ornamentation or cladding in existing buildings.

3. DESCRIPTION OF CLADDING AND ORNAMENTATION.

Cladding and ornamentation fall into two broad categories. These are:

A. Attached Veneer. This category includes stone, both natural and man-made; glass - carrara and block; sheet metal and curtain walls. Stone may be further broken down into natural stones such as granite, limestone, marble and sandstone and man-made stone including brick, block, terra-cotta, tile and cast stone. Attached veneer may be on exterior or interior walls.

B. Ornamentation. Ornamentation includes the materials described for veneer and additional metals such as cast iron, bronze, aluminum, copper and sheet metal. Examples of ornamentation include parapets, cornices, balconies and other appendages and other cast ornamentation.

While the cladding or ornamentation may be structurally competent, the critical factors are the substrate and attachments.

Substrate materials are a concern in seismic zones. Often, the substrate is unreinforced masonry, generally brick or hollow clay tile. The stability of the substrate is a major factor to consider in evaluating the safety of the assembly.

Attachments may be iron, bronze or other metals. The veneer in multi-story structures is supported on a steel shelf angle. In wood frame buildings, as well as in other types of construction, steel wire may be used to hold the ornamentation.

4. RESEARCH NEEDS.

Research needs include methods for in-place inspection and testing of veneers and ornamentation; methods to analyze the degree of hazard; and methods and devices to competently reattach these architectural elements.

REPAIR AND RETROFIT OF INDUSTRIAL AND INSTITUTIONAL BUILDINGS

Nicholas F. Forell

Forell/Elsesser Engineers, Inc.

The repair and retrofit of industrial and institutional buildings presents a number of unique problems. The motivation for repair or retrofit is often to protect life safety from the direct effects of earthquakes, such as structural collapse or falling objects. In the past few years, an additional purpose is to maintain post-earthquake operational function and/or to safeguard against secondary effects of the earthquake, such as the escape or spillage of toxic chemicals. The need for strengthening industrial facilities or components, whose partial or complete destruction as a result of earthquakes would cause release of poisonous gases into the air or spillage of toxic materials, is easily understood. The need to maintain operation of industrial and institutional facilities after an earthquake is, however, more controversial. There appears to be a consensus that buildings essential for post-earthquake emergency services, such as emergency command centers, police and fire stations, hospitals, etc., must be designed to remain functional after a major earthquake; and building regulations require that this be accomplished. No such consensus or regulations exist as far as other facilities are concerned. It can be argued that such lack of consensus and policy is against the interests of society. Clearly the operational loss of key industrial facilities could lead to severe economic losses and possibly prolonged unemployment. Severe damage and loss of production capabilitiy can adversely affect the national defense effort by putting military contract vendors out of production. As previously stated, the effects of severe damage to the chemical industry, as well as other industrial plants utilizing toxic materials, could result in a significant loss of life and severe environmental pollution.

The issue of the repair and retrofit of industrial facilities is complicated by the direction and aims of seismic design and hazard mitigation, which is primarily focused on the protection of life. Property protection along with post-earthquake functionality (with the exception of "essential" facilities) is not a matter of priority. Many codes clearly state that life protection is their only goal and protection of property is not included. An anomaly is the Uniform Building Code, which states in its preamble that its purpose is to "...safeguard life and limb, health, property and public welfare..."

Interestingly, the SEAOC Blue Book, which is the origin of the UBC seismic design provision, makes no reference to protection of property.

FEMA's Action Plan for Reducing Earthquake Hazard of Existing Buildings, published in 1985, states that this action plan is focused on life safety and, "property protection is neither a specific goal, nor an objective of this action." Further, there are no references to industrial facilities and the codes are basically written and directed at the protection of buildings.

If a seismic hazard mitigation effort to maintain operation of specific facilities is considered to be in the national interest, then a different design approach is necessary than is now contained in seismic design regulations. Even if such design procedures are not, or should not be, considered to be mandatory, guidelines should be developed to permit a voluntary design, repair or retrofit program.

The major problem with current design regulations is that they are prescriptive. Specific force levels and design procedures are provided, the compliance with which is assumed to provide the desired results. In the case of ordinary structures, this is to avoid collapse and loss of life. In the case of essential facilities, a design using a 50%-higher force level is assumed to provide post-earthquake operational function, a notion that is, in the minds of many knowledgeable engineers, a gross oversimplification.

If guidelines are to be developed to assure post-earthquake operation or to prevent damage, then they must be performance-oriented and take into consideration both the realistic force levels to be used as well as the performance of the structure or components subjected to those forces. The force levels required for design in the code represent an average of the seismicity of a region but do not take into account the specifics of the site. Therefore, a site-specific seismicity evaluation may be necessary. Rather than a probabilistic approach, an event-oriented approach that takes into consideration the most significant faults should be considered.

If the design is to accommodate the expected maximum earthquake, then the required performance of the structure and its components must be established. In the design of structures, the difference between response spectrum demand and structure capacity is accomplished through the use of "k" or "Rw" factor, expressing the ductility or reserve capacity for the structural system. These factors are neither accurate enough nor detailed enough to give assurance that the structure will perform as desired. Less certain is our knowledge of the capacity or performance of retrofit systems. What are the appropriate "R" values for buildings using various retrofit systems?

As far as building contents and industrial equipment are concerned, we have little guidance for their seismic bracing. The "Cp" values in the code were not written for industrial equipment and probably do not suffice.

The voluntary seismic upgrading of industrial facilities is increasing and should be encouraged. Unfortunately, the criteria and methods used in this effort seem to vary from project to project and are dependent on the engineer who is given the upgrading task. The resulting confusion could be eliminated if guidelines for such work were developed. Such guidelines as the minimum should contain methods for the determination of design ground motions, including their implied level of risk; methodology for the evaluation of the capacity of building systems and their components, as well as the capacity of their retrofit. The development of such guidelines and the research necessary for making it possible should be given a high priority.

