NSF/CEE-81116

PB93-188276

THE INTEGRATION OF SEISMIC DESIGN PRINCIPLES INTO PRELIMINARY ARCHITECTURAL DESIGN

Prepared for the National Science Foundation
Division of Problem Focused Research
Earthquake Mitigation Program

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JUNE 1981

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All material incorporated into this report was developed with the financial support of the National Science Foundation under Grant No. PFR-7900007.

However, the opinions, findings, conclusions, and recommendations expressed in this report are those of the researchers and do not necessarily reflect the views of the National Science Foundation.

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ACKNOWLEDGEMENTS

Several individuals have contributed to the production of this report. The researchers would like to thank Robert Sockwell and Bev Broadbent of the AIA/RC, Christopher Arnold of Building Systems Development, Melvin Green, Ralph Goers and others who advised us during our research. We would like to thank Jim Goldman and William Durkee of Urban Design Associates, and other architects who participated in the survey. We would like to thank Meredith Myers, Michelle Nalepa, Sue Ritchie, Al Cuteri of the Department of Architecture and Louis Sauer, Department Head, for their support and contributions to the project. We wish to thank Howard Matz, who did the final typing, formatting, and compilation of this report and Stuart Rehr, who designed the report covers. We want to especially thank Dr. Frederick Krimgold of the National Science Foundation for his advise and encouragement.

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June 1981

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1. INTRODUCTION:

The Problems of Enlisting the Architectural Profession's Assistance in Mitigating Eastern U.S. Hazards

Major earthquakes have occurred in the eastern part of the United States; and what is known about the origin of these earthquakes clearly infers that they will reoccur. The greatest earthquake to occur in the mainland United States was the New Madrid, Missousri Earthquake of 1811 whose shocks were felt as far away as Charleston, South Carolina and Washington, D.C. Strong Earthquakes have also been recorded in Massachusetts (1755), Tennessee (1843), Charleston, S.C. (1886), the St. Lawrence River region (1925), Newfoundland (1929), and New York State (1929, 1944). Moreover, studies done by Prof. Otto W. Nuttli at the University of St. Louis, have indicated that because of eastern geological conditions, a given seismic event in the east is about 20 times as efficient in transmitting ground motions as a west coast earthquake. Therefore a strong earthquake occurring in, say, Tennessee could affect property hundred of miles distant.

The problem is that the sparcity of historical data on eastern earthquakes and the uncertainty about their cause makes it difficult to say how often we can expect the occurrence of a damaging eastern quake. Purely statistical analyses show that the annual probability of an event on the order of the New Madrid earthquake would be perhaps 1/600. Nonetheless, so much property and so many lives would be at risk in such events, that it is necessary to assume strong eastern earthquakes will occur within the lifetime of existing eastern settlements and their inhabitants. In recent history however, no such damaging events have occurred and most local government officials and architects believe the potential risk of earthquake damage is negligible and can be ignored. The general population of architects, we believe, feel that current building codes provide adequate protection against earthquakes, and that the procedure for wind load design, in effect, should provide sufficient structural capacity to withstand probable tremors. They tend to feel that if a disaster should occur, and heavy wide-spread property damage and life loss result, federal disaster relief and Federal Emergency Management Agency programs will be able to meet the needs of impacted communities.

The federal government desires to regionalize earthquake hazard mitigation.

The goal is to implement disaster planning and damage preventive strategies at the local level. Here local architects could play a significant role by learning to integrate seismic principles into preliminary design and to promote seismic safety in design as part of their local practice.

In recent years, the National Science Foundation and the AIA Research Corporation have sponsored Summer Seismic Institutes, and a National Disaster Recovery and Mitigation Resource Referral Service to promote the dissemination of research results to architects and engineers, and to state and local officials. However, the availability and dissemination of seismic knowledge does not exhaust the issues to be addressed in the adoption of better seismic design in the East.

Besides educating more eastern architects to the problem and technical solution, we have to encourage them to initiate consideration of seismic issues in their design work and to manage seismic mitigation as a design issue in their practice. It will become routine to do so once better seismic codes are adopted in the East, but to achieve that objective we have to educate architects first, then enlist their support in a campaign to adopt better seismic legislation at the local level. First however, we have to promote utilization of research findings in design.

The difficulty of including seismic issues within the preliminary phase of design can be described separately as being knowledge based, aesthetic, and strategic.

Knowledge-Base

Standing in contradistinction to the West, eastern architects in general know little about seismic forces. Although the NCARB architectural licensing examination contains questions on seismic design, it is possible that architects still perceive earthquake hazards as an "engineering problem." Many eastern architects are also unaware of seismicity within their geographic areas of practice. They are also largely unaware of technical information relevant to building components, which have been forth coming. Therefore, architects tend to discount seismic design because they have not been exposed to useful knowledge in that area, and because generally, the problem of Eastern seismicity has been ignored by state and local governments.

Aesthetics

An area of widely desparate views, implicit values, uncertainty and subjectivity, aesthetic concern nonetheless underlies a significant proportion of the architect's efforts and distinguishes his particular contribution to the building process. An architect may be troubled by any mandate which he perceives as a constraint upon his freedom to make form and space. Architects may be uncertain about the extent and effect of seismic codes; and the implications for aesthetics in architecture could affect professional attitudes about seismic design.

Strategy

Architects attempt to balance the various criteria generated by their clients, consultants, contractors and local codes. Through experience architects have learned to resolve building problems within the bounds of constraints which have become typical. Budget, material availability, site topography, site context, all of which constrain solutions, are familiar issues to architects, and such constraints are ordinarily anticipated in the course of programming and preliminary design. It follows that architects may simply allow for seismic provisions as added constraints within the matrix of more familiar criteria. However, it is also possible that in certain situations, a deliberate sequence of decision-making and evaluation will be necessary to avoid least desired tradeoffs and less than optimal solutions. The successful integration of seismic principles requires that they be compatable with the architect's requirements to remain flexible in meeting user-needs, to respect the client's economic constraints, and to achieve architectural results which enhance the visual quality of the environment. To make seismic design compatable with current practice, judgement has to be used in applying existing seismic mitigation strategies to the less certain seismic environment in the East.

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2. RESEARCH OBJECTIVES

The initial objectives of this project were as follows:

1. To assess the sensitivity of Eastern United States practicing architects to seismic hazard and seismic design principles;

2. To discover, through direct interaction with participating firms, the problems associated with the inclusion of seismic design strategies within the preliminary design process, and seek useful methods for their solution;

3. To study the issues of aesthetic preferences and normative building typology to see how seriously they may be challenged by adherence to seismic design principles.

In the process of achieving the second objective, our persceptions about the problems of integration were changed and it became more important to observe and report on what is required to manage the issue of seismic design in eastern practice, and to be able to suggest an outline strategy for establishing some better level of seismic design in the East.

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3. METHODOLOGY

3.1. SURVEY

3.1.1. Data Requirement and Survey Questionnaire

Since an objective of this study was to make a contribution to knowledge about the problem of integrating seismic design into current architectural practice, a series of surveys were developed to assess approaches to seismic design among Eastern architects. This survey posed questions involving both current practice and hypothetical situations. The questions were designed to determine factors that would affect architect's decision-making when integrating seismic design into his preliminary designs. In order to evaluate the architect's responses to questions about seismic design, some of the survey questions were included to determine the architect's knowledge of research published on non-structural architectural components.

Because so many factors influence the architect's knowledge of seismic design principles and his desire and ability to use those principles, an objective of the surveys was to provide a profile of the 'typical' Eastern architect. To obtain this profile, questions were directed toward generally establishing the architect's level of experience (in both general practice and seismic design); knowledge of seismic issues; exposure to technical information; and hypothetical approach to seismic design.

Also included in the survey were questions to determine how information about seismic design can best be disseminated among architects. These questions included how they currently gain access to technical information and how they believe they could best be informed about seismic design.

Finally, a follow-up survey was done to assess factors influencing the response rate to those questionnaires requiring written replies. This survey was done to determine whether "no responses" were due to the questionnaire format, lack of interest in seismic design or unrelated reasons.

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3.1.2. Pilot survey and editing of questionnaire

The scope of the project did not include a major survey effort requiring rigorous adhearence to survey techniques. (The description of the survey methodology follows.) However, a pilot test of the questionnaire was made. After a draft questionnaire was written, it was given to two Pittsburgh-based architects who were asked to respond to it. They were told of the nature of the research, but given no further information about seismic design or the seismicity of this region. Our main purpose in having the draft tested was to assess its clarity and the power of the questions to elicit responses meaningful to the research questions.

The questionnaire was edited somewhat after its test. The wording of a few questions was changed, and some additional questions were added. The fault in the pilot survey perhaps was that only two and not, say, twenty architects were asked for their responses. It is likely that a larger test could have revealed the tendency for non-responses to certain questions. The questionnaire could have been improved further for we realize its value when it is well conceived and constructed. Nonetheless, given the minimal pre-testing we did, we believed the questionnaire was adequate for our purpose.

3.1.3. Selection of sample

Stratified random sampling was done in a series of three surveys in the Eastern United States. These samples were taken in states that have historically (though infrequently) been regions impacted by earthquakes. A total of 300 architects in Boston, New York, Philadelphia, Hartford, Baltimore, Pittsburgh, St. Louis and Washington were surveyed with written questionnaires, while 247 architects in a later survey were asked the same questions by telephone.

The random sampling of architects were queried to identify the range of experience Eastern architects have in seismic design; their attitudes toward seismic design; their knowledge of seismic hazard and issues of seismic design in their area of practice; their exposure to technical information in general; and finally their knowledge of research done relative to the response of non-structural architectural components during seismic activity. The questionnaires also identified the architect's place of education and practice, their experience in general, and any other experience in seismic architectural design.

3.1.4. Discussion of Sample Problems

However, because the response rate was so low (20% responded), the results from the surveys can in most cases only indicate a tendency toward factors influencing seismic design. Although some questions indicated valid relationships by contingency tables and Chi-square tests, the majority did not.

In every area of the Eastern United States that was polled, the response rate was low. Since this response rate could be the result of factors that were related to the survey method or to extraneous factors, a follow-up survey was done to determine the basis of the response rate. This follow-up showed that the primary reasons for non-response were too little knowledge of seismic design issues and too much other work in architects' offices to respond.

In the questionnaires that were returned, there was a significant non-response rate to certain questions. These were questions that were concerned with assessing the respondents knowledge of seismic design issues. Although a no-response could indicate a lack of knowledge, it is possible that the placement or wording of the questions could have influenced the architects' response.

3.1.5. Discussion of Telephone Survey

A telephone survey was done after the responses were received from the questionnaires. This was done to increase the sample size and was done by random sampling of those areas surveyed for the questionnaires. 75 were contacted with 47 responding to the questions. Of the entire group, 28 did not respond, primarily because they weren't interested in seismic design. The questions asked were similar to those asked in the questionnaires.

3.1.6. Use and Interpretation of Responses

The responses from all surveys were combined and used to give answers to the questions and to provide comparisons among different classifications of respondents by means of constructing contingency tables. As stated above, the response rate was too low, in most questions, to affirm that the survey had concurrent validity with respect to the general population of Eastern architects. When this is the case, the material is presented as indicating certain tendencies among Eastern architects in their approach to seismic design. Contingency tables are presented in the text when it is intuited that the material is representative of norms.

Also, in some questions the variety of responses is too broad, given the response rate to give an accurate indication of the architect's attitudes. When this happened, if possible the responses were evaluated as either yes or no, to increase the reliability of the conclusions. Where appropriate, questions from different surveys were combined.

By using the method of random sampling, the research could identify within the Eastern United States, and state by state, factors that influence the integration of seismic design into current architectural practice. The responses could identify the range of experience, attitude and knowledge, as well as, the "typical" response in each region and each state.

3.2. PRIMER

3.2.1. Use of the Primer in the Interactive Sessions

The team wanted to have a compendium of seismic information to introduce the subject matter to the architectural participants, and to have them use this information in conjunction with the workbook during the interactive sessions. The purpose of the primer was, therefore, conceived as limited to the research effort and was not envisioned as a manual complete in itself and aimed at wider distribution. The team suggested that the primer be used as a reference during the architect's sessions with the workbook exercises.

3.2.2. Sources Used

The sources used for the primer were texts and articles on the subject of seismicity in general and earthquake mitigating architectural design in particular. The material selected emphasized basic principles of seismic load and building response. Some attention was also given to known causal relationships between building configuration and performance, and represented fairly the general state of knowledge about architectural or non-structural aspects which would be relevant for consideration during preliminary design.

3.2.3. Editing and Format

As stated above the primer was not designed for wider distribution independent of the final research report. For that reason, no attempt was made to be as comprehensive as primers for architects which were already published. Instead the research team selected what it considered to be important concepts and illustrations from other works, and with these, assembled a compendium. No topic was elaborated upon because we were concerned with covering a range of relevant concepts in a limited length of text which would be use for our interactive sessions.

The format was decided upon quite simply. We set the text and illustrations so that the primer and workbook pages could be inserted in looseleaf binders (for easy removal), and so that a page had its longer axis horizontal, and could be flipped up or down. We also felt this made referencing easier, and made the primer format consistent with the workbook format, which was also going to be horizontal in order to make illustrations and sketching easier.

3.3. WORKBOOK

3.3.1. Use of Workbook in the Interactive Sessions

The workbook was the chosen means to develop the participants design thinking in terms of seismic resistance. The series of exercises were designed to simulate design conditions wherein problems of potential hazard had to be recognized and the architect had to make a critical response in terms of a change to the design, or as in the case of later exercises, the generation of an original design. The overall purpose was to have the team apply and gain knowledge of seismic design by responding to these hypothetical situations.