ATC-14 - EVALUATING THE SEISMIC RESISTANCE OF EXISTING BUILDINGS

Chris D. Poland and James O. Malley

H. J. Degenkolb Associates

The Applied Technology Council has developed a methodology for evaluating specific buildings that is tailored for use by practicing structural engineers, which leads not only to conclusions concerning the adequacy of the structure for a given event, but also identifies the structure's weaknesses and, therefore, areas of needed rehabilitation. It has been structured to permit the rapid screening of a large inventory of buildings followed by detailed evaluation where necessary.

ATC-14 has been developed consistent with the latest building codes but tailored to the often non-conforming characteristics of the variety of buildings in existence. It is specifically aimed at assessing a building's life-safety level of resistance, with a recommendation that all buildings be strengthened to this minimum level.

The project was organized around a steering committee, the ATC Project Engineering Panel, two special consultants on strong ground motion, a subcontractor, the ATC staff, and an NSF program manager. The subcontractor was responsible for the development of the methodology under the supervision of the Project Engineering Panel. The special consultants developed the nationwide strong-motion criteria to be used in the evaluation procedure.

ATC-14 is the type of methodology that will serve to guide but not restrict the evaluating engineer so that consistent and fairly complete thinking can be brought to bear on each seismic evaluation. It stands as a catalog of our collective earthquake experience which is incorporated with appropriate analysis and design techniques in a concise format that can guide a knowledgeable engineer in the evaluation of an existing building.

The methodology begins with data collection procedures which are required to gather the information necessary to classify the building and perform the evaluations. The appropriate procedures for using existing documents, performing site investigations, and testing the structural materials are outlined. While the methodology is tailored to the evaluation of buildings on an individual basis, it is structured to permit preliminary screening of an inventory of buildings in order to identify the ones that need to be evaluated at length. Simple, small-to-medium sized, regular buildings, with good performance record in past earthquakes are screened out. Others are identified for additional evaluation in the specific areas that they are possibly deficient.

The evaluation of a building is directed by a specific section in the methodology written for the related model building. It includes a building description, a summary of the performance characteristics based on past earthquake observations, paragraphs related to the expected building loads and load paths, references for examples of performance in past earthquakes, and a rapid evaluation procedure. The rapid evaluation procedure attempts to provide a quick method to assess the basic strength and/or drift control provided by the structure.

The evaluation procedure consists of a collection of statements with a related concern and suggested, specific analysis technique if further study should be necessary. Each statement relates to a vulnerable area in the structural system that requires specific consideration. A separate set of statements is presented for regions of different seismicity.

The evaluation statements are written such that a positive or "true" response to a statement inplies that the building is adequate in that area. If a building then passes all the related statements with true responses, it can be passed without further evaluation. It must be once again stressed that these evaluation statements are intended to flag areas of concern for the evaluating engineer and, by nature, must be quite conservative. Not all critical elements of buildings can be evaluated by simple true or false statements. The final decision regarding adequacy, need for further study, or need for strenghtening still rests with the engineer, regardless of the statements. For this reason, these evaluation procedures, even the initial screening procedures, must be applied by a knowledgeable structural engineer.

Each statement carries with it a concern which explains in commentary style why the statement was written. These concerns are carefully written and intended to further assist the evaluating engineer in dealing with the issue stated. Obviously, addressing the concern takes precedent over the specific statement.

For statements that are "false," additional evaluation is required. This does not necessarily imply that a complete structural evaluation is necessary, or that the building is automatically deficient. In fact, the suggested procedure limits the evaluation to only the area of concern. It is offered as a suggested procedure since the responsiblity for the evaluation rests with the structural engineer, who may elect to perform an alternate evaluation procedure. This is permissible as long as it addresses and leads to an opinion regarding the issue raised in the statement. Deficiencies are therefore identified only after an appropriate detailed evaluation has been made.

APPENDIX A4

TASK GROUP REPORTS

Repair and Retrofit of Existing Structures
Los Angeles, California
September 30-October 1, 1987

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TASK GROUP I - REINFORCED CONCRETE AND STEEL STRUCTURAL SYSTEMS - FRAMES, WALLS, FOUNDATIONS, CLADDING, BRACING

L. A. Wyllie, Jr., Moderator; R. D. Hanson, Recorder;
R. Burkett, P. F. Fratessa, M. Green, H. S. Lew, J. Warner, N. Youssef

A. Issues Related to Response of Existing Buildings

In making a life-safety hazard analysis of an existing building, realistic earthquake input must be established for all locations in the U.S. Once the earthquake hazard is well defined, analysis of existing buildings can be carried out. For response in the inelastic range there are many issues that cannot be characterized accurately at the present time. Buildings with infills and non-ductile concrete or steel buildings with various deficiencies in details and reinforcement pose special problems. Data is needed to establish -

1. Models for member behavior.

2. Behavior of structural systems, with or without infills, incorporating existing deficiencies into the behavioral model.

3. Dynamic response.

The error level or degree of confidence in the analysis of existing buildings needs to be established. One possible way of doing this is to find old buildings ready for demolition where full-scale, realistic testing could be done and the response compared with computed values. In addition, information on collapsed, damaged, and undamaged buildings from actual earthquakes should be correlated with measured ground motion using a variety of analysis techniques. A coordinated effort to understand behavior of various types of full-scale structures is needed. For example, all unreinforced masonry buildings used to be condemned but with better knowledge, much now can be done to reduce the hazard. Such approaches need to be extended to other types of buildings.

There is a need for better understanding of cladding performance and interaction with the structure. The performance of 8 to 12-story steel frames built from 1911 to 1930 with clip angle connections and offset columns at the second floor and with unsymmetrically located solid masonry or concrete walls needs to be studied to know how to assure stability in an earthquake.

B. Issues Related to Design of Strengthening and Retrofitting Schemes

Common practices for strengthening procedures are needed. The performance of weak elements, in-plane and out-of-plane response, should be studied. The performance of various methods used to brace unreinforced brick walls out of plane is not understood.

New materials need to be thoroughly tested to provide data on their performance. The structural properties of new materials continually being developed need to be examined. The implications of compatibility of materials, e.g., the modulus of resins vs. concrete, are not understood. The strength and deformation of the original structure and the strengthening techniques must be matched.

Special construction techniques need to be examined. Tilt-up construction is a major concern; workmanship varies greatly. The performance of various wall tie details should be established. Drag steel is used to strengthen a diaphragm but its performance is not known. For example, is it really needed for life safety performance? The whole area of lift slab performance has not been studied, nor has much effort gone into flat slab performance and strengthening. Post-tensioned flat plates are often cracked due to slab shortening and wall restraint. The influence of such cracks on structural response is not known. Performance of existing structures with base isolation needs to be studied.

Foundation work is very expensive. Issues and techniques relative to strengthening of foundations need to be better understood. For example, how will precast piles perform and how does one predict their behavior?

Few large size test facilities are available in the U.S. Large, full-size buildings, or components can not be realistically tested to include 3D effects. This is especially important for studying strengthening schemes where details cannot be easily modeled or simulated in reduced scale.

C. Summary

The types of structures representing the greatest hazards to life safety are:

1. Unreinforced masonry structures including bearing wall masonry and infill walls in concrete or steel.

2. Non-ductile concrete buildings, including tilt-up construction.

3. Older steel frame buildings.

4. High occupancy buildings built prior to recent earthquake codes revisions.

The ability to determine the potential hazard a building represents should be developed. The factors which must be considered in such a determination include

1. Site response.

2. Building performance - experimental work is needed to develop performance/response models which can be used for analysis of structures. The biggest gap is in the response of an existing structure from moderate damage to collapse.

3. Analytical and experimental studies should establish the sensitivity of the design/evaluation process to the parameters governing response at all stages of behavior.

Strengthening procedures must be refined and understood. Of special concern are

1. Compatibility of strength and deformation of the existing structure and the strengthening scheme.

2. Development of new materials and techniques.

3. Experimental work to verify performance and to establish design and construction limitations.

Better investigative and inspection techniques need to be developed including

1. The use of ultrasonics, tomography, and other "high-tech" procedures.

2. The number and type of material tests needed to establish the condition of a structure.

3. Methods to determine rebar location and details when no drawings are available.

The ultimate goal is to develop retrofit/strengthening codes and guidelines which cover a wide range of structural types and retrofitting schemes. Such codes and guidelines must be based on common terms and utilize available literature in the U.S. and elsewhere. Much work has been done in Japan and continued cooperative efforts and exchanges with designers, researchers, and building officials in other countries should be encouraged.

TASK GROUP II - MASONRY STRUCTURES

D. P. Abrams, Moderator; J. M. Plecnik, Recorder;
A. Asakura, J. Kariotis, S. P. Prawel

A. INTRODUCTION

Topics were divided into the following six major catagories.

1. Definition of seismic hazard zones.

2. Evaluation of materials and systems.

3. Development of analytical techniques.

4. Development of specific retrofit techniques.

5. Development of details and connections.

6. Development of strength design concepts.

B. SUMMARY

It was generally felt that solving the repair and retrofit problem was much more challenging than solving the problem of designing new seismically resistant construction. For repair or retrofit, both old and new structural systems need to be examined as well as how they interact. Furthermore, many existing buildings must be analyzed which have not been engineered previously. Analytical and evaluation techniques need to be developed for this purpose.

Not only does research need to be done to model response of existing systems, research needs to be done to model response of systems strengthened with new and innovative technology. Of primary concern was the development of specific strengthening schemes for unreinforced walls and infills. Listed below is a detailed summary of the discussion of the group on masonry for each one of these subtopics.

1. <u>Seismic Hazard Zones</u>

a. <u>Definition of threat and extent of threat</u>

When faced with a possible strengthening problem, an engineer needs first to determine whether the unstrengthened structure can survive without modification. To do this, he or she needs an estimate of the seismic threat at a particular site. If repair or retrofit is found necessary, definition of the threat is again required, so that the necessary degree of strengthening can be determined. Stated simply, the loads must be first defined before one attempts to proceed further with a design.

b. Degree of hazard reduction appropriate

As well as knowing the intensity of the seismic event, it is also relevant to define for what degree of hazard reduction should the repair or retrofit solution be provided. Although this may not be a topic for engineering research, it is an essential question which must be addressed for a rational retrofit design.

2. Evaluation of Unstrengthened and Strengthened Structures

Repair or retrofit schemes might not be necessary if methods of evaluation are developed that provide a more accurate estimate of the stiffness and strength of a particular structure. This is particularly relevant for masonry structures, because of the relatively high safety factors used in design and the large uncertainty in behavior at the time of design. Needs exist for improved methods of evaluation for both materials and components as well as for structural systems.

a. NDE of masonry materials and components

Although there have been a few studies on nondestructive evaluation (NDE) for masonry, there still is much to be learned and standardized regarding how to measure the resistance of the materials and components. Because of the many different types of masonry used throughout the past, NDE methods of assessment are an attractive alternative to overly conservative code specifications of strength. Of particular importance are ways to evaluate compressive and shear strength of unreinforced masonry walls.

b. Analysis of systems

Once properties of material and components are known, analytical procedures are needed to assess the safety and serviceability of a given structural system. Computational models need to be developed for masonry buildings that incorporate relevant behavioral modes. Improved nonlinear dynamic models may show that there may be no need for strengthening. In fact, they may show that certain schemes may be more disastrous than the original structural system.

As well as more complex models, simple models need to be developed and verified so that a rapid analysis can be done to provide quick estimates of vulnerability. Results of this type of analysis can be used to determine if more evaluation is necessary.

3. Development of Analytical Techniques for Specific Retrofit Schemes

a. Response predictions

Analytical tools need to be available to the engineer so that he or she may predict dynamic response of the strengthened structure. In so doing, he or she may decide to alter the scheme for repair or retrofit, or conversely, provide verification of the suitability of a particular solution. With increased computer facilities, engineering offices can now have the capabilities to perform nonlinear dynamic analyses on simple systems. Software needs to be developed for this purpose and scope.

b. Statistical and probability based design

Because not all parameters are deterministic (ground motion characteristics, stiffness of structure, etc.), analytical techniques need to be developed that provide the engineer with tools that assess the risk of a particular repair or retrofit scheme and aid in the overall decision making process.