3.3.2. Content

The question for the researchers was a simple pedagogic one. What type of exercises should be used, how many were sufficient and would any of these be serialized? Having no priority to experiment with the teaching-learning technique--the integration of the knowledge was the objective, not a refined educational technique--we adopted a conventional approach. First there was a series of abstract exercises meant to cover the most basic principles of structural frame response to seismic loads. Thus, we created five problems involving a one or two level, 3 or 4 bay structural frame. Panels, half or whole, infilling between columns were placed or required to be placed in the structure. In some cases the problem posed the removal of parts of the frame. The objective was always to alter the panel arrangement or add panels or, if required, add and subtract bays so that the final configuration was more seismically resistant than the original. It seemed that these abstract exercises, without reference to function or other more specific non-structural components could serve to focus attention on primary forces and primary means to react to them. Yet the association between the rational response and architectural or configurational implications was readily clear. It also seemed that an adequate field of the specific notions of load and strengthening could be covered in five exercises of this type.

The other type of exercise also posed a hypothetical condition; but, this time describing a realistic circumstance, that is, a building type and a given architectural plan. The plan and a specific caution or identification of seismic hazard was given to focus attention on inherent conditions which required adjustment. In all cases, changes were required and in a few exercises, it was obvious that there would be trade offs between implied architectural intent and the mandate to maximize resistance. Although many such exercises could have been presented, the researchers realized that the time available for the interactive sessions, and more important, the limit to the effectiveness of repeated exercises, would impose a constraint on how many exercises should be given and how much time should be expended on them. Three exercises of this type were given.

In a final exercise only the building type, site, zoning envelope and space requirement were given--an office building on a CBD site-- but no plan was presupposed. The intent in the last exercise was to synthesize some of the principals in seismic design which would relate to building configuration, placement of resisting elements, and curtain-wall design. The strategy was to rely on the professionals familarity with the prototype so that he/she could quickly generate a plausible scheme while carefully considering its seismic ramifications.

3.3.3. Format

The diagrams and explanatory text were set on the same or immediately succeeding pages and ancillary sheets labeled "Solutions" and "Commentary" were grouped with each exercise. The intent was to have a convenient place for recording final solutions and important comments, but sketching elsewhere (for example on scratch paper or tracing paper) was allowed. Thus, the summary of all output was recorded in an 8 1/2 x 11 format.

The five more abstract exercises were placed first with the simplest frames preceding those having two levels. Then followed the hypothetical building problems, in no particular order of difficulty but with the office building problem placed at the end. The strategy of this order was to use the abstract exercises to call attention to seismic design principals and then have this knowledge applied again in more complex situations. The building problems were also used to add circumstances which could not be posed in the simple abstractions, for example, the problems of finishing materials, explicit circulation routes and program. The office building problem was to be somewhat of a culmination and so logically it would be placed last in the workbook but also inasmuch as it was somewhat more open-ended it could be expanded or contracted to fill whatever time was left after all the other exercises had been completed.

It was explained to the architects that the nature of the workbook was of an instrument designed for learning and discussion. It was not meant to be a test of knowledge. Therefore the exercises were done in the presence of researchers; and at any time the architects could ask questions of the researchers, research into other materials themselves, and even suggest ways in which the exercises might be improved. Although it turned out not to be pursued, the researchers had anticipated that some improvisation with regard to the problem development as well as the solution might occur because of this intended interaction. Again, however, improvisation as an experiment in learning technique would have been beside the point, and the participants dealt with the givens of each exercise generally as presented.

3.4. INTERACTIVE SESSIONS

It was presumed that the professional participants in the research would require some basic training in seismic principles and design. Moreover a working relationship between the architects and the research team was necessary to the final research tasks. Therefore, it was planned that the researchers would instruct the architects directly. Also, by being present while the architects worked on the design exercises questions could be immediately answered, greater latitude could be had in exploring the implications of a particular problem, and the overall effectiveness of the exercises as learning tools could be assessed.

At the meetings prior to the interactive sessions the researchers introduced themselves to the architects and explained the scope of the project to them. When the researchers and architects met for their interactive session the objectives of the session were made clear--primarily that it was a training session to prepare the architects to work independently of the researchers at the later time when the architects would attempt to apply seismic principals to an actual project.

The participants were informed of the content and organization of the workbook and primer. Moreover, the researchers explained the research objectives to be achieved by means of the two documents and informed the architects that questions, comments and further perusal of seismic literature were all encouraged as part of the interactive process.

The principal researcher in his outline of the research tasks (as stated in the proposal) reasoned that a two-day interactive session would be a necessary and sufficient amount of time to allocate to this basic training. It was reckoned that the researchers would not develop substantive material requiring more than two days to absorb, that for the purpose of considering architectural aspects of the building problem, two work days would be sufficient, and pragmatically, neither the researchers or the architects could devote more than two work days to this task.

The number of exercises constructed had less to do with the time allocation than with the assessment described above that the information we felt needed to be conveyed and assimilated could be "packaged" within a small number of exercises which turned out to number ten in all.

Actually we did not know beforehand whether the ten exercises would all be worked out in two days. We knew that the latter problems could take an extended period of time to resolve but that we could guide the resolution of these to suit the need for brevity if our time limit became a factor. After the first interactive session, however, the time likely to be spent on each exercise became more clear. The second and third sessions, therefore, could be paced to allow adequate discussion of various seismic design topics arising out of particular exercises.

Because sketching was a natural tool used in exploring possible resolutions to the exercises, many sketches were generated. The sketches can be considered process documents particularly as we asked that the architects annotate them as they proceeded.

The sketches also become part of the future reference material for the architects particularly because of the personal cognitive material they can suggest to the architect in his review of them at a later time. And there is the possibility that sketches can indicate how architects using this particular mode of analysis, translate seismic principles into spatial design.

The most immediate benefit from the workbook session was the stimulus it provided the architect for final "wrap up" discussions with the researchers. Having just completed work in seismic design, the architects appeared eager to relate this topic to general conditions of research and design within their own practice, and to speculate critically on the pragmatic factors bearing upon the application of seismic principals in preliminary design. Summary discussions were, of course, held for this reason. Also their comments being based largely on the hypothetical conditions which underlay the interactive session, could later be compared to the process "logs" and evaluations they would write in regard to the actual projects to be undertaken.

The researchers too, had to assess the interactive sessions in regard to three research issues. First, was the architect's knowledge base effectively increased in terms of his ability to deal independently with seismic issues? Second, did it appear that a combined primer-workbook package could be an effective dissemination tool? Finally from our discussions, what ideas emerged concerning the dissemination of seismic knowledge in the East, and the constraints on implementing seismic safety measures in the East.

3.5. PRELIMINARY DESIGN

The most important task in the research plan was to be the application of newly gained (or at least refurbished) knowledge to an actual design project in the architectural office. The purpose of this application would not be to experiment with design itself but to consider any and all prerogatives, conflicts or bases which affect the application of seismic principles in eastern U.S. practice at this time. The proposition is that seismic design has yet to be seriously introduced into eastern practice and factors involved in its integration have yet to be gaged. If the responsibility of mitigating seismic hazard is to be placed on building professionals at the local level, if that has not occurred in the east in a substantive manner, and if there are problems of integration inherent in professional practice, then the research effort was to identify these in the execution of this research task.

Each of the three participating architectural firms had to identify a project which would be executed by their office, and which would be suitable for the purposes of the research. Factors which were pertinent to a selection were: (1) the scheduling of that project, that is its concurrence with the research effort; (2) the complexity of the project, where some assumption had to be made as to the time necessary for preliminary design; (3) the particular context and criteria of that project which would make it a worthwhile subject for the research. A factor which, we felt, was not to be strong as a determinant of selection was the current seismic regulations which might be placed upon construction at the location of a given project. Regulations at a particular location might not have been what we feel they ultimately should be, and we found that none of the possible locations currently enforced rigorous and specific provisions with respect to non-structural components. As to our second factor, we realized that certain projects, for example large projects involving public agencies and local government, might have protracted periods of preliminary design which would exceed the time limit we had to impose.

The selection in terms of context and criteria could have been guided by either of two opposing viewpoints. In one, we could have sought projects whose program requirements would certainly raise the issue of optimal seismic reinforcement versus important criteria such as flexibility in spaces, long spans, or large glass enclosed spaces. The opposite view would be to select building types which, though they require architectural design, have no programmatic requirements which obviously conflict with seismic design. Most buildings, we believed, would fall into this latter category and so no effort was made to choose projects particularly problematic in terms of seismic design. The researchers felt that the implementation problems we wished to focus upon would be addressed in any case, and projects which were problematic from an architectural planning or engineering point of view, while emphasizing technical constraints might confound discussion of the broader issue of overall design process management and the broader constraints upon adoption of seismic design in eastern practice. Nonetheless it should not be forgotten that as successive projects are executed, recurrent tradeoffs between seismic and other criteria would eventually be studied as factors in determining a general level of seismic reinforcement which might be specified for a given eastern locality.

The preliminary design task as mentioned, had to produce information about design process and process management in regard to seismic design. To make the experiences of the three firms comparable the researchers devised questions and instructions to be given to the architects prior to the commencement of their preliminary design work. The questions were about the project, the design team, the design objectives, the seismic design considerations actually made, and a design process "log." This was to be a capsulization of the points made in each instance of design-decision-making regarding a seismic related design issue. The questions are reproduced in Appendix D.

3.6. EVALUATION

A final task for the architects was the evaluation of their attempt to integrate seismic design in preliminary architectural design. The architects were asked to make assessments as to:

1) the appropriate level of seismic design for their area and whether it was achieved;

2) the rank order of seismic among other specified criteria;

3) what design consideration should be on a seismic design checklist;

4) what non-structural provisions might be included in local codes;

5) what practical means of integration can be described;

6) what additional (if any) design costs might be expected in including seismic design;

7) what might facilitate learning about seismic design;

8) the presentation of seismic design as a practical concern, to clients and building officials.

We hoped their experience in the preliminary design task would give them insights for the evaluation they were to make. Positive answers would certainly contribute to the strategies for integrating seismic design in the east. Difficulty in answering might point to areas where our own research was inadequate to explore underlying economic factors or inter-professional or architect-client relationships which affect integration.

Based on a review of documents to be returned by the architects, the researchers would make their own evaluations as to the effectiveness of the architects participation, in terms of useful knowledge about design management and the adequacy of the present research in terms of defining and exploring design process problems related to seismic design.

4. FINDINGS

4.1. SURVEY

4.1.1. General Awareness of Seismic Issues

Observations concerning architects' perceptions of the issue of seismic design in the Eastern United States were directed to assessing experience in seismic design, knowledge of seismic issues in their area of practice, knowledge of technological developments in seismic design, and how seismic safety is considered as a priority in preliminary design.

As expected, the majority (69%) of Eastern architects have no experience in seismic design. But in spite of that lack of experience, and poor knowledged of seismic phenomena, over half of the architects questioned were knowledgeable of areas of seismic activity, of the seismic zone classification of their area of practice, and of the existence of state-mandated codes.

In terms of more specific design issues, although 85% could identify vulnerable non-structural components and 88% could name geometric forms resistant to seismic forces, only one third of this group were aware of research done on the behavior of non-structural components during seismic activity.

4.1.2. Process Clients, Codes, and Learning

A primary area of concern in this study of Eastern architects, is how the architects would accommodate seismic design criteria within the design process. As expected, considering the lack of experience in seismic design, no particular method of integrating seismic design principles within the preliminary design is consistent among those questioned, other than consulting a structural engineer. Seventy-seven percent of the architects would use a variety of methods in dealing with seismic design. When asked how seismic safety is placed as a design consideration during preliminary design, the response varied from a high to low priority placement. In a hypothetical situation of more comprehensive codes, 68% would rank seismic safety in the upper 1/3 in importance of criteria considered during preliminary design; but 91% rank it as a low priority criterion in their current practice (where no comprehensive codes actually exist). Considering that a low priority is given to seismic safety in preliminary design in their current practice, and that so few are aware of research on non-structural components, it is likely that the integration of seismic design at the preliminary stage would deal only with structural issues.

Among those firms currently involved in seismic design, the original impetus for including seismic design principles in a project does not come from the client. However, the client is more receptive to the inclusion of those principles if there is a long-term positive cost factor or if the client sees a positive factor in the publicity from being in the forefront in utilizing these design features.

Among firms interviewed that are currently involved in seismic design, there seem to be two favored approaches to integrating seismic design principles. Among these firms the procedure varies mostly between utilizing an "in-house expert" architect and working closely with a structural engineer during preliminary design.

The way in which eastern architects regard code requirements and client influence is another primary question in analyzing the response to seismic design. Over half of the architects were aware of the existence of seismic codes and believe that those codes would make architectural design more difficult. However, since the majority of the respondents were inexperienced and we must remember they were reckoning with a hypothetical situation.

Because so few eastern archtiects are aware of research done in seismic design, the method of the dissemination of such information is an important question to address. Most of the architects preferred receiving general technical information in the form of textbooks and manuals. Because of the permanent availability of this form while initially learning and later referencing the material, the textbook for seismic design is also preferred over other methods, such as, seminars and films.

A final critical issue in researching seismic design among eastern architects is how technical information is reaching architects and what factors play a part in making it easier or harder to absorb new research findings. Over half of those questioned regularly come across news of significant technical information. However, although 77% of all the architects say new technical information is easily assimilated, 67% of them are generally apprehensive about trying new techniques or products. But whether they utilize the information or not, all of the architect questioned said they seek new special technical information when working on projects and over 30% of that information comes from combined sources of publications and engineers.

4.1.3. Relationship Between Relevant Variables

In addition to these primary issues of response to seismic design among eastern architects, much more information was obtained which deals with the implications of experience vs. inexperience in seismic design; the problem of aesthetic and code constraints; the difference in design approach among different experience groups; and the difference in seismic knowledge with different experience in seismic design.

Responses to questions about aesthetic constraints resulting from introducing seismic design principles indicate that 50% of the architects were not concerned about aesthetic constraints and the remainder were only mildly concerned. However, this response to concern about aesthetic constraints may be due more to their general attitude towards aesthetic considerations relative to other design criteria. It should be noted that those surveyed ranked aesthetic constraints low in a list of other design criteria. Their response may be influenced by a general lack of concern about aesthetic problems rather any seismic design influence or they rank seismic safety higher than aesthetics and, therefore, avoid conflict by preempting aesthetic concerns in favor of seismic safety.

When comparing concern for aesthetic restraints to the rank-ordering of seismic safety, contingency tables indicated that the tendency is for concern about aesthetic to diminish only slightly when seismic safety is highly ranked. Given the sample size this difference is not significant.

Rank Order Seismic Safety

Aesthetics	High rank		Low rank		
Not concerned	18	(64%)	7.5	(58%)	25.5
Concerned	10	(36%)	5.5	(42%)	15.5
	28	(100%)	13.0	(100%)	41.0

In dealing with seismic safety during preliminary design, those who are not concerned about aesthetic constraints are a little more likely to consult an engineer during preliminary design than those who are concerned about aesthetic constraints.

Integration of Seismic Design

Aesthetics	All Other Methods		Consult Engineer			
Not concerned	22.5	(67%)	7.5	(33%)	30	(100%)
Concerned	14.5	(76%)	3.5	(24%)	18	(100%)
	37		11.0		48	

Since 30% of the architects could not name aspects of preliminary design that might be affected by the consideration of earthquakes, it is possible that those architects concerned with aesthetic constraints do not understand the basic structural options and, therefore, try to deal with the aesthetic issues apart from the structural issues. But the day-to-day practice of this group of integrating design criteria into the preliminary design is unknown; and their concern about aesthetic constraints relative to other design criteria is unknown. It is possible that this group rarely consults structural engineers during any preliminary design and is always concerned because they don't realize the structural options.

Aside from calling in a structural engineer, neither group has a preferred method of integrating seismic design. There is no significant difference between groups in their view of the importance of seismic safety as a design constraint during preliminary design;

Priority Given Seismic Safety

Aesthetics	Constraint	Less Constraint	
Not concerned	2.5 (9%)	27 (91%)	29.5 (100%)
Concerned	1.5 (9%)	16 (91%)	17.8 (100%)
	4.0	43	47.0

but as a group, it is important to note that 91% of the respondents consider seismic safety as a less important design constraint during preliminary design.

Exposure to technological information in general and seismic information specifically seems to have some bearing on these architects' concerns about aesthetic constraints. When examining the relationship between concern about aesthetic constraints and knowledge of seismic phenomena, less than a third of the architects asked could name over half of the seismic phenomena listed, but in the group who knew over half of the phenomena, there were more concerned than in the group who knew less than half the phenomena.

Knowledge of Seismic Phenomena

Aesthetics	Phenomena Named		
	0-6 Named	7-13 Named	
Not concerned	22 (65%)	8 (57%)	30
Concerned	12 (35%)	6 (43%)	18
	34 (100%)	14 (100%)	48

The same relationship holds when the comparison is made relative to new general technical information.

Rate of Exposure to New
Technical Information

Aesthetics	Infrequent	Frequent	Regular	
Not concerned	2.5 (75%)	10.5 (61%)	16.5 (65%)	29.5

Concerned	1.5	(25%)	7.5	(39%)	9.5	(35%)	18.5
	4.0	(100%)	18.0	(100%)	26.0	(100%)	48.0

Over 90% of those questioned have frequent or regular exposure to new technical information.

Although the majority of the respondents are at least regularly exposed to new technical information, less than a third can identify half of the seismic phenomena listed and only a third are aware of research on non-structural architectural components.

Given the low concern about aesthetic constraints, it is possible that while the respondents regularly receive new technical information, that information does not address seismic design and the aesthetic constraints are not foreseen by this group. The lack of knowledge of seismic phenomena and research on non-structural components is indicative of the fact that little seismic design information is being published and very little of it is read by eastern architects. In only a few cases did respondents indicate that when seismic problems became apparent new information was needed, found, and implemented in preliminary design--so the accessing and utilization of seismic information is exceptional.

Experience in seismic design does tend to alter the architect's attitudes toward seismic design. Although there is a fairly even breakdown in expectations about difficulties with code compliance, those without experience in seismic design tend to be more pessimistic about having difficulty than those who are experienced.

Experience in Seismic Design

Code Complience	NO		YES		
Expect no difficulty	14.5	(45%)	8.5	(60%)	23
Expect difficulty	16.5	(55%)	6.5	(40%)	23
	31.0	(100%)	15.0	(100%)	46

Although these relationships indicate that experienced architects do not generally view seismic design as a constraint, there is no greater concern about it as a constraint among inexperienced architects. This could imply that seismic design is not inherently a complicating issue or that existing seismic codes do not address enough factors (i.e. non-structural as well as structural components) to complicate design. These relationships could also suggest that experience in seismic design does not necessarily mean that any significant learning has been accomplished by that experience.

It should also be reiterated that aesthetic concerns are generally given low priority; the respondents have not been asked whether all codes create difficulty or whether seismic codes are exceptional; and one-third of the respondents could not identify preliminary design aspects that could be affected by earthquakes.

Experienced and inexperienced architects also tend to integrate seismic safety in similar ways in preliminary design;

	Method of Integration					
	All other methods		Consult Engineer			
Inexperienced	22.5	(71%)	6.5	(29%)	29	(100%)
Experienced	14.5	(69%)	4.5	(31%)	19	(100%)
	27.0	(77%)	11.0	(33%)	48	

that is, they use a variety of methods. Consulting a structural engineer is the only single method that has any significant preference.

This comparison indicates that experienced and inexperienced architects view seismic safety in similar ways as a design criteria. This implies that experienced architects have not encountered problems of significant magnitude in their design to view seismic design as a high priority constraint; seismic codes have not been stringent; they are not concerned about the probability of an earthquake occurring.

In the case of knowledge of seismic information about their own area of practice, as expected, learning about seismic information increases with experience. A comparison of experience in seismic design to knowledge of seismically active areas shows that the more experienced are more knowledgeable and the majority are knowledgeable.

Knowledge of Seismic Areas

	Don't Know		Know			
Inexperienced	13	(87%)	15	(13%)	28	(100%)
Experienced	7	(64%)	11	(36%)	18	(100%)
	20		26		46	

Again, when experience is related to knowledge of codes, the experienced are more knowledgeable of seismic codes, but half are not familiar with seismic codes.

Knowledge Of Seismic Codes

	Don't Know		Know			
Inexperienced	25.5	(63%)	15	(37%)	40.5	(100%)
Experienced	8.5	(32%)	18	(68%)	26.5	(100%)
	34.0	(51%)	33	(49%)	67	(100%)

From these comparisons, it is very probable that inexperienced architects are less aware of areas of seismic activity than experienced architects. Of all respondents, 57% are aware of these areas. However, in the matter of zone classification there is no significant difference between the groups in knowledge of this classification. Again, over half of these architects are aware of their classification . In dealing with seismic codes, inexperienced architects are much less likely to be aware of seismic codes, but over half of the total group are aware of seismic codes.

Seen together, these results could suggest that general issues of seismicity are known in eastern areas of practice but experience yields more knowledge of codes and areas of seismicity. This could result from experienced architects being generally more interested in earthquakes, therefore, learning more about earthquake areas or that general principles of seismicity are learned through job-related experiences. Although the group is generally poorly informed about eastern seismicity some of those with experience have retained some factual knowledge.

This proposition is reinforced when knowledge of seismic hazard is compared to knowledge of seismicity in the architects' area of practice. When comparing knowledge of seismic phenomena to knowledge of seismic activity, those with more knowledge of seismic phenomena have a greater knowledge of areas of earthquake activity. But again we have not been able to show a significant distinction.

Knowledge of Areas of Seismic Activity

General Familiarity with Seismic Terms	Don't know		Know			
Know 50% or less	17.5	(51%)	16.5	(49%)	34	(100%)
Know > 50%	6.5	(46%)	7.5	(53%)	14	(100%)
	24.0		24.0		48	

Again, in testing the relationship between knowledge of seismic hazard and knowledge of zone classification, there is slightly less knowledge of zone classification among architects who have less knowledge of seismic phenomena.

Knowledge of Zone Class

Know of Phenomena	Don't know		Know			
Know 50% or less	18.5	(54%)	16	(46%)	34.5	(100%)
Know > 50%	5.5	(41%)	8	(59%)	13.5	(100%)
	24.0		24		48.0	

And in the comparison between knowledge of seismic hazard and knowledge of seismic phenomena coincides with an increase in knowledge of seismic codes.

Knowledge of Codes

Know of Phenomena	Don't know		Know			
Know 50% or less	16.0	(68%)	7.5	(32%)	23.5	(100%)
Know > 50%	6	(48%)	6.5	(52%)	12.5	(100%)
	22		14.0		36.0	

The question of experience vs. learning in seismic design is addressed by the questions about the architects' areas of practice. As stated before, some learning occurs, but in all three surveys almost 50% of the architects responded that they had learned less basic seismic information than information about zones and codes. They may know of the existence of these "titles", maybe even know the codes by rote, but they are very lacking in an understanding of the seismic principles that generated them. Either by a formal education system that does not teach seismic principles, codes that address only structural issues; and/or a lack of interest in eastern seismicity, learning is not a direct result of exposure to seismic designations.

4.2. INTERACTIVE SESSIONS

The purpose of the interactive sessions as mentioned was to prime the participating architects in preparation for the preliminary design task. The act of the researchers priming the architects itself may be viewed as dissemination. In that regard we should consider dissemination issues which were made manifest during the interactive sessions, and which relate to the objectives of the research. In fact the discussions at the end of the interactive sessions highlighted the subject of dissemination as well as integration so it is appropriate to discuss dissemination here and leave the report on integration efforts to the next section. Before dissemination is discussed, however, the some observations about the primer and workbook results should be reviewed.

4.2.1. Performance

The New York firm had two architects, one of them having a structural engineering background (we refer to this pair as the New York team). The firms in Cambridge and Charleston had one architect each working on the workbook.

The New York team dealt with the abstract problems of Exercise One more easily because the engineer in the team could direct the effort with his competence in structural principles. The Cambridge and Charleston architects started the exercises with less confidence in their knowledge of the behavior of structures under seismic loads although both were reasonably well versed in structures. By the start of the second exercise (the reader is directed to Appendix B in reference to the workbook exercises) the Cambridge and Charleston architects began to confront their lack of seismic knowledge by doing some research with the materials at hand and asking questions as they went through the exercise. Exercise Two, in the principles it reflects, follows Exercise One closely. Exercise Three refers to principles not yet introduced in the first two; and indeed at the start of Exercise Three each architect needed coaching as to how to proceed, which wasn't necessary for One and Two. Again in Exercise Three the Charleston architect referred to the primer.

Exercise Four was an extension in principle of Three and the New York team took quick grasp of it. The Cambridge and Charleston architects still utilized our coaching and the available references--the Architects and Earthquakes, our Primer and articles by Christopher Arnold. The references in themselves were not adequate in providing the information needed to continue but with our coaching the latter two architects were able to complete the exercise.

Exercise Six began the specific building problems where other non-seismic criteria were to be considered as a matter of course. The plans as shown required the architects to assume the type and location of structural members. Thus, within the whole plan, one first identified the existence of, or lack of resisting elements; then one was at liberty to manipulate plan elements and even whole subsections of the plan to improve seismic resistance. The emphasis, however, switched from pure structure to considerations of function, circulation and physical systems. For example, the Cambridge architect discussed problems of piping, electrical service and the possibility of motion-induced automatic emergency cut-offs to services. Architects in both Cambridge and Charleston apparently began to apply the principles illustrated by earlier exercises and so by the end of Exercise Six one had the impression that some of the principles had been absorbed and were now aiding in the solutions to the next series of exercises. The New York team moved easily through Exercise Seven and it became apparent that the engineer facilitated that progress by suggesting and reviewing design decisions related to structural behavior. The Cambridge architect was aided by a colleague for this Exercise and the two began to discuss explicitly the architectural or non-structural and more aesthetic aspects of plan manipulation. The Charleston architect concentrated more on the design of the assumed framing as the New York team had done. By this time, all three firms began to show proficiency at dealing with building configuration and the placement of resisting elements.

However, Exercise Eight emphasized non-structural building contents, and here the participants again showed lack of confidence. The New York team first sought some guidance in the reference materials but did not seem to find out what they wanted. They had to draw on their knowledge of the normal connections of equipment to structure, walls and floors. The reactions of the Cambridge and Charleston architects were much the same--the behavior of mounts and attachments under seismic load were intuited. The architects had no preconceived solution for seismic loads and their responses were cast in some doubt as to the extent to which conventional designs such as in suspended ceilings or vertical pipe chases might be reinforced seismically.

Exercise Nine dealt more with material selection and the addition of resisting elements and this brought the architects back somewhat to an area of greater assurance. Drawing on their professional experience the New York team easily integrated their knowledge of materials with seismic criteria. They did, however, do some research into glazing details. In Cambridge and Charleston the reaction to the exercise was the same-- here it was not difficult to select viable materials; and the placement of resisting elements or seismic joints was something already devised as a solution during the earlier exercises.

The final exercise was lengthy but it was not the grand summation the researchers thought it perhaps would be. A tendency to avoid details was evident largely due to the perception of a time limit for the exercise. With the engineer guiding structural considerations, the New York team worked smoothly and thoroughly but they seemed conservative in their approach to the parti. However, this was probably due to the site and seismic constraints. Nonetheless, this group concentrated on getting the core, circulation, and ground floor spaces to be reasonable and seismically correct. The Cambridge architect (and the others as well) could only indicate the fundamentals of a sound seismic approach by positing a rectangular plan with emphasis on symmetry and balanced placement of walls. The Cambridge architect, however, also indicated concern for natural light, open space, and the urban context. The architects were told not to go into great detail and the only explicit suggestion was to consider curtain wall design. The New York team did review tall building seismic design but other than that no research was done and no substantive questions about seismic principles were asked.

Teamwork enhanced confidence in working out the exercises. The New York team generally appeared to be confident in their progress and when the Cambridge architect was assisted by a colleague there was an interesting discussion of Exercise Eight, which perhaps was the most difficult exercise. Teamwork aside, all the architects seemed to increase their confidence as they went through the exercises. The New York team was particularly proficient by the end of the fifth exercise but had less experience with detailing and materials so that aspect hindered them slightly where it was at issue in later exercises.