4. Development and Verification of Retrofit Techniques

Unlike the previous topics, the following ones are focused on masonry in particular. The two major types of masonry structures requiring attention were identified as unreinforced masonry walls and infilled frames. Strengthening methods for each type of structure were mentioned as areas where further research is needed.

a. Unreinforced masonry walls

The day after the workshop, a number of buildings collapsed as a result of weak unreinforced masonry walls. Simple procedures need to be developed to improve the shear strength of these elements. Present methods are, perhaps, the first to investigate before innovative schemes are developed. These include, but are not limited to, surface coatings, strengthening with steel frames, new reinforced wall elements and use of confined masonry (RC internal frame).

Sprayed on gunite is common, but little is known regarding the strength and stiffness characteristics of walls strengthened in such a manner, or what is the effectiveness of mesh reinforcement.

Many times a new steel frame is secured to an older masonry wall to provide strength and ductility. Unfortunately, compatibility of deformations is not considered, and therefore, significant cracking of the masonry must occur before the steel frame can resist the story force as intended for design. The solution also tends to be costly because of the steel material and connection requirements. Such systems need to be examined experimentally as well as analytically so that serviceability and cost effectiveness can be improved.

Older unreinforced masonry structures are often renovated in such a manner that new reinforced walls may be added. In such cases, it is common to neglect the lateral-force resistance of the old masonry entirely, and assume that the new reinforced elements resist all of the story shear. This is done so that the relative stiffness of the old and new elements need not be determined. Like the steel frame, this approach may lead to unsightly cracking in the unreinforced walls and may not necessarily be the most cost effective. Analytical methods can be developed to account for the interaction of old and new components. Criteria for adding stiffness, strength and ductility can be established so that the resistance of the old and unreinforced, but massive construction, can be best enhanced.

In many other parts of the world the use of "confined masonry" is common. This entails placing a reinforced concrete column or beam integrally with the masonry and results in what may be termed in this country as a "partially reinforced" wall. As in the previous two repair schemes, this one also adds strength and ductility to an unreinforced wall, but little is known regarding the strength or stiffness characteristics of the combined system.

b. Infilled frames

Infilling reinforced concrete or steel frames with masonry panels is a very common way to construct buildings, or to strengthen them; however, very little is understood regarding the interaction between the frame and the infill panel. It is not generally accepted whether the infill panel should be separated from the frame to avoid attraction of undesired story shears, or securely attached to it to reduce interstory drifts. No code specifications presently address this problem.

Following earthquakes, it is fairly typical to observe cracking within a masonry panel or distress within frame elements adjacent to a panel. This is often because the stiffness of the panel has not been considered in the design of the system, but merely placed for architectural considerations. Partial-height infill panels, in particular, have resulted in significant damage to reinforced concrete structures. The pattern of infilling bays throughout a frame structure is another factor which should be considered for design of a frame, but is usually ignored.

A number of knowledge gaps can be identified with respect to masonry infills. The research that has been done has been diverse and not organized in such a way that building code specifications can result. For example, essentially no studies have been done on steel frames with masonry infills.

Questions arise regarding the effectiveness of using infills as a solution for repair and retrofit. Because many buildings already have infills, there are also questions regarding how to best strengthen the panels themselves. This is also appropriate to repair of cracked infill panels following earthquakes.

5. Anchorage and Splices

The strength of a masonry structural system is usually dependent on how the walls are tied together with themselves and the floor or roof slabs. Of critical concern is the pullout strength of bolts and reinforcing bars which connect these elements together. The strength of anchors must be known to assess the integrity of existing structures as well as to repair or retrofit them. For example, many times steel fixtures are secured to an existing masonry wall using anchor bolts that are set into the bricks or mortar with epoxy grouts.

Recent research has developed suitable criteria for establishing splice lengths for reinforcing bars in masonry. Many of the older values have been found to be inadequate. It is, therefore, necessary to know how much an existing splice may be relied on, so that repair or retrofit schemes can be prescribed. It may also be necessary to know how to repair a defective splice. If new reinforcement is added that requires splicing, it is necessary to know what splice length may be needed.

6. Development of Methods for Strengthening of Connections

Connections between walls, and between walls and floors, are recognized as one of the vulnerable parts of masonry systems. Dynamic response and damping of a system can depend significantly on slippage or separation of these connections. Loss of connection strength can result in immediate collapse of a system. Poor connection ductility can result in a brittle system. Yet, little is known regarding the behavior of the most typical connections under repeated and reverse loadings. Furthermore, for repair and retrofit, research needs to be focused on development of methods for strengthening these existing weak connections, and to what the properties of the strengthened connections might be.

7. Development of Strength Design Concepts for Different Retrofit Schemes

By the time a coordinated research program on repair and retrofit is concluded, it is likely that new masonry structures will be designed using strength concepts. It is, therefore, consistent to develop repair and retrofit schemes based on similar ultimate-strength concepts. For example, it would be rational to design a masonry infill panel using the same strength-design approach as the rest of the frame. Because research should follow a need, the adoption of strength design concepts for repair and retrofit should come early, if at all, so that future research programs can be directed at obtaining the necessary parameters.

TASK GROUP III - INDUSTRIAL, INSTITUTIONAL BUILDINGS - EMPHASIS ON CRITICAL SYSTEMS WITHIN THE BUILDINGS

N. F. Forell, Moderator; J. P. Moehle, Recorder;
I. Buckle, W. T. Holmes, J. O. Malley

A. Issues for the Retrofit of Industrial and Institutional Facilities

1. Damage to institutional and industrial facilities can have detrimental impact on private, regional, and national interests. Loss of function in certain high-tech areas can result in loss of competitiveness of US industry. Loss of function of major governmental contractors or of military installations can impact national defense and other areas of national interest. Leakage of toxic chemicals due to earthquake effects can pose a hazard to the population over regions extending well beyond the structure itself. For these critical facilities, retrofit design should focus on post-earthquake operational function or hazard reduction rather than the conventional focus of "life safety."

2. Where performance of a facility poses a hazard extending beyond the structure itself, or where loss of function will impact significantly on the broad public interests, governmental policies should be imposed to ensure a minimum performance index. The policies should ensure that retrofit measures are undertaken and that the measures will be appropriate to adequately protect the public interest.

3. In an evaluation of the anticipated performance of an existing or retrofit structure, likely ground motions should be ascertained. For this purpose, site response spectra should be developed and used.