All the architects easily absorbed what information was presented them, and the few principles involved did not seem difficult to apply. They all appeared to enjoy doing the exercises. The workbook was very useful in provoking questions and assimilating knowledge, but it is clear that the workbook and the reference material alone would have been insufficient in imparting a working facility in seismic design, for the research texts did not have the detail or organization to provide ready guidance to answer typical questions of non-structural component design, or the behavior of various frame systems under conditions of seismic load. The architects had to ask the researchers for guidance in these matters.

4.2.2. Dissemination and Assimilation

At or near the conclusion of the exercises the researchers and the participants had a discussion covering the following topics:

A) How seismic design should be disseminated in the Eastern United States;

B) How technological information is reaching architects and what factors play a part in making it easier harder to absorb this information;

C) How architects may deal with seismic problems in the design process;

D) How architects may manage the issue of seismic design with their clients and with regard to local building codes.

The summary that follows combines the three separate discussions which were held. Topics A and B are the most closely related to each other and to the interactive sessions insofar as thes constituted dissemination. Therefore we will present these first.

A. How Seismic Design Should Be Disseminated in the Eastern U.S.

The answer to the question of dissemination begins with the recognition that different firms and different design communities have different resources for receiving new information, and different management policies which make them more or less receptive to new findings. A firm may be outside the mainstream of practice or academia, which makes it harder for them to "plug-in" to state of the art information flow. Conversely, firms in a larger design community will have many informal as well as formal contacts with information sources. In some design communities, there are established programs for dissemination by means of lecture series and continuing education courses.

Perhaps publicity in books, articles, or television programs would draw the local professionals' attention to new information relevant to their practice. The potential for cable television channels and video tape being used to disseminate specialized information is great.

Presently, special corporate and institutional clients directly instruct architects at interactive conferences during the design process. Examples would be owners of nuclear plants, factories, hospitals, elementary schools, airports, etc. In many instances architects themselves, having completed work on one or more projects of a certain type, evolve into specialists; and clients gravitate toward the few local firms which have achieved a reputation for a specialty. The recipients of new information, therefore, become self-selecting. But in earthquake hazard mitigation all firms practicing in a zone of considerable seismicity should be aware of the appropriate measures to be taken.

A computer information base with adequate data, rapid retrieval, adequate specificity, linked to in-house hardware for access could be an improved substitute for catalogues and texts. However, at this time it would be an expensive system to build and use. Still, one can envision interactive computer-aided design in the near future. Manufacturers and researchers would be able to supply data just as the medical profession has computerized symptom-diagnosis dictionaries. Perhaps software with interactive capabilities could be as useful as conferences. Self-paced, self-activated learning using computers is certainly no new concept.

Unfortunately architects who are part of the dissemination process are in the minority which partly explains the difficulty in arousing the interest of practicing architects. In the East, the question is not so much what there is to learn or how to present it, but what is the incentive to learn and incorporate seismic principles? In the areas of fire protection, products representatives and even local builders initiate and support code revisions (even more so the architect). But in seismic safety, being aware of the low probability of occurrence, these usual initiators of change probably won't appear because they have no financial incentive to cause changes. Certainly a good damaging earthquake would be best. Perhaps as is prevalent in human nature, the profession is waiting for a disaster before it extends its knowledge and techniques into the East. Disasters always galvanize previously reluctant people. Short of that, the argument for seismic safety in the Eastern U.S. has to be articulated with realism and practicality; and be addressed to local legislators as well as architects.

B. How Technological Information is Reaching Architects and What Factors Play a Part in Making it Easier or Harder to Absorb This Information?

Fifty-four percent of the architects polled said they were receiving news of technological developments on a regular basis, and an additional 37% said such news came into the office frequently, if not regularly. Seventy-eight (78%) percent said they gained new technical knowledge through textbooks or manuals and the same proportion indicated that the best means to learn about seismic design would be through carefully prepared brochures , as opposed to classes, lectures, or conferences. Perhaps the vote for brochures is biased by the architects' awareness of how much it costs to go to conferences.

Access to classes may be a point for many firms. Unless the firm is in a large design community or has access to an architectural department doing research, the academic channel does not exist for them. Nonetheless, the output of academic institutions otherwise out of reach could still be used. For example, texts with photographic documentation explaining the occurrence of seismic damage in specific instances is very instructive as we have seen. To show the architectural diversity of buildings which have survived earthquakes would be beneficial since it would help prevent the tendency toward obvious and simple-minded solutions.

Books, tapes, and computer programs might be technical means to increase or enhance the flow of technical information to the field of practicing architects. In some circumstances, these can replace personal contact; but the immediacy and the potential for feedback in interpersonal contact may be a stronger influence on the architect's inclination to use new technological output than purely inanimate sources. A workshop logically seems more conductive to learning than even the best brochures even if it is not as comprehensive. But we must be careful not to confuse learning with dissemination; they are separate issues though part of the same question.

After an architect has been out of school and in practice for some time, brochures and manufacturers representatives replace text books and professors in his learning experience. Knowledge input becomes more casual than deliberate. As stated earlier, a firm's alertness to new information develops when it is confronted with a building problem where the firm's own experience proves insufficient. The firm then contacts known and tested architectural sources. However, the majority of projects do not involve special design criteria and the typical situation is that there are more "reps" casually visiting firms than there are solicitations by a firm to manufacturers for help.

Assuming that adequate sources are accessible what factors then inhibit or facilitate the adoption of new principles? Their inclusion in design decision-making is a function of the office management, and the design process. The office policy strongly influences the way in which the assigned members of the design team approach a project. Office policy must encourage the design team to investigate possible innovative design approaches. If the firm has one or more persons-- especially partners or associates-- interested and capable in innovative design problems, of course new information and perhaps the generation of new information is more likely. Partners of this sort usually seek others with this attribute to be their employees. Thus the strong desire among partners to be innovative become pervasive in the firm.

The philosophy of office management may be less of a factor in small projects where only one designer is working alone. What one or two man offices can and will do with respect to innovation is subject to the same influences cited above, but it is difficult to generalize upon. If the client or contractor encourages innovation, so much the better. But most often the architect himself dictates his own design criteria and must be self motivated towards research. Moreover, his network of contacts must enable him to anticipate that new information could be developed or that latent design issues exist. Often this recognition results from contacts in disciplines outside of architecture.

Returning to the pragmatics of office practice, the cost of information could be minimal, but its adaptation for integration into particular projects may indeed be an expense at least initially. (The last phase of our research sheds some light on this.) That cost is usually not passed on to the client. However, the assumption of education costs is a relatively short term phenomenon. In time, the new principles are integrated with little additional design costs attributable to their application.

In seismic design, in the eastern U.S., the additional costs of construction may also be small relative to total construction costs. This may even be true, but to a lesser extent, with rehabilitation work. The additional materials or time in fabricating assemblies or placing extra reinforcement may not amount to a considerable expense, given the design standards assumed for the maximum expected magnitude of seismic force. Unlike solar or handicapped design, after the initial ignorance and after the reactions of doubt and reluctance, a relatively short period of investigation and trial may prove that adequate seismic safety measures can be provided without significant increases in either design time or construction costs.

C. How Architects May Deal with Seismic Problems in the Design Process within the Design Process

The financial structure of most firms apparently requires research to be strictly job-related. Therefore, the opportunity to do new research is when a new project is started; and more often, it is the time when the relevant findings may be assimilated. It is usually at the project's outset that the architect's perception of client willingness, consultant and product availability, scope and complexity of program and allotted design time become factors which govern the pursuit of known approaches or the search for new approaches.

If there is an inter-office project conference to initiate the project, seismic issues along with other specific problems may be identified. Depending on how the problems are defined, more background information (an expanded knowledge base) will be sought before design proceeds very far, which means that the firm will approach familiar, accessible and reliable information sources as soon as possible.

The information sought should act as performance standards or prescriptive measures ultimately, but just how information is translated to be used in that capacity is a function of the existing expertise or experience of the firm. Information must be translated to forms useful in particular design projects, and someone in the office has to be capable of doing that. (One can, at this point, question whether the pedagogy of many design studios in architecture school develops this capability.)

The accessibility of information usable in the design process, therefore, will also be a factor in integrating research findings. For example a wide range of industrial magazines come into an office with articles that could "whet the appetite" for some new product or technique. However, pursuing a direction prompted by such articles often requires hiring a consultant. Articles usually cannot be written to be used as instructions capable of dictating part of the design decision-making. Articles of an explanatory nature addressed to architects are not uncommon but it is unlikely that they would eliminate the need for a consultant.

Therefore, consultants would be called upon to enter the design process, bringing with them digested knowledge ready to be directly applied. Products representatives who may be as accessible and less expensive than ordinary consultants may be called to work with the firm on an aspect of the project. More often now, these representatives have architectural or engineering training, and even though they are predisposed to limit their solutions to those which include their product, they are capable of helping the firm to incorporate their product in an effective way. In this manner, seismic principles would be incorporated indirectly through the adoption of modified products or techniques developed by manufacturers who have gained seismic experience in the western U.S. and elsewhere.

4.2.3. Integrating Techniques

Two specific steps could aid in integrating seismic criteria. A well written, organized (and well illustrated) checklist would be helpful. It may or may not be one checklist for all building types. It might have a rank ordered list of measures, ranked in terms of expense, or of impact on design concept, or of effecting resistivity; so that on a project-by-project basis, decisions could be made to determine how far down the list one should venture, given other design parameters. Similar checklists and guideline formatting have already been invented during efforts devoted to solar energy and handicapped design so that seismic information may be readily made useful for design using the same techniques.

Another step important to the integration of seismic principles may be specification writing. When architects can assume, a priori, that specification for new techniques or products can be made in a fashion acceptable to subcontractors, they may accept those new techniques or products provisionally during preliminary design. Actual construction and use of the innovations will, of course, provide the experience which allows for greater certainty in the preliminary design and specifications for subsequent projects. Careful planning and foresight, informed by prior experience can forestall innovation problems which become apparent during the contract document and construction phases.

To the conclusion that assimilation of seismic design, as with all off design, is a heuristic process must be added the point that there has to be some incentive to owners and architects to incorporate seismic principles. Incentive is related to cost-effectiveness, as well as the language of building codes. Seismic design, if executed, will be evaluated in terms of its impact on actual building production. After time passes, an equilibrium state should be reached where a fairly well defined level of seismic design achieves the stature of conventional practice.

To reiterate, the most influential factor in successful integration besides effective dissemination will be "hands-on" experience and personal job-related feedback. However, Eastern U.S. earthquakes, unlike other hazards, have been historically few and unstudied so that eastern architects will have to take the western architects experience vicariously.

D. How Architects May Manage the Issue of Seismic Design With Their Clients and With Regard to Local Building Codes

Clients

Assuming some level of seismic design will be attempted, eastern firms will have to determine how extensive the effort should be. Some time will pass before local practitioners establish some standards. Will owners influence this process or accept the emerging conventions as simply the cost of doing business?

Clients do get involved in design issues, usually when they have had prior experience with the building type. Also, they may have become familiar with particular systems or special equipment which prompts them to offer suggestions to their architects. For very special or highly technical activities, the client may have detailed instructions to be followed; but in any case, it is always prudent for the architect to verify these inputs. In seismic design, it is doubtful that a client would offer much input. Their readiness to become involved may depend on the scope of the job. If it is a small job and the added cost will be minimal, there should be little client objection. Where the scope and size of the building may impose problems of seismic vulnerability, the client may be disinclined to incur the extra cost for design time, and special construction. This would be particularly true in rehabilitation work where it is likely that only code enforcement would cause the owner to pay for seismic design.

The owner may talk with an insurance agent first. The owner's position may be that life loss is not likely and the losses due to building damage and curtailed business or production are not insufferable, if recoverable through insurance. In that case, the owner would rather pay the premiums than pay any increase in construction costs. Clients will pay extra for special equipment or detailing germane to their uses, but they are less inclined to pay for something perceived less useful, in fact with a low probability of coming into use whatsoever. As for design time, clients come to the architecting to take full advantage of his present expertise and they would view dimly extra fees charged for the architects edification. Again, job-related research becomes a week night and weekend vocation.

Seismic considerations, then, will perhaps be made after some preliminary resistance. The hope is that in the preliminary design process, architects can devise reasonable measures that would be within the cost ranges judged appropriate for that building and location. Then, hopefully, owners will not stop short of those measures because of any disinclination to spend any amount on seismic resistance. Still, in the eastern U.S. there is as yet no clear answer to how much seismic resistance is enough, i.e., how much of the building and its contents should be invulnerable under what seismic loads. Architects and owners will have to balance both investigation and implementation against development costs and the economic analysis of building use.

Codes

The revisions to present codes may indeed mandate the education of architects and in turn their clients. New provisions could require the architect to do some extra design work. There is some doubt, however, that in the long term design time would be routinely lengthened as a result of having to comply with code requirements.

At the present, codes would hardly seem to require greater architectural design. The code for Charleston (which follows the Southern Building Code), as an example, has but one or two paragraphs which refer the user to the ANSI code, which is basically of concern to the engineer; and non structural building components are not addressed. Codes may be more helpful in the future, but with the exception of the tentative provisions complied under ATC-3, most codes used in the East give no instructions for non-structural building components. ATC-3 provisions if adopted would offer some performance standards for non-structural components.

Once the issue of code revision is explored, the usual compliance problems will arise. Prescriptive codes can be unduely restrictive. Their prescriptive nature tends to make architects, let alone code administrators, relax their judgement. Performance codes, while allowing the writers intent to be manifested in various ways, carry a necessary measure of ambiguity. Their interpretation must be directed by the architect's own judgement. The easier route is some prescriptive provision which , in technical terms, expresses the desired legal limit of risk, and allows state and local agencies to adopt only those measures necessary to exhibit a level of regard for public safety. With the flexibility of performance codes comes the responsibility of professional insight and inventiveness which must be borne by the architect and his engineer.

4.3. PRELIMINARY DESIGN

Originally three architectural firms were engaged to participate in the research project. Each firm was to apply principles and strategies of seismic design, as covered in the interactive sessions, to an actual design project in their office. Each project selected was to be at the stage of preliminary design. At that stage, it was felt, primary understandings are reached between the architect, client, engineer and code administrator in terms of the seismic context in which the project is to be built, and the seismic design strategies which will be accepted. Therefore, practical problems of integrating the concept of seismic design itself into professional practice are to be profiled most clearly in this phase of the work.

The uncertainties of professional practice being what they are, it was not unexpected that one of the firms engaged might have its targeted project delayed; and in fact that is what occurred, which left the research team with two preliminary design experiences to study.

4.3.1. New York Firm: Design Process

In New York, the firm of Steven Winter Associates had a consulting contract with Rocky Mountain Log Homes, a manufacturer of prefabricated log home building systems, who ship their product to customers in the western United States. Steven Winter Associates is under contract to provide special architectural and engineering services for the manufacturer. The particular project selected for our purposes was a single family, detached, two-story, precut log home. The square footage was 1800 square feet. The user for this particular house was a private family who wished to build the house in Phoenix Arizona, on a flat site, having silty soil with bearing capacity of 2000 pounds per square foot.

The house is constructed using a prefabricated system which is erected in the following manner. Wall logs and roof framing members are precut in a factory to exact specifications. Each log is labeled to indicate its location in the wall. The logs are shipped from the clients Montana factory to the site by truck.

Either the homeowner himself or a hired contractor then builds a conventional foundation and first floor platform. Next the owner or contractor installs a roof, windows, doors, and all non-log components.

The firm's design team consisted of two members: one architect and one engineer. A senior associate familiar with the log system supervised execution of the work. The team did not actually design the log home; the design was provided by the manufacturer's sales personnel, who develop design standards. As to the team's responsibilities, the architect was to ensure local building code compliance in terms of room sizes, head room height, HVAC (heating and cooling), energy codes and any minor modifications which are requested by the owner. The engineer's responsibilities were also to ensure code compliance in terms of structural design of walls, roof and floor diaphragm, to secure soils data, and to recommend a foundation type.

The design objectives were few and simple. The logs themselves were to remain exposed on the interior, and the general appearance of the exterior was to recall the early cabins of the pioneer west including extensive use of covered porches. These objectives were very much the standard for the manufacturer.

Since this particular house would be located in a seismic Zone II area, the homeowner was not concerned with seismic safety; and the manufacturer was concerned only with whatever provisions had to be made to secure a local building permit. The manufacturer had no reservation about seismic criteria per se. The firm made the following record concerning a design with respect to the code (The Phoenix Building Department strictly abides by the Uniform Building Code):

> "There is always some confusion as to the importance a building department places on the seismic provisions of a building code. In this case, the building inspector accepted the fact that the seismic requirements could be met and that wind load requirements governed. However he required that steel reinforcing bars be used to dowel the logs together, which would provide vertical continuity and horizontal shear transfer as well as tie the roof to the walls. This construction has been employed by other manufacturers in the past."
>
> "While the above method of fastening the wall logs together is acceptable, it is not the only solution to the problem of making a log wall a shear wall."
>
> "In this case, very long steel spikes are used to fasten a log to the

> one below...The spikes provide horizontal shear resistance and a vertical tie against overturning. It is our opinion that this is the best and most easily employed method in view of the fact that the homeowner/builder is limited in construction ability. Of utmost importance here is that the design and construction technology be simple to enable most homeowners to build on their own, with inexpensive tools."

The experience of the team was that the UBC code did not provide any guidance in terms of seismic design or plan or layout.

Design Process

The team followed an office standard procedure for the structural design. This covered the design of the roof and floor diaphragm, shear walls, securing the exterior porches and balconies and ensuring that the house would exhibit "box structure" behavior. There was, in fact, a seismic analysis available for the standard model of the log home from which this version was derived, thus there was no confusion about how seismic criteria would be incorporated into the design. In this version, modifications to the first floor were suggested, but not approved. One bedroom wall was found to be heavily loaded in shear as a large window was present there, decreasing the amount of shear resisting timber. In general seismic criteria did not conflict with other criteria for the house.

As indicated above the manufacturer had a standard model house whose plan is conventional and known to be accepted in the market as evidenced by previous sales. Therefore, the manufacturer would not experiment with modifications to the plan unless specifically requested by an individual owner-to-be. Since this was the case, the architect and engineer in this firm were employed in the minor modifications which were made. The redesign was largely pertinent to structure, so the engineer provided the solutions and documentation for that. However, it was understood that any structural solution would have to be simple. As the team states, "The seismic strategy could not dictate construction techniques or skills beyond the ability of the average handyman/homeowner."

4.3.2. Cambridge Firm: Design Process

The second participating architect worked with the Architect's Collaborative, Inc. of Cambridge, Massachusetts. The chosen project was a three story suburban office building of 160,000 gross square feet which was connected to an existing four storey building. It was to be the state headquarters building for a national organization and was to be located in North Haven, Connecticut. The low-rise massing was decided upon based on preliminary studies which indicated that the bearing capacity of the soil would be poor (Class B under the Massachusetts Code).

The team assembled to work on the preliminary design included two architects, a landscape architect and two engineers employed by engineering consultants hired to work on the project. The project manager for the team was the architect who had participated in the interactive sessions; and she described the teamwork as "A collaborative process (which) is used in analyzing the problem and developing the appropriate design solution." The firm's principle in charge of the project had also participated in the interactive sessions.

Planning goals for the project were to:

1. stimulate increased worker productivity
2. reduce the cost of operations
3. conserve energy
4. project an appropriate corporate image
5. preserve and enhance the natural environment
6. be responsive to the location and compatible with existing neighboring areas.

Objectives derived from these goals which were especially relevant to building design were related to energy conservation and site conditions. To respond to energy conservation, the objective was to develop " a building design whose orientation, massing, fenestration, and layout of interior spaces will reduce heat gain in summer, capitalize on solar heat in winter, and take advantage of daylighting and natural ventilation to reduce energy consumption in building operation." To respond to the site, the objective was to develop "a physical form which will be compatible with adjacent residential areas."

As the team reported, "These criteria and objectives were derived from the analysis of user needs, from statements regarding corporate policy and image, and from the investigation of environmental factors...influencing the project."

While there was no confusion as to what seismic criteria might be, there was a lack of data regarding the area's seismic history which (the architects believed) contributed to the lack of awareness of potential seismic problems on that site. The architects believed that in general "there were serious reservations about seismic criteria both in terms of need and cost. Even when accepted as a design factor, seismic design was incorporated into structural design rather than into architectural design and detailing."

There were two planning objectives which could have conflicted with earthquake mitigation strategy. In one, the objective to maximize daylight suggested emphasizing the longer east-west axis, and maximizing north and south light penetration. This required placing the resisting elements such as stair towers and utility cores at the east and west ends. This could create a potentially excessive oblong shape with less resistance to lateral force in the north-south direction. A second objective was to bridge between the new and existing building at each level thus placing a bridge connection between two heavier masses. Non-synchronous movements of the buildings could produce shear and torque forces at the bridge connections.

Design Process

The Cambridge team did not have nor did they construct a checklist at the outset. They understood the seismic risk to be very slight and found that the local governing code (BOCA Basic Building Code) was vague with regard to architectural design and had limited requirements. In view of these conditions, seismic design criteria received a very low priority. The team reported that, "Since the proposed building is only three stories high, it was agreed that seismic issues that would have an impact on architectural decisions regarding massing and configuration of forms could be resolved relatively simply by the structural engineer. Structural devices such as isolating the volume into separate parts and extra stiffening at unevenly braced columns would be incorporated into the engineering design." Thus, the building configuration did not have to be changed where structural design of the framing provided the desired level of resistance, or avoidance of seismic constraints.

There was some alteration of environmental design which was made to accommodate a desire for seismic reinforcement.

It is clear that an engineer was involved in the preliminary design process; but it is also surmised---given the discussions carried on with the architects during the interactive sessions---that the architects could and did contribute to offering solutions to seismic reinforcement issues which were posed.

The Cambridge team's report indicated that, in general, integrating seismic design into preliminary architectural design required the owner as well as the design team to determine whether seismic forces represented a significant aspect of the design problem. Doing so depended on the availability of information regarding local seismic conditions and upon their familiarity with the design implications arising from those conditions. While the interactive sessions served to provide the architects with some knowledge of design implications, there was typically little information about seismicity; and the absence of positive knowledge about local conditions lead to the prevailing assumptions that minimal structural provisions would not only satisfy requirements of the code, but would also avoid life threatening damage. The team, therefore, operated under the assumption that the most likely earthquake expected to occur would not represent a life threatening situation with respect to the occupants of that building, given its intended configuration and structural detailing. At the same time, the team recognized that the expectation of an earthquake was imprecise as to intensity and probability. The team also understood that the ground motion which might occur at that location could cause damage to components and contents of the building and the criteria to keep those elements (such as doors and utility connections) operative would be addressed in later stages of design. The appropriate level of design to meet that criteria, however, was not yet determined at the time of preliminary design; and they perceived that the lack of information would make the decision difficult. The implication was that without convincing evidence of a potential hazard to building components and contents, no special provisions would be made.

4.3.3. New York Team Evaluation of Preliminary Design

The New York team's project involves a type of manufactured housing where standardization is important. It is a building designed to be compatable with prototypical residential lots, and it is not predesigned to suit particular local conditions. The basic design does not consider local geologic or seismic data. substantial deviation from the standard design.

The owner is supposed to be able to build the house himself using the manufacturer's instructions. Significant changes would add complications the manufacturer could not control. Without that control the manufacturer would be unwilling to place a warranty on an altered design. Therefore the manufacturer did not allow substantial deviation from the standard design; and the team felt they did not have the opportunity to ascertain the appropriate level of design response to the seismic hazard in the locality of the project.

Homebuilders in most regions of the country try to standardize construction to achieve economies of scale. Even when a housing manufacturer reaches a multiregional market, he may not be producing enough units in any one region to create a separate version to accommodate conditions typical of that region. The manufacturer will expend only the minimum resources - including consultant input - to meet local codes. In this case, from the view point of architects endeavoring to create an appropriate design response, the economics of pre-engineered building proved counterproductive. In fact there were no code provisions for non-structural components and this combined with the housing type left little leverage with which to persue innovation.

The team, in its evaluation suggested that improved codes regulating non-structural design should primarily address occupancy and the functional importance of the building. They also indicated that the level of protection desired would be bimodal; either life safety or protection of property. Though the team did not elaborate upon this, one can assume that life safety would imply providing a greater degree of reinforcement and the choice to achieve that level would be based upon use and occupancy. Among quantitative or prescriptive code provisions, they would include local seismicity, and component mass, and among performance criteria they would include consideration of the purpose of the component.

In this case there were in fact climatic imperatives, and in adapting the design to these, the team actually found seismic design to be the least difficult constraint. Both snow load design and energy conservation were more difficult requirements.

Asked to comment on the most practical way to integrate seismic design principles, the team responded that they would (as they did) combine structural and preliminary design considerations in the preliminary phase. This is expected of a firm which typically has architects also trained as structural engineers, in charge of projects which utilize special technical applications.

In responding to the possible added design cost attributable to seismic considerations, the team felt that in the case of single family dwellings added cost is a function of the local building departments requirements, and can be easily predicted. That is, the number of applicable regulations, and the possible conflicting objectives among them must be considered; and this is readily translatable into time and cost. Moreover, in regard to California, design cost is also a function of site conditions, and as the demand for building on more difficult sites increases, there will be more incidents of difficult site constraints. In addition, if more accurate structural analyses become available and if the requirement for their use is legislated, costs will certainly increase. Construction costs will rise for the same reasons.

To learn more about seismic design the New York team declared that "participation in EERI and LFE programs are the only forums where state of the art design has meaning." To make a case for seismic design the team suggests the presentation of historic seismicity and seismologic data, and the presentation of examples of seismic design. For this, of course, persuasive data would have to be assembled.

There are two ways to evaluate the New York attempt. Unfortunately, even though the project was located in a seismic zone 3, it was really predesigned before it entered the architects office. There was little interaction with the manufacturer (actually the client in this case). The only special contribution by the architects was to specify the insertion of long steel spikes perpendicularly through the logs to reinforce against shear. There was no first hand exchanges with the local code officials other than correspondence. The Plan Review

Superintendent at Phoenix checked the plans for zoning compliance and the structural drawings and calculations for code (UBC) compliance. In fact the steel spikes were put in at the suggestion of the superintendent who also requested that this be the means of tying the roof to the walls.

The superintendent was not so much concerned with seismic loads as he was with wind loads. The calculations for the structure showed that the required design for wind loads exceeded the requirements for seismic load. If one were looking for interesting interfaces between the architect and other actors in the process there is little here. However, when one considers how typical this situation is especially with respect to housing and light industrial buildings, it becomes more noteworthy.

As Steven Winter Associates point out, housing producers will more readily adopt technolical innovation than changes in building plan. Also here, as in many eastern locations, structural requirements for wind load often take precedence over seismic reinforcement. But seismic reinforcement can be easily incorporated with little resistance from code administrators. If a seismic design for multiple unit production does not seem to add synificantly to labor and material costs and if the design cost is a one-time expense, seismic design should be easily incorporated into this kind of building production. Architects and engineers then should continue to work with housing system manufacturers, building institutions such as the National Housing Partnership or National Association of Home Builders to adopt regional standards for structural design, in terms of seismic resistance.

4.3.4. Cambridge Team Evaluation of Preliminary Design

The Cambridge team believed they had made an appropriate design response to the seismic hazard potential for that site with the qualification that there was great uncertainty about the magnitude and probability of the hazard.

In regard to the relative difficulty encountered in addressing seismic criteria, the team felt seismic constraints were of the same moderate level of difficulty as functional organization and energy conservation. They perceived both aesthetic issues and site constraints easier to manage; and other natural hazards such as wind and rain, easier still. The team made these observations regarding fire safety as criteria related to seismic design: "Fire safety in terms of seismic criteria postulates the following conditions:

- That occupants may be able to get out before the building, or parts of it collapse.
- That utility connections withstand seismic forces so as not to cause fire, flooding, gas leakage, etc.