4. The influence of structural response characteristics on damage of contents and equipment should be established. Characteristics to be studied include drift, velocity, acceleration, period, and duration.

5. Serviceability, strength and deformation capacities of existing structural elements and systems should be established. In many cases, the existing elements will not conform to current requirements in strength and detail. Performance of such elements should be established.

6. Behavior of retrofit structural systems should be established. Local performance, and effects on overall performance of the

structure, should be studied. The interactions between new and old structural systems having different strength, stiffness, and ductility characteristics should be determined. Serviceability as well as conventional strength criteria should be examined.

7. Strength and deformation characteristics of equipment and contents should be established.

8. Anchorage, bracing, and isolation techniques for new and existing equipment and containments should be established.

9. Building isolation and other innovative techniques should be considered as possible retrofit schemes.

B. Research Needs Related to Retrofit of Critical Industrial or Institutional Facilities

1. Little is known about the performance of elements and structures that do not conform to recent or current code requirements. Experimental and analytical studies of strength and deformation capacities of existing elements/structures should be conducted. These should include

   a) laboratory studies of elements/systems, including static, pseudodynamic, and shaking-table studies,

   b) field tests of complete or partial structures salvaged from buildings about to be demolished. These studies should be coordinated with analytical studies to determine relationships for stiffness, strength, deformability, ductility, system configuration, and performance during a given event.

2. A wealth of data is available on the performance of existing buildings. The data include reconnaisance studies and records from instrumented buildings. Much is to be learned from buildings that have performed well and from those that have not. Systematic studies should be carried out to develop a better understanding of the behavior of these existing buildings. Likewise, behavior of retrofit systems should be examined.

3. The performance of equipment and containments should be further studied including

   a) evaluation of available data from nuclear industry and others,

   b) additional tests as required,

   c) studies of effects of structural performance characteristics on performance of equipment and containments.

4. Risk analysis studies should be undertaken to determine the effects of damage in industrial and critical facilties on local, regional, and national economy and interests.

5. Analytical and experimental studies should be made of the performance of retrofit elements and systems including

   a) performance of retrofitted structures that have been subjected to strong ground shaking,

   b) connections between existing and new construction,

   c) interactions between new and existing elements in a system with consideration of the possible incompatibilities in strength, stiffness, and deformability. In all cases, the studies should consider not only the conventional "life safety criteria but also the impact on function of the existing facility.

6. Studies should be made to develop and implement innovative earthquake-protective systems for equipment, containments, systems, and buildings. The studies should include but not be limited to isolation techniques.

APPENDIX B

U.S. JAPAN WORKSHOP

Tsukuba, Japan, May 8-9, 1987

AGENDA

Repair and Retrofit of Existing Structures
TSUKUBA, Japan
May 8-9, 1987

Friday May 8

	9 : 30 A.M.	Call to Order	M.Hirosawa
	9 : 40 A.M.	Adress of Welcome	S.Okamoto
	9 : 50 A.M.	Adress of Greeting	J.O.Jirsa

**** Session I (Inspection Method, Damage Evaluation Method) ******
Co-chair : J.O.Jirsa, M.Hirosawa

(A1)	10 : 00 A.M.	Overall Design Standard for Earthquake Resistant Capacity of Govermental Buildings	K.Onisawa K.Shimizu
(A2)	10 : 25 A.M.	Post-Earthquake Inspection and Evaluation of Earthquake Damaged in Reinforced Concrete Building	H.Hiraishi M.Murakami T.Okada M.Ohkubo K.Takiguchi S.Otani
(A3)	10 : 50 A.M.	Methods of Temporary and Permanent Restoration Applied to Reinfrced Concrete Buildings Damaged by Earthquake	M.Yoshimura T.Okada T.Endo M.Okubo
(A4)	11 : 15 A.M.	Seismic Capacity of Reinforced Concrete Buildings Which Suffered 1985.9.19-20 Mexico Earthquake	T.Okada M.Murakami T.Minami N.Ishikawa
	11 : 40 A.M.	******** LUNCH ********	

*********** Session II (Experimental Study) ************
Co-chair : L.A.Wyllie, T.Okada

(B1)	1 : 00 P.M.	Behavior of Expansion Anchor Bolts	T.Endo Y.Shimizu
(B2)	1 : 25 P.M.	Performance of Reinforced Concrete Components Repaired with Epoxy Resin	A.Tasai H.Aoyama S.Otani
(B3)	1 : 50 P.M.	A Study on the Strengthening with Carbon Fiber for Earthquake Resistant Capacity of Existing Reinforced Concrete Columus	H.Katsumata Y.Kobatake T.Takeda
(B4)	2 : 15 P.M.	Recent Five Years Source List on Repair & Retrofit for RC Buildings due to Earthquakes	S.Nakata

(B5)	2 : 40 P.M.	Experimental Studies on Repair and Strengthening of R.C Frames	J.O.Jirsa
	3 : 05 P.M.	******* Coffee Breake *******	

******* Session III (Rehabilitation of Steel Building) ********
Co-chair : N.Forell, K.Takanashi

(B6)	3 : 30 P.M.	An Outline of the Manual for Rehabilitation of Earthquake Damaged Steel Building	T.Takanashi T.Murota H.Yamanouchi I.Nishiyama
(B7)	3 : 55 P.M.	Evaluation of Seismic Resistance Capacity of Damaged Steel Building	S.Morino K.Takanashi I.Nishiyama
(B8)	4 : 20 P.M.	Ultimate Strength and Repair Method of Beam-Column Connections Fabricated by Fillet Welding	K. Morita K. Takanashi T. Murota

5 : 10 P.M. CLOSE

6 : 00 P.M. WELCOME PARTY

Saturday May 9

********** Session IV (Retrofit Design etc) ************

Co-chair : J.P.Moehle, H.Aoyama

(C1)	9 : 30 A.M.	Design and Construction Schemes for Buildings	L.A.Wyllie
(C2)	9 : 55 A.M.	Seismic Strengthening of Existing Reinforced Concrete Buildngs by Braces and Panels of Structural Steel	S.Sugano M.Fujimura
(C3)	10 : 20 A.M.	Repair and Strengthening of Industrial Facilities	N.F.Forell
(C4)	10 : 45 A.M.	Seismic Inspection and Retrofit of Nine-story RC Building Damaged by the Mexico Earthquake, 1985	M.Hirosawa T.Noji H.Yoshida Y.Endo H.Yamanaka T.Akiyama
(C5)	11 : 10 A.M.	Research Needs for Repair and Strengthening of Reinforced Concrete Floor Slab Systems	J.P.Moehle
	11 : 35 A.M.	******** LUNCH ********	

*********** Session V (Free Discussion) *************

Co-chair J.O.Jirsa, M.Hirosawa

(D1) 1 : 00 P.M.