> "These performance requirements imply that the structural and architectural elements associated with the means of egress (i.e. corridors, doorways and stairs, floor finishes, and ceilings) should be constructed as not to obstruct passage. This implies that door frames should be rigid enough to avoid excessive deformation which would prevent doors from opening, floor finishes should not get broken up so as to impede traffic flow, and ceiling tiles, etc. should not fall down. Many of these issues would influence the decisions taken mainly during the later stages of the design process."

Though the team did not construct a checklist, based on their experience they suggested the following points should be included:

1. "Investigate seismic conditions and ascertain level of impact on building, location, height, and configuration.
2. Assess danger to life safety and to building safety associated with the building type and particular site.
3. Identify building elements likely to be influenced by seismic forces.
4. Determine potential range of failure that may occur.
5. Establish criteria and priorities for the level of safety to be achieved.
6. Detailed structural considerations:
    - Sufficient bracing/moment frames
    - Adequacy of diaphragm
    - Soil behavior under seismic loading
    - Adequate moving joints
    - Story drift
    - Stability of non-structural elements."

Inasmuch as the Connecticut code did not address non-structural components sufficiently, the Cambridge team said they might call for greater specificity in that regard; but not in the near future. The caution is to refrain from further regulations until there is better information regarding non-structural component behavior against seismic forces. They believe that "a code pertaining to the design of non-structural elements not related to life safety concerns would likely increase cost significantly" if such a code were prematurely implemented.

However the team suggests that, as a practical matter, damage to non-structural elements can "be avoided with proper detailing, and not necessarily (at) higher cost." They therefore suggest "an explanation of considerations for non-structural elements to minimize damage to them." They specifically call for instruction with respect to the attachment of facade elements to exterior wall structure as this is a potential hazard to life safety.

They continue by reiterating the association between professional liability and the code. Major unresolved issues are:

- The magnitude of earthquake one should expect in the possible life of the building.
- The type and extent of damage that could result without seismic reinforcement.
- The extent of damage that would be accepted as impractical to avoid.
- The level of protection sought which may range from,
    - life safety alone; and extend to
    - life safety and structural element, or
    - life safety, structure, certain architectural elements and electrical mechanical systems, or
    - life safety, structure, all architectural components and all electrical and mechanical systems.

The team believes that due to the uncertainty concerning the expected magnitude of a regional earthquake, any mandated code should define the design conditions upon which regulations would be based. If an earthquake exceeding those conditions were then to occur the State would have to waive claims of professional liability where the code was followed.

The team's approach towards integrating seismic design into practice stresses education and training. Clear illustrations of the consequences of seismic forces on building elements would be a first step. In practice structural and architectural design must be coordinated from the outset especially in regard to the location of architectonic elements which also act as bracing elements.

Sufficient experience in seismic design should enable the architect to manage the issue without extraordinary time being spent. This might not eliminate the need for an engineering consultant, however, and ultimately the severity of the design conditions will affect the cost of services in any case.

> "As the general level of expertise in seismic design increases, it is reasonable to expect that the cost of providing such services may also increase because of the need to develop new systems and innovative approaches to the problem."

The best means and format to learn about seismic design, they feel, is exposure to the material in college and continuing education courses.

To make a case for the level of risk and the extent of damage which regional earthquakes may cause, the team believes that there must be convincing arguments for the damage that may be expected in each seismic zone. As materials in support of the architect's proposal for better seismic design, the team cites:

1. Pictorial survey of buildings which either were damaged by or survived earthquakes in various zones around the world.
2. Explanations of how damage occurred.
3. The dollar value of the damage
4. The dollar value of preventive measures that could have been taken before the earthquake occurred.
5. Life safety hazards: classification and description of preventive measures.
6. Clear descriptions of damage that may be expected in each seismic zone.
7. Justification of seismic zone classification.

4.3.5. Summary of Preliminary Design Experience

There were six major issues underscored by the experiences of the participating firms. These were code content and guidance, the success in or impediments to using seismic principles in the design process, client reservations about incorporating seismic design, uncertainty and assumptions concerning local seismicity, extra design costs associated with seismic design, and topics and methods of dissemination.

Code administrators were not highly concerned about seismic hazard mitigation and accepted designs which were governed by wind loads. The New York team felt that local codes should address local seismicity, while the Cambridge team went further suggesting that local code provisions should be prefaced by officially adopted local design conditions--i.e. the magnitude of seismic shock to which design standards are related--and that the State should waive the architect/engineer's liability where an event exceeds the design conditions. The New York team also felt that the purpose as well as the mass of non-structural components be explicitly considered in the code; however the Cambridge team stepped back from an immediate position on components saying that refinement of regulations on non-structural components must be deferred until more is known about their behavior under seismic load. The New York team and Cambridge team found the UBC and BOCA codes respectively to give no guidence to architectural planning and design.

Both firms combined preliminary structural and architectural design in the first phase of design study. Neither team found seismic criteria difficult to include; the Cambridge team thought that the inclusion of seismic criteria was no more difficult than providing for energy or even functional performance. The Cambridge team pointed out however, that the consideration of components which would have to perform in the event of post-earthquake fires, such as doors, stairs, stand-pipes, alarms, lights, etc., would have to be made in later stages of design. Yet uncertain knowledge of how these would be affected was going to make an appropriate level of design response difficult. The doubts that the Cambridge team had arose because the seismic history of the project area was not well known to them; though they did make the assumption that the more likely events would not be life threatening.

The client for the Cambridge team project likewise expressed serious reservations about the need or cost of seismic criteria in that project, so the team felt that their charge was to deal with seismic considerations within the building frame--to "hide" the seismic design, as it were. The client for the New York team likewise put restrictions on their design, but his concern was that the seismic strategy employed could not dictate construction skills beyond the capabilities of the prospective homeowner. There was also the implication that in the case of the pre-designed housing, if seismic design is to be included, it is done in the development of a standard model for a given region or it is not done at all.

Both teams believed that if more accurate structural analysis is legislated and design expertise must be increased, then the cost of providing design services will rise.

And finally, in regard to dissemination, the New York team believed that historical and seismologic data, and examples of seismic design should be presented to local architects; but the team also felt that the only viable forum for direct contact with experts was at EERI and LFE programs.

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5. RECOMMENDATIONS

As stated in Chapter 2, the research indicated that it was important to report on how seismic design strategies can be included in the design process, how to manage the issue of seismic design within Eastern U.S. professional practice, and related to this second question, what strategy could be followed for establishing an improved level of seismic design in the East.

Part of the answer to these is the education of architects through effective dissemination, part is analyzing where, in routine design and practice, innovative activities could occur, and part of the answer lies in capitalizing on education and dissemination in a particular manner so as to persue the adoption of imporoved seismic code provisions.

Therefore the following sections address these three aspects seperately, and each is predicated on ideas emerging from the research experiences of the research team and the participating architects. The final recomendations as to dissemination strategy and code adoption however, are those of the researchers only.

5.1. EDUCATION OF ARCHITECTS

5.1.1. Comment on Text Reviewed

Integration means utilization of knowledge in practice; but Seismic knowledge must be obtained and assimilated before it can be used. Most of the architects we polled preferred texts and manuals as instruments of their instruction in technical subjects. Texts were preferred because of their permanence, which makes it possible to refer back to them occasionally. However, we found that there are few earthquake manuals available which are addressed to architects. Architects and Earthquakes seems to give architects the basic theoretical knowledge they would need to be conversant about how earthquakes occur and how they cause building damage; but it did not discuss probabalistic analysis and how that effects the decision to employ mitigation techniques, in a way that can aid architects with that issue in eastern practice. Also, we found Architects and Earthquakes to appear rather unattractive as a volume and the value of the graphic quality of a publication should not be underestimated when we are trying to induce interest. The McCue, Boone, and Tomsick volume as well as the AIA/RC volume on Police and Fire Stations are better graphically and more practical.

The Interaction of Building Components During Earthquakes by McCue Boone and Tomsick was first published by NTIS in January 1976 and remains perhaps the best text specifically addressed to practicing professionals, and sets forth a thorough technical discussion of earthquake damage mitigation. It does so by establishiing a conceptual model of buldings as interdependent and dependent systems which interact under dynamic loads. It then posits that the model can be used for analysis and design. The book then suggests a clear design process framework to analyze components in complex dynamic situations. It concludes with a discussion of two design approaches, one in which components are to remain undamaged, and a second, called a "controlled damage" approach, where components are designed to sustain minor earthquakes without damage, and suffer increased damage as they respond to larger intensity earthquakes.

The McCue text is valuable because it is a comprehensive discussion of the causes of building damage and presents a strategy for deciding, in purely technical terms, when and how to mitigate against damage.

Seismic Design for Police and Fire Stations is somewhat different in orientation. Less theoretical or technical, it is an explicit guide to programing and preliminary design indicating how necessary non-structural components are vulnerable and how to view the assembly of spaces, the selection of materials and the installation of equipment in consideration of seismic forces. The AIA/RC publication is very valuable as a reference to planning and design because it can be easily extended to other building types, because it is particularly helpful during the interaction between the architect and his client or users during preliminary design, and because it's organization, content, and illustrations make reference to it easy.

Lastly there is Christopher Arnold's Building Configuration and Seismic Design which studies the size and shape of building masses, the location and geometry of lateral force resisting elements, and the role of these design elements in making a building seismically resistant.

These three volumes taken together provide most of the technical and design process input architects would need.

McCue (et al) pointed out in 1976 that there existed very little data about damage thresholds for components of enclosure systems, finishes, and service systems, ie, non-structural components. Arnold is soon to conclude a study of the non-structural component damage suffered in the Imperial Valley and San Fernando earthquakes. For the Imperial Valley earthquake, Arnold will use records and recorded observations of damage to the County Services Building. For San Fernando Valley, Arnold's firm will interview people who experienced the event. Also Professor Satwant Rehal has completed his study of non-structural building partitions under seismic loads. The data on damage thresholds is therefore slowly being produced.

We also learned that it would be particularly useful to have a compendium of well illustrated case studies which show a variety of buildings both surviving and not surviving earthquakes so that architects could be shown that the "solution space" for seismically designed buildings is not restricted in the formal sense.

Earthquakes published by the American Iron and Steel Institute show damage of buldings in four major earthquakes. An elaboration on this would combine this kind of observation and analysis with a discussion of design implications, similar to Arnold's work. The difference here would be to concentrate on the record of specific buildings selected for their variety of type, material, and architectural design.

5.1.2. Topics to Present

Our own study has shown that there are issues which remain to be discussed at length. Morever, even though the issues are important to architects, some may require investigation by economists and writers on public policy and administration. For example, the economics of employing mitigation strategy should be discussed in terms architects can appreciate even though economic variables such as discount rates make long term judgements difficult.

If architects are to use architectural design to contribute to earthquake hazard mitigation anywhere in the country, information is needed about local seismic conditions and design implications arising from those conditions. As has been suggested, for specific regions in the East more detailed discussions must be published on:

- The magnitude of earthquake one should expect in the possible life of the building
- The type and extent of damage that could result without seismic reinforcement
- The extent of damage that might be accepted as impractical to avoid
- The level of protection to be sought.

These constitute important priori discussions of what to do which must be addressed clearly in order to give the local architect confidence to take action. The technical question of how to design and detail has been, and is being well answered already. Failure to press the issue has been caused in part by a lack of understanding about what is appropriate. Without that information, and in the absense of very specific prescriptive local building codes (not plausible in the foreseable future), architects cannot make convincing arguments to their clients.

Our experience indicates that the topics be presented in well illustrated manuals oriented toward the management of all aspects of seismic integration, that is, in relations with clients and code officials as well as in the design process itself. Perhaps a volume of case studies could be assembled. In addition to the production of texts, direct personal instruction is evidently very effective. Given the regional nature of these issues, it may be appropriate to consider regionally based manuals, workshops and continuing education courses. Getting the practicing architect to take a course or attend a workshop however, is as problematic as inducing him to buy a book and read it, only perhaps more so. What is his incentive to initiate his study?

5.1.3. Suggested Method for Dissemination

The idea of pressing for better building codes so that architects would feel obligated to take "remedial" courses is perhaps the reverse of the strategy which should be followed. We cannot expect local government at this point to pass comprehensive seismic codes, which would make it imperative for architects to acquire new knowledge. We must educate architects first so that they may form the vangard of an influence group which will persue the passage of better seismic legislation. Offering conferences to disseminate information has not been effective in gaining wider interest in seismic design, as have solar energy design conferences, premarily, because the underlying economic incentives and the latent opportunities for design (not to mention the sale of solar products) do not seem to have their counterparts in the realm of seismic design.

Instead we must identify an organization which can be charged with the responsibility of making a solicitation of selected architects and firms in a specified region. The criteria for selection may include the size of firm, the type of work it has done, and its previous history of innovation or research involvement. The firms would be contacted and asked to participate in a campaign to establish a comprehensive, rational seismic mitigation plan, including approaches to new construction and rehabilitation. The first step in this campaign would be the education of the firm itself. The second step would be to approach local engineering firms, contractors and other consultants, to participate in a project to assemble the information and develop the knowledge required to determine the appropriate level of seismic design for certain types of building in the region. This group would then form a coalition which would have the objective of improving the local building code based on their work. The specific strategies for the coalition are discussed later in this report. The key point here is not to rely on voluntary dissemination nor even to attempt broad adoption of better seismic design everywhere in the east at this time. The lists of selected firms should be made for the areas around St. Louis, Louisville, New Madrid, Buffalo, Attica, Boston, New York, and Charleston. These are obvious places in which to carry out the campaign. The time and funding for such work should be concentrated where it is most likely to succeed and do some good.

The funding might come from state urban development or redevelopment funds or from local Community Block Grant funds. These funds could be used to have local agencies enter into contracts with the AIA/RC, local AIA chapters, and if possible local architectural schools. This consortium would be contracted to draw up the list of selected architects, solicit them, enter into subcontracts with them, and then educated the selected architects and guide them in the formation of local coalitions.