Topics

a. Inspection Techniques
b. Strengthening Procedure
c. Repair Procedure

3 : 00 P.M. ****** Coffee Break ******

(D2) 3 : 30 P.M.

Continue

5 : 00 P.M. CLOSE

TABLE OF REPORTS AND PRESENTATIONS

Repair and Retrofit of Existing Structures
TSUKUBA, Japan
May 8-9, 1987

A. PRESENTATIONS FROM U.S. PARTICIPANTS

1. Research Needs for Repair and Strengthening of Reinforced Concrete Floor Slab Systems

   J. P. Moehle

2. Design and Construction Schemes for Buildings

   L. A. Wyllie

3. Repair and Strengthening of Industrial Facilities (oral presentation)

   N. F. Forell

4. Experimental Studies on Repair and Strengthening of RC Frames (oral presentation)

   J. O. Jirsa

B. PRESENTATIONS FROM JAPANESE PARTICIPANTS

1. Comparison of Building Seismic Design in U.S. and Japan (Report on the 2nd U.S.-Japan Workshop on the Improvement of Building Seismic Design and Construction Practices)

   Y. Ishiyama

2. Evaluation on Positions of Dynamic Response Analyses in Seismic Design by a Full-Scale Six-Story Steel Building Structure

   H. Yamanouchi, A. Hori and T. Yomo

3. Overall Design Standard for Earthquake-Resistant Capacity of Governmental Buildings

   K. Onisawa and K. Shimizu

4. Recent Five-Years Source List on Repair and Retrofit for RC Buildings Due to Earthquakes

   S. Nakata

5. Post-Earthquake Inspection and Evaluation of Earthquake Damage in Reinforced Concrete Buildings

   H. Hiraishi, M. Murakami, T. Okada, M. Ohkubo, S. Otani and K. Takiguchi

6. Methods of Temporary and Permanent Restoration Applied to Reinforced Concrete Buildings Damaged by Earthquake

   M. Yoshimura, T. Okada, T. Endo and M. Ohkubo

7. Seismic Capacity of Reinforced Concrete Buildings which Suffered 1985.9.19-20 Mexico Earthquake

   T. Okada, M. Murakami, T. Minami and N. Ishikawa

8. Seismic Inspection and Retrofit of Nine-Story RC Building Damaged by the Mexico Earthquake, 1985

   M. Hirosawa, Y. Endo, T. Noji, H. Yoshida, H. Yamanaka and T. Akiyama

9. Seismic Capacity of Reinforced Concrete Four-Story School Buildings which Suffered 1985 Mexico Earthquake in Mexico City

   S. Sugano, H. Eto, T. Noji and K. Tamura

10. Inelastic Analysis of the Namioka Town Hospital Building Damaged During the 1983 Nihonkai-Chubu Earthquake

    Y. Yamazaki, M. Hirosawa, Y. Kitagawa and M. Teshigawara

11. Behavior of Expansion Anchor Bolts

    T. Endo and Y. Shimizu

12. Experimental Study of Strengthening Effect on Reinforced Concrete Shear Wall Thickened with Retrofit (Mashiuchi) Wall

    T. Goto and H. Adachi

13. Performance of Reinforced Concrete Components Repaired with Epoxy Resin

    A. Tasai, H. Aoyama and S. Otani

14. A Study on the Strengthening with Carbon Fiber for Earthquake Resistant Capacity of Existing Reinforced Concrete Columns

H. Katumata, Y. Kobatake and T. Takeda

15. Study on Retrofit Method of Existing Structures by Steel Braces with Dampers

M. Seki, H. Katsumata and T. Takeda

16. Seismic Behaviors of Existing RC Frame Strengthened with Retrofitting Steel Elements

Y. Yamamoto and H. Aoyama

17. Seismic Strengthening of Existing Reinforced Concrete Buildings by Braces and Panels of Structural Steel

S. Sugano and M. Fujimura

18. Seismic Inspection and Strengthening of Public Reinforced Concrete Buildings, Chiefly in Case of School Buildings

M. Hirosawa and T. Akiyama

19. Damage Aspects and Hysteresis Properties after Repair and Installation of Non-Structural Elements

S. Nakata, A. Baba and H. Itoh

20. Strengthening of Steel Buildings Against Strong Earthquakes

K. Takanashi, B. Kato and A. Tanaka

21. An Outline of the Manual for Rehabilitation of Earthquake-Damaged Steel Building

K. Takanashi, T. Murota, H. Yamanouchi and I. Nishiyama

22. Evaluation of Seismic Resistance Capacity of Damaged Steel Building Structure

S. Morino, K. Takanashi and I. Nishiyama

23. An Experimental Study on the Repair of Steel Structures Severely Damaged Due to Earthquake

H. Narihara, A. Tanaka and M. Izumi

24. Ultimate Strength and Repair Method of Beam-Column Connections Fabricated by Fillet Welding

K. Morita, K. Takanashi and T. Murota

25. Seismic Strengthening of Reinforced Buildings in Japan

S. Sugano and T. Endo

26. Actual Examples of Seismic Judgment for Existing Buildings With or Without Retrofitting

H. Aoyama and M. Hirosawa

SUMMARY NOTES ON U.S.-JAPAN WORKSHOP

Repair and Retrofit of Existing Structures
TSUKUBA, Japan
May 8-9, 1987

Activities

5 sessions- 18 presentations

General Discussion on issues

Concluding Remarks

1. Similarities of current techniques for repair and strengthening indicate the opportunities for fruitful exchange of ideas. Commonality of techniques and solutions make such exchange and coordination of activities particularly beneficial in the area of repair and strengthening activities.