State funding would be preferable strategically because local governments will be the ultimate receptors of this work and they may be too skeptical or financially pressed to fund the coalition initially.

5.2. INTEGRATION OF SEISMIC DESIGN INTO PRACTICE

Finding key firms in a strategic --not passive-- dissemination effort requires a clear understanding of the factors that predispose certain architectural firms and individual architects to being receptive. It is important to review characteristic problems of attitude, communication, and economic pressure which, as referred to earlier, make it easier or (more often) difficult to assimilate new technological input. We do this here under the heading of Design Process and Design Management.

5.2.1. Design Process - Supportive characteristics of the firm

The integration of seismic principals into practice is not to be accomplished merely by prescribing design standards. Some aspects of seismic design, like energy design, are resolved through composition which cannot be codified. Therefore to thoroughly integrate the range of seismic safety measures, some aspects of seismic design which can not be merely inserted but must evolve with the design, must become completely familiar and routine within the total design process. It is not that difficult to train an architect to do that. What is difficult is to get all architects to do that. We can't expect all architects to do research to learn how to handle seismic problems; but we should try to educate all archtiects in the techniques devised by the few architects who have done the research.

The utilization process is not only dependent on how well we reach and teach the practicing professional, but also on how predisposed he is to hearing and learning. Our own research has indicated that firms predisposed to learning about seismic design could easily assimilate research findings. But our study also showed that many firms were not interested in learning. This should be briefly discussed.

One can assess whether a given architectural firm is likely to assimilate and utilize research findings by observing certain characteristics of the firm, and identifying basic problems firms have in utilizing research. For the purpose of this disucssion we have named three characteristics of a firm: Goal Orientation, Operational Behavior and Research Competence, and listed under each, three or four issues which relate the characteristic of the firm to the problem of research utilization. This framework is set forth below.

A. GOAL ORIENTATION	B. OPERATIONAL. FACTORS	C. RESEARCH COMPETENCE
1. Translatability of non-spatial research material to spacial concepts	1. Coincidence of research introduction with immediate design problems	1. Difficulty in data gathering and structuring information
2. Predisposition of principals to visual information	2. Level in firm's hierarchy at which new input enters	2. Methodology for discerning among research findings, ie, assumptions of validity
3. Reconciliation between research and design processes	3. Opportunity costs of research assimilation	3. Methodology for post-construction evaluation. Transferability.
4. Potential impact of research on firms architectural images	4. Economic viability of non-mandated technological shifts	

We want to elaborate on each point:

A1. Dissemination of research is a substantial task in itself, involving the packaging of research findings so that they can be assimilated by an intended audience. The package cannot be too technical, too academic, or on the other hand, oversimplified. It is time consuming and possibly tedious work. Consequently researchers are usually not interested in the job. Much of the research which has been done in the past dealt with the response of soils, foundations, whole frames, etc. to seismic loads; and the presentation format was not very translatable into spatial concepts. We believe that the recent research being done by architects on reducing the vulnerability of historical buildings, and restoring older buildings in seismic regions, by their nature are easier for architects to assimilate because they deal more directly with existing spaces. The information stemming from seismic research related to those problems which an architect can address, must be imageable. Verbal material must evoke a visual concept. Indeed information on seismic principles in building must be packaged in a variety of forms, all of which encourage utilization.

A2. New knowledge is not used merely as a result of its being available in a useable form. The target audience must have characteristics or strong demands which make them reach out to absorb the new knowledge. Regarding architects, one has to first understand that they prefer visual information. They are accustomed to verbal expression which tends to be subjective and even metaphoric. The value system and modes of learning in non-architect researchers are in conflict with practitioners. The replicability aspect inherent in the explanation of research is not applicable to the architects search for aesthetic concepts. The typical architect will view research as meaningful only if it impacts building form in terms of images, because he usually uses images as the basis for conjecture about building form; and his images are personal subjective knowledge. It is only if the architect and let us say the principals of the firm believe that research is actually part of architectural design, that they and the firm will be likely to take the initiative in seeking out new information and thereby enhancing their expertise.

A3. The image oriented design process is not conducive to creating building form in response to the typical products of research. To be useable for design, research findings must be compatable with the cognitive process of design, and appropriate to several levels of the design process. Architects looking at behavioral research have noted that for non-spatial principals to be conveyed, the presentation should employ several graphic and verbal modes in redundant patterns.

A4. Social science research affects design only if it can produce information that can have a significant impact on architect's images (this assumes a perceived positive impact). Likewise the implications of some seismic principals for building configuration are directly related to architectural images, so the perception of their possible impact must be positive.

B1. The architectural firm must be motivated to change existing modes of designing. As we have observed in our discussions, research is most often project related. Architects, like anyone, absorb unfamiliar ideas best when they have a reason to apply them to an already familiar context. They will use seismic principals when they see their utility in solving a seismic problem which clearly bears upon their own architectural criteria.

B2. An idea is good especially if it comes from the "boss." Use of seismic research can depend upon the users status in the firm. Principals in larger firms often spend their time with clients and may not be among the first to come across new information or be among the first to realize that a problem exists for which a research effort must be made. It helps if the principal decision makers are part of the planning team which discovers the need for research.

B3. What is the firm giving up if it takes time to do research? If trying out new principals can be deferred, should they be? Experiences in applying behavioral research show that well organized guidelines and case studies are viewed as cost-competitive with design methods that don't involve behavioral considerations. Does the research have secondary benefits beyond solving immediate design requirements?

B4. Over time, is there a measurable benefit to experimenting with emerging technology, in terms of production quality and attractiveness to potential clients?

C1. For some of the above points the questions is whether the firms personnel are predisposed to assimilating new findings; in other points, the question is whether the firm itself would initiate research. Regarding the latter, the cost and difficulty in getting data and organizing it requires that there be personnel in the firm skilled in research techniques. Architects rarely have that training in their background.

C2. The same lack of training is a serious impediment to discerning among available research reports those that have validity in themselves and for the problems at hand. Unstudied application of questionable findings could lead to serious design errors. In providing seismic information to architects, an explanation of the research methods may be important to the architect's ability to judge among different studies. The architects should at least be able to make a prediction about the protection offered by the seismic strategy they may employ.

C3. Finally, if the practitioners economics can allow for it, post-earthquake studies of buildings employing non-structural mitigation strategies should be made. Currently such post-event evaluations are being funded by the government and conducted by firms not involved in the original design and in situations where generally the damage can no longer be observed first hand.

In summary we can place firms in three categories. Some will be willing to accept new information on Eastern seismicity if it is disseminated to them. Others, if made aware of eastern seismicity, will initiate contact with persons or organizations which can increase their knowledge. Still others, will initiate original research themselves. In order to seek or successfully adopt seismic principles, the firm has to be able to make a positive response or effect a positive resolution with respect to several of the issues outlined above. And in regard to certain of those issues, such as the translatability of research to spatial concepts, the disseminated material itself must be made conducive to assimilation.

5.2.2. Design Management--Interfaces with engineers, code administrators, and clients

Our objective is to examine how seizmic principles can be incorporated into preliminary design, in other words, how we may amend the list of design criteria to include seismic reinforcement, and inasmuch as professional design involves tangible projects and actual clients, how the issue of seismic design may be introduced and managed in professional practice.

We can attest from our experience with the three architectural firms during our interactive sessions with them, that the heuristic process of design is itself certainly not strained by the addition of these criteria. In our poll of firms, where aesthetics were not of any profound concern we did not find seismic criteria perceived as problematic in that regard. In firms where a great deal of attention is paid to aesthetics, it is likely that good designers may actually create architectural significance out of constraints upon building geometry and the placement of resisting elements. In any case, in the eastern U.S. at least, the maximum seismic loads expected are not of significant magnitude to warrant concern that the freedom to devise the building parti will be strongly influenced by seismic regulation. Indeed no aspect of the design process as such is likely to be perplexed much less altered by the inclusion of seismic design.

The reason to examine the design process here is rather to focus on the aspects of planning and production. Where the architectural end is intended to include the built product, the force driving activities toward that end is the economic value of the building to its owners. Therefore, in actual building production it is obvious that the architect works multilaterally with other actors and has to assess their interests and react to them, providing his services while attempting to assert his professional values as well. Inasmuch as architectural practice (once building production is associated with it) becomes an economic service, business pragmatism cannot be ignored. Time and money are involved and these factors do constrain or affect what the architect might otherwise be at liberty to produce. The architect is obliged to work with his client, possibly with users, with his consultants, with contractors, etc.

Through this process the pragmatic architect will follow a path of minimal resistance, intellectually as well as economically. He wants to conclude each interaction with other actors with as little alteration from his expected course as possible. Therefore for most architects, innovative behavior is adopted only if it is not intellectually forbidding (it should be appealing) and if he knows that he will encounter minimal resistance. But he tends to anticipate resistance where innovation upsets standard practice, and he tends to avoid it even if the resistance could be easily overcome. Let us examine where resistance might actually occur in practice. Let us assume that resistance to change will be evident in the interaction between the architect and other actors in the building process.

INTERACTION

The architect in practice interacts professionally with several other actors in the building production process. It is important to consider how the issue of seismic design may be managed during these interactions.

We have three kinds of interaction which we are considering for the architect, in the course of his building project. These are with his consulting engineers, with his client, and with code administrators. Our concern is to promote innovation--the adoption of seismic resistant design--at each appropriate interaction. (Of course there is more than one instance of an interaction occurring between actors during the design process.) In order to promote innovation during some interaction, we should analyze what happens there. We can do this by answering the following questions. What respective Authority and Responsibilities are exercised by each actor during an interaction? What factors, beyond those being central to the decision-making occurring during an interaction, nonetheless impose a constraint upon the actors?

The responsibilities and authority, which establishes the conduct between two actors during their interaction in pursuit of a project, we refer to as the protocol. Let us examine the three types of interaction identified. To be concise we include only the protocol wherein we might witness the promotion of seismic design (as an innovation in eastern U.S. practice). For the architect and the engineer we have their separate postures described below in brief lists.

ARCHITECT AND ENGINEER

Responsibilities and Authority

Architect

- To convey architectural concept.
- To respond to structural imperatives related to specific architectural designs.
- To coordinate structural and other building systems.
- To reject particular systems or detailing.

Engineer

- To provide structural information.
- To design for safety and efficiency in structure.
- To inform of hazards imposed by architectural or site condition.
- To integrate structural with architectural design.
- To evaluate structural viability of architectural solutions.

Exogenous Factors

Codes, client input, site conditions, availability of materials, technological limits.

In similar fashion we can outline the protocol for the interaction between the architect and the code official and between the architect and his client.

ARCHITECT AND CODE OFFICIAL

Responsibilities and Authority

Architect

- To explain design performance vis a vis code requirements.
- To suggest design changes.
- May appeal or accept rulings.

Code Official

- To interpret code in specific applications.
- To allow for alternative means of providing safety standards.
- To reject design, with explanation.

Exogenous Factors

Contractors, manufacturers supporting or opposing liberal interpretations. Movements in local industry to strengthen or change codes. Local government moving to strengthen or change codes.

ARCHITECT AND CLIENT

Responsibilities and Authority

Architect

- To interview client/users
- To provide or obtain technical information
- To exercise aesthetic and technical judgment
- To control costs
- To accept allowable inputs from client
- To give design direction

Client

- To provide information in timely fashion
- To authorize changes when necessary
- To request changes
- To suggest design direction
- To approve or disapprove of design

Exogenous Factors

User input (if independent from client/owner); community residents, local government; contractors; unions; prices; availability of materials.

It is within the bounds of established professional protocol that innovation can be introduced, promoted, resisted, accepted, or rejected. Thus it is possible to make extraordinary decisions in the course of following protocol in an interaction, but we should note that the responsibilities and authority, and the types of decisions to be made tend not to change, except over very many years. For practical purposes these are considered givens.

ARCHITECT AND ENGINEER

Now to consider what we might reasonably expect to transpire between actors, we examine first the interaction with the engineer.

The engineer will readily familiarize him/herself with the structural engineering prescriptions for seismic design. He must then coordinate with the architect's plans to resolve potential conflicts resulting from the interaction of structural and non-structural components. Therefore, the communication with the architect, especially during preliminary design may have to be enhanced somewhat beyond what now occurs in many building projects.

In a few specific areas where historic records indicate the possibility of strong earthquakes--the St. Lawrence River Valley, southern Missouri,, western Tennessee and Kentucky, Boston, and Charleston, S.C.--the architect and engineer together must consider the parameters to be put on building configuration and massing. In our approach it may be the architect who first imposes these parameters, thus, certainly making the engineer's work easier.

Aside from these localities, in most of the Eastern United States seismicity is far less than that in the West, and, therefore, structural reinforcement in new construction should add little expense or complexity to framing systems. Moreover, except for extremely vulnerable building configurations, the overall architectural concept would not be expected to pose serious potential risks. Then the mutual area of consideration for the architect and engineer, will be the building contents and their attachment to structure; and the materials and construction of the building envelope. But again, given Eastern seismicity, the amount of extra material and the added complexity in detailing for attached building contents should prove minimal and not add significantly to costs in most cases. Therefore, within the interaction between architect and engineer there should not be conflicting interests preventing the integration of seismic design, once communication between the two on this subject is established.

ARCHITECT AND CODE ADMINISTRATORS

In localities where there are no building code provisions for non-structural components, but where there is a considerable probability of moderate earthquakes, the architect, desireous of including seismic reinforcement should not meet resistance from code officials per se, because his object is to enhance building safety; and as long as the design does not conflict with other code-mandated safety provisions, the code official being neutrally disposed, should accept it.