2. Presentations emphasized concerns related to performance of elements and connections, need for quality control, cost of construction.

3. There appears to be a need in both countries to stimulate technical discussions on repair and strengthening. This workshop provided a means for initiating further discussions within each country and the desirability of similar joint meetings in the future.

Areas of future research activity

1. Most pressing need is for experimental verification of repair and strengthening techniques in the following areas.
   a) Use of new materials
   b) Development of innovative techniques
   c) Evaluation of foundation effects
   d) Influence of member response on overall structure response
   e) Implementation of analytical techniques calibrated from experimental results.

2. Need to continue efforts for common understanding of performance, design, and construction data. Documentation of data and exchange of information should be carried out to permit development of a data base in area of repair and strengthening.

3. There is a need for studies related to damage control for prevention of environment hazards and for maintenance of operations in existing structures.

4. Discussions between researchers and designers should be continued for maximum benefit from activities underway in each country.
   a) Benchmark structures could be used for comparison of techniques and design procedures.
   b) Typical methods used need to be discussed in detail.
   Examples - bracing systems, infill walls, jacketing columns. It is proposed that future workshops consider a particular topic in detail and prepare a state-of-the-art report for use by designers and researchers.

PARTICIPANTS

Repair and Retrofit of Existing Structures
TSUKUBA, Japan
May 8-9, 1987

NAME	BELONGING
Tomoaki Akiyama	Tokyo Soil Research Co.,Ltd.
Hiroyuki Aoyama	University of Tokyo
Osamu Chiba	Toda Research Institute of Construction Technology
Toneo Endo	Tokyo Metropolitan University
Nicholas Forell	Forell/Elsesser Engr. San Francisco
Tetsuro Goto	Building Research Institute, Ministry of construction
Hisahiro Hiraish	Building Research Institute, Ministry of construction
Masaya Hirosawa	Building Research Institute, Ministry of construction
Norio Inoue	Kajima Research Institute of Construction Technology
Yuji Ishiyama	Building Research Institute, Ministry of construction
James O. Jirsa	University of Texas
Hideo Katsumata	Technical Research Institute of Ohbayashi Corporation
Takashi Kaminoso	Building Research Institute, Ministry of construction
Shigemi Kikuta	Toda Construction Co.,Ltd
H.S.Lew	National Bureau of Standard
Jack P.Moehle	University of California, Bekeley
Shosuke Morino	Dept. Architecture, Mie University
Tatsuo Murota	Building Research Institute, Ministry of construction
Shinsuke Nakata	Building Research Institute, Ministry of construction
Hiroyuki Narihar	Taisei Research Institute of Construction Technology
Isao Nishiyama	Building Research Institute, Ministry of construction
Tsuneo Okada	Univ. of Tokyo, Institute of Industrial Science
Shin Okamoto	Building Research Institute, Ministry of construction

NAME	BELONGING
Yutaro Omote	Technical Research Institute, Ministry of Construction
Hiroshi Onisawa	Government Building Department Ministry of Construction
Kazuhide Sato	Sato Kogyo Co.,Ltd.
Tadaaki Sato	Sato-bond Construction Co.,Ltd.
Matsutaro Seki	Ohbayashi Corporation, Technical Research Laboratory
Kazushi Shimazaki	Hazama-Gumi, Ltd.
Kohji Shimizu	Government Building Department Ministry of Construction
Yasushi Shimizu	Tokyo Metropolitan University
Shunsuke Sugano	Takenaka Technical Research Laboratory
Koichi Takanashi	University of Tokyo, Institute of Industrial Science
Akira Tasai	University of Tokyo
Richard N.White	Cornell University
Loring A.Wyllie Jr.	Degenkolb Assoc, San Francisco
Yasutoshi Yamamoto	Shibaura Institute of Technology
Hiroyuki Yamanouchi	Building Research Institute, Ministry of Construction
Yutaka Yamazaki	Building Research Institute, Ministry of Construction
Manabu Yoshimura	Building Research Institute, Ministry of Construction

WORKSHOP ON REPAIR AND RETROFIT OF EXISTING STRUCTURES

U.S.-JAPAN PANEL ON WIND AND SEISMIC EFFECTS (UJNR)

May 8, 1987

SUMMARY OF SESSIONS I AND II

Loring A. Wyllie, Jr.

H.J. Degenkolb Associates, Engineers

The Workshop was held in Tsukubu, Japan on May 8 and 9, 1987 and included presentation of eighteen papers, a discussion period relative to common issues and a field trip in Tokyo on May 11.

The first session contained four papers by Japanese participants which emphasized analysis or evaluation issues. A paper by Onisawa and Shimizu discussed evaluation of existing government buildings (of which 1,171 exist) relative to their anticipated seismic performance and their desired performance. Buildings are classified according to function and mathematical expressions are described to assist in the evaluation. A paper by Murakami, Okada, Ohkubo, Otani, Takiguchi and Hisaishi describes an inspection guideline and its trial use on twenty buildings in Mexico City in 1985. A checklist is included and an Appendix describes evaluation and proposed strengthening of a twelve-story building in Mexico City. A paper by Okada, Endo, Okubo and Yoshimura describes temporary and permanent restoration of damaged reinforced concrete buildings. Of particular interest are temporary repairs of columns by wrapping wire rope or welding steel bars to provide temporary confinement including test results of various stengthening methods. The paper summarizes methods described in the Japanese "Manual of Restoration Techniques for Building Structures Damaged by Earthquakes". A paper by Okada and Nakano describes analytical procedures to evaluate existing buildings relative to indicies used in Japanese codes.

The second session dealt with experimental studies. A paper by Endo and Shimizu on "Behavior of Expansion Anchor Bolts" describes various expansion and adhesive anchors and cyclic test data on their performance. A paper by Tasai, Otani and Aoyama describes reinforced concrete members repaired by epoxy resin, specifically, addition of flexural reinforcement in a layer of epoxy resin on the face of a beam. Cyclic test results are provided. Katsumata, Kobatake and Takeda describe a study of strengthening reinforced concrete columns with carbon fibers. High strength carbon fibers are an experimental material and cyclic behavior of tests of columns wrapped with these fibers is described. Nakata presented a summary of source lists on repair and retrofit of reinforced concrete buildings due to earthquakes in Japan including references and test results (most in Japanese) and cost summaries. Jirsa concluded the session by describing strengthening procedures to a reinforced concrete frame carried out at the University of Texas.

SUMMARY OF SESSION III

Nicholas F. Forell

Forell/Elsesser Engineers, Inc.

In Session III three Japanese participants presented work on rehabilitation of steel buildings. An outline of a manual for rehabilitation of earthquake-damaged steel buildings and some experimental results on repair and retrofit were presented by Takanashi, Murota, Yamanouchi and Nishiyama. Following the 1978 earthquake in Japan, a five-year research program on the repair and retrofit of earthquake-damaged buildings was initiated in 1981 which led to the manual described. The manual provides a structured and detailed procedure for the evaluation of damage, the classification of the damage, preliminary selection of repair methods, as well as the building evaluation. Inspection forms are developed to determine the urgency of repairing damage and to establish the damage grade. The risk assessment is based on the following factors: earthquake-induced uneven settlement, permanent story drifts, buckling state of structural elements, and the non-structural damage state. The form appears easy to fill out, requiring little specialized knowledge. The result of this exercise leads to one of three classifications: Safe, Warning, and Danger. The evaluation of damage grade form is quite similar in concept and leads to the classification of one of five damage levels. The selection of the repair method is a function of the earthquake intensity and the determined damage level. For instance, if the damage level is slight as a result of a severe earthquake, then only rehabilitation to restore the building to its original strength is required. On the other hand, if the damage level is moderate as a result of a minor earthquake, then the repair must increase the seismic performance of the building. The decision as to the method of repair is done on the basis of an evaluation of the remaining seismic capacity of the building. Tables are provided that give reduction ratios of the remaining capacity based on the measured P-delta effects, and local and torsional buckling. The paper further reports on the experimental evaluation of various repair methods.

Evaluation of seismic resistance capacity of damaged steel building structures was presented by Morino, Takanashi and Nishiyama. The paper describes the methodology for evaluating the seismic resistance capacity of damaged steel buildings. Two indices are used: the seismic resistance capacity index of the damaged structure, and the seismic resistance capacity index of the repaired structure. The indices are the ratios of the ultimate shear resistance capacity and the required resting shear capacity. The indices must be equal to or greater than one in order to meet the desired criteria. The seismic resistance capacity is based on an evaluation of the earthquake effect on P-delta, local buckling and torsional buckling. The degree of damage determines the damage grade which in turn establishes a strength reduction factor. The reduction factors used are based on both analytical and experimental data.

The final paper was on ultimate strength of repair methods of beam-column connections fabricated by fillet welding by Morino, Takanashi and Murota. The paper describes experimental tests of the repair of beam-column fillet weld connections which failed. Although the typical method of steel beam to column connection is through full penetration welds, the fillet weld has been used in small buildings. The repair of failed fillet weld connections was made by air-gouging the welds and providing full penetration welds. The tests showed that where thin weld metal and marks of cracks were left in the weld roots, unsatisfactory performance was observed. The report points out the need for back-gouging and back-welding the full penetration welds.

SUMMARY OF SESSION IV

Jack P. Moehle

University of California, Berkeley

Session IV on Retrofit Design included papers by Wyllie, "Design and Construction Schemes for Buildings," Sugano and Fujimura, "Seismic Strengthening of Existing Reinforced Concrete Buildings by Braces and Panels of Structural Steel," Forell, "Repair and Strengthening of Industrial Facilities," Hirosawa, et al., "Seismic Inspection and Retrofit of Nine-Story RC Building Damaged by the Mexico Earthquake, 1985," and Moehle, "Research Needs for Repair and Strengthening of Reinforced Concrete Floor Slab Systems." The theme of the session was the evaluation of existing buildings and design and implementation of retrofit schemes. Several examples of retrofits of actual building systems were described, and evaluations of performance expected after the retrofit was compared with that anticipated for the original structure.

In his presentation, Wyllie described the general philosophy of retrofit/strengthening design as typically implemented in U.S. practice. Appropriate selection of strength, ductility, and configuration were emphasized. Difficulties in construction were identified. Two examples of strengthened reinforced concrete structures were presented.

Sugano and Fujimura described schemes employing steel braces or steel panels for the retrofit of concrete buildings. Available experimental data were summarized. Most satisfactory performance was identified for bracing systems that comprised braces and perimeter frames that were anchored within the bays of the concrete frame. The system was used to strengthen an existing concrete school building. Design, construction, and analytical evaluation of the retrofit building were described. A cost comparison with possible concrete retrofitting schemes were presented.

Forell described requirements for industrial facilities. In such facilities, damage can result not only in loss of the structure but environmental hazard or economical disaster over a region extending beyond the structure itself. For such facilities, there is a need for damage control so as to avoid environmental hazard or to ensure continued operation following an earthquake. In addition to controlling damage to the structure, the retrofit/strengthening design should ensure that deformations of the structure are controlled so that nonstructural damage is avoided.

Hirasawa, et al. described the evaluation and retrofit of a concrete building damaged by the 1985 Mexico earthquake. A detailed evaluation led to several recommendations for strengthening. The strengthening involved addition of steel braces to several bays and addition of concrete and reinforcement to beams, columns, and walls. Construction of the retrofit is described. An analytical evaluation of the structure indicates significant improvement in anticipated response.

Moehle emphasized that retrofitting may be required for new as well as old buildings. The slab-column construction currently popular in California (slab-column floors braced by walls and frames) was selected for discussion. Deficiencies in deformation capacity of the slab-column connection were identified, and requirements for improving performance described. Possible retrofitting details were described, and an example structure considered.

Two primary themes were apparent in all of the presentations. One of the themes was that any retrofit/strengthening scheme is not merely a matter of strengthening, but of providing increased strength, increased ductility, more regular structural configuration, and reduced deformations. A second theme of all presentations was that retrofit of any structure requires an evaluation of the performance both of the existing and of the retrofit structure. Criteria for evaluation are not well established, and should be considered a major part of any research effort.