The problem will be to have the municipal codes amended to include seismic provisions, and to enforce these by consciencious review of drawings and field inspections. To codify seismic provisions architects will have to, in effect, form a coalition with local structural engineers, contractors, and products representatives. The key information they will require is the best information available concerning seismicity in their area. But they must also determine the design reinforcement levels appropriate for their area. Appropriateness will be a function of the maximum event recorded, the annual probability of more moderate events, the predicted losses which would result from such events, and the design strategies which could mitigate against such losses. Appropriate design response will also be a function of economics; and for this perhaps the aid of insurance firms and economic consultants will be necessary. As a technical reference, appropriate seismic design strategies implemented on the west coast may be transferred to the East. Supported by this information the "coalition" must then convince the local mortgage lenders and legislators that there is a potential seismic problem that a technical solution exists, and that in implementing this solution the promotion of the general welfare outweighs the perceived disbenefit to building owners. Indeed the building producer who expects economic benefits from his building should be expected to prevent building conditions which might impose social costs and externalities upon the public should an earthquake occur. This rationale follows that justifying other safety regulations already established. Of course the practical issue will not be the constitutionality of such regulations; it will be to determine what financial burden may actually be put upon building producers and whether this will be a disincentive to do capital projects in that location. If a city imposes such regulations while suburban townships don't, city locations could lose their competitive position. But the state should mandate equivalent codes in all localities deemed to have equivalent seismicity. If, let's say, western Tennessee must mandate stricter codes while Mississippi or Louisiana does not have to, the former state could be at a disadvantage, however, reflecting upon the experience in the western U.S., other factors for location preference should outweigh seismicity. And, therefore, the possible adverse affect on location choice should not be an argument against seismic regulation.

ARCHITECT AND CLIENT

Returning to the point where seismic regulations are not in effect, the architect, perhaps with the aid of other process participants, must persuade his client of the utility to him of seismic design. Here the architect mwith the cognitive process of design, and appropriate have much evidence to substantiate the claim that the added costs for seismic reinforcement are worthwhile. We do not have sufficient data to predict, for a given locality, what damage may be inflicted by earthquakes of various magnitudes, and we do not know how much reinforcement is just sufficient to avoid that damage.

However, the deliberation would proceed beyond that. When the appropriate amount of investment is estimated it would have to be annualized so that the hpothetical yearly cost could be compared to the stochastically derived annualized expected loss. For example, if seismic reinforcement were to amount to a $16,000 additional cost to a total construction cost of $2,000,000, the annual debt service constant on $16,000 for 40 years at 13% interest would be approximately 16,000 x .13368 = $2,139. Suppose the Central Damage Ratio (CDR) for the building's location is estimated to be .25 for strong earthquakes. CDR is the ratio of losses due to the event to the replacement cost of the building. Suppose further that the annual probability of earthquakes of that magnitude is .007 (143 year return period). The expected annual loss (EAL) would then be the product of the CDR and the EAL or .007 x .25 x 2,000,000 = $3,500. Here the reinforcement represents a savings if one holds all three factors (CDR, EAL and replacement cost) constant. Or the present value of the loss in year t could be compared to the sum of the present values of the stream of payments of t years. Suppose that the $2,000,000 structure is damaged by an earthquake 30 years after its completion. Using 6% as the mean inflation rate for the 30 year period, the building replacement cost would be $11,487,000. If the CDR is accurate the loss might be 2.87 million. The present value of that loss would be $484,000. The sums paid to avert that loss would have been 2139 x 30 = $642,000. However, the sum of the present values of that stream would be $29,111. So a long term investment--the present value of which would be a bout $30,000--would avert a loss, the present value of which would be about $490,000. The weakness of such a procedure is the sparse data upon which expected damage and annual loss is predicted, and the virtually impossible task of predicting the discount rates.

The owner may decide that he would rather pay small insurance premiums than initial added construction costs amortized with interest. Underwriters in earthquake-prone areas do offer earthquake coverage. The rates for commercial buildings are low. For example, in Charleston, S.C. for a building with a reinforced concrete frame, the 1979 insurance rate was $0.131 per $1000 of coverage and $0.357 per $1000 of insured contents. Deductibles are from a minimum of 2% to a maximum of 40%. Building and contents rates are then reduced by 1% for each percent increase in the deductible percentage chosen in excess of 2%. Thus if the builder figured the replacement value of his building was $2,000,000-holding the dimension of time constant —and he took 5% ($100,000) as his deductible, his annual premium for the building would be $248.88. This reflects the low probability of the event and the fact that the risk to any individual building is being shared among a large pool of insured buildings. But this figure may or may not be lower than the annualized cost of an initial construction investment. On the other hand, one must also recognize that in earthquakes, damage losses are widespread thus aggregate costs could be great. Therefore, in order to protect the insurer, how much less than the annualized investment should premiums be?

For the owner, is it better to pay the added construction cost to avoid damage and in addition, take the maximum deductible (believing total damage would be slight) and pay a very small premium?

Because the economics of seismic reinforcement will be an indefinite proposition at best, the architect may be able to motivate his client to pay for seismic reinforcement nonetheless. If it turns out that a given predicted level of seismic load requires reinforcement which only marginally increases the initial construction cost, the architect could appeal to the moral imperative of providing safety for the building's inhabitants. If life loss is improbable, personal injury is not -- once building contents are dislodged, dislocated, overturned, etc. An insurer should also raise premiums in recognition of the fact that fire potential is great in post-earthquake situations. That possibility also warrants an investment to avoid it. Finally the owner may be motivated by the opportunity to avoid disruption in the building's operation -- perhaps a business or industrial function -- after the more moderate (and more likely) event.

The underlying problem which will impede innovative behavior on the part of each actor during interaction will be insufficient motivation in the face of uncertainty as to the benefits of seismic design. The reluctance to overcome resistance has in part to do with confronting the other actors and dealing with them on a motivational level. This means not only infusing them with the motivation to be innovative but to understand their motivations in resisting change.

In viewing the protocol during the interaction between actors one must respect the idea that actions or intent may not always be rationally linked to motivation.

As a practical matter we should not assume that architects, clients, and code officials always act rationally in considering extraordinary design issues. And since we are concerned with practice we recognize that tacit motives will exist behind both enthusiasm and reluctance in promoting seismic design. However, the dominant apparent factors in decision-making will be the improbability of eastern seismic hazard, and the uncertainty over the utility of expending resources to counter potential seismic hazard.

Therefore, in each interface wherein the agenda may contain the issue of seismic design, the architect should be capable of speaking to the probability of eastern earthquake events, and the level of architectural response which could be optimal from a damage and disruption control point of view, and from the client's economic point of view. Then he should be able to understand the project context under which decisions will be made so that he can surmise the motivation behind the decisions expected of his client, the engineer and the code official. Of these, the client is the actor who must be persuaded. Here the architect may not have much evidence to substantiate the claim that the added costs for seismically reinforced buildings are worthwhile.

5.2.3. Checklist for Seismic Design

During the interactive sessions and in the survey questionnaire, the idea of a checklist was presented. A checklist, of course, is not an original concept. Moreover checklists are more likely to be used when a design process is somewhat prescriptive, rational, lenthy, complex and likely to be often repeated. Other checklists for less complex processes are usually meant for the uninitiated to follow until the task becomes "second nature" to them. A seismic checklist probably belongs to this latter classification, yet at this point in time there are significant numbers of architects who are in fact uninitiated in seismic design.

The checklist presented here is only one example whose elements are basic to seismic design considerations. Another well worked-out example is the design team checklists in Seismic Design for Police and Fire Stations which, while project specific, are much more thorough, and follow detail steps in the design process more closely. The checklist presented here is intended to act as a very basic guide through preliminary design primarily to make the architect aware of the inter-relationship of the parts of the design to the whole in its seismic resistance. It is placed as a section at this point because it is clearly related to the discussions concerning design process.

The example checklist begins with the relationship of site and soil conditions and building configurations to factors mitigating seismic force. These are considered fundamental in planning a project that is optimally resistant throughout. The checklist then continues through a basic list of non-structural components (and their attachments)that are most vulnerable to seismic hazard and that pose possible threats to the safety of occupants.

The intent of the checklist is to bring a readily accessible tool to the designer that will allow for the co-ordination of the parts with the whole during the design process. Its aim is not to instruct the designer in how to design the pieces (since some design calls for engineering analysis and code compliance) but to quickly bring an awareness of the parts that must be considered in the preliminary design for the optimal resistance of the final design. This can enable the designer to work through the preliminary design without missing the consideration of a part that could require a re-working of the preliminary design if it is bypassed in the early stage of the design process.

Example Checklist Seismic Design

I. Determine these issues if necessary:

- A. What possible hazard to life and building can be expected in this locality?
    - 1. Damage to structural system
    - 2. Damage to non-structural components
- B. What are the seismic code requirements?
- C. Is the client willing to support an effort beyond the code requirements?
- D. What additional expense can be expected for more design time, building time. (Answer may have to be reworked several times during design process.)

II. Analyze the Site

- A. Observe site contours
- B. If possible select a part of the site is most resistant to seismic motion, the most regular in contour
- C. Determine the soil type of the site
- D. Note whether the soil will add or detract from seismic resistance
- E. Determine what adjacencies and accesses are most beneficial to life safety and seismic resistance of the structures.
  For proposed alternative conceptual designs:

1. Will exits be blocked by damaged buildings?
2. Will buildings impact upon one another under seismic loads?
3. Will emergency personnel have access to all parts of the project?

III. Building Configuration

A. A regular (symetric) building is more resistant to seismic forces than an irregular building. Do the alternative designs tend to be regular or irregular in plan?
B. If the program/site favors an irregular geometry, consider the design of particular sections to act as independent regular pieces.
C. The more regular the vertical configuration, the more seismically resistant the design. Do the alternative designs tend to be regular or irregular in section?
D. If extreme height/width ratios, offsets, or "soft" storeys are highly preferred, design changes in frame geometry with concentration and distribution of seismic loads in mind.

IV. Structural System: In addition to the effects of gravity loads from structural members, construction, live and snow loads, the building frame must also resist seismic loads.

A. What kind of structural system can be optimal for the program and seismic resistance?
B. What are the economies of the alternative systems?
C. What are the Code requirements for each system?
D. What are the risks to the components dictated by the structural system?
E. What, if any, are the code requirements for the structural material?
F. Can an optimal combination of economy and resistance be achieved in the selection of the structural system?
G. Is the client willing to trade off his "image" of the building for a more resistant structural system?

V. Architectural, Mechanical and Electrical components and Systems

Analyze the occupancy load use need for operational continuity and the interrelationship of the structural, architectural, and mechanical systems. Components must be connected or attached so that seismic forces are transferred to the building. They must not impair life safety by falling, detaching, blocking egress, or interrupting vital systems.

A. Curtain/screen/partition walls: consider the most resistant material and connection.
B. Hung ceilings: if necessary, consider resistance of material and connections.
C. Water, gas, electric lines: consider placement, connections for resistance; consider automatic shut-off if possible.
D. Light fixtures: whether recessed, surface-mounted, or pendant-hung, should be evaluated for resistance to seismic lateral force.
E. Stairs provide emergency exits during earthquakes. These should be designed for resistace to lateral force and attached to the structure in a manner that will not make one element of the structure stiffer than other members.
F. Elevator enclosure walls should be stiffened for seismic resistance. Guide anchorage, motor generator equipment and support beams should be resistant to lateral force.
G. Paths of egress/exit should remain free of falling debris after seismic activity for the safety of occupants and access by emergency personnel.
H. Marques and canopies should have anchorages resistant to seismic force to prevent hazard to occupants and to prevent blockage of exits.
I. Fire escapes should be designed for resistance to seismic force.
J. Mechanical-electrical equipment may be supported by structural frames. Equipment must be evaluated for stability when its overturning could be hazardous to life safety. Stability can be given by the use of resilient mounting devices, restraining devices, elastic restraining devices.
K. Chimneys (which often fail due to bending above the roof or point of lateral support) should have ties which meet code requirements and may have reinforcement added to increase resistace.
L. Water storage tanks must be evaluated for bearing capacity from lateral-vertical loading. Framing and connections should be designed for seismic resistance.
M. Appendages and veneers and their anchorage should be designed for their resistance to seismic force and location as a possible hazard to life safety.
N. Parapets should be analyzed for their resistance to lateral force and possible hazard to life safety.

5.3. REVIEW OF PRESENT MAJOR SEISMIC CODES

One premise of a strategic dissemination effort is that Eastern architects today have little incentive through building codes to provide better seismic design. The codes which are followed in most regions may be up to state-of-the-art in terms of structural design but not architectural design. If seismic design is to be more seriously considered at all in the East, part of the impetus must be code provisions which better address architectural decisions. While it is true that much of the seismic resistance probably required can be achieved within the design of the structural frame, for particular areas of the East where stronger earthquakes could occur, the design of non-structural components and the attachment of contents is not discussed adequately in the codes.

Meeting code requirements for seismic design and using existing seismic building codes as a learning tool for seismic design is currently very difficult because of the manner in which the various seismic codes are presented.

After researching the content and language of the ATC, SEAOC, UBC and MSBC, the comparison indicates that none can independently give the designer enough information to deal comprehensively and efficiently with seismic design. The problem results from the difference in emphasis in the existing codes. In all cases, very few requirements are prescriptive, but the most elemental problem is that some codes deal primarily with non-structural architectural components and others with structural components. While all emphasize the importance of integrating non-structural and structural decisions in the preliminary design process, no single code contains enough information about both types of components to facilitate the design process. Accessing code material requires referencing several different codes which interrupts the process of seeing seismic design as a problem of integrating the parts of the design; and allows for error in overlooking information.

Both the ATC and the SEAOC have introductory sections that present seismic design issues critical to preliminary design. They both discuss site, plan, and building configuration and the effects of seismic activity on different configurations. But after this introduction, these codes differ significantly in content. The ATC has a chapter dealing primarily with non-structural architectural components (see Appendix C for outline) while the SEAOC deals primarily with structural components. The UBC and MSB offer much less seismic design than the ATC and SEAOC and are not adequate for comprehensive seismic design. The language of the ATC (being only a tentative model) presents most of the material as choices (that greatly affect life safety and building durability) that "may" rather than "must" be followed, while the SEAOC presents the material in terms of structural choices that "must" follow from given engineering equations. There is very little crossover between the two.

In addition to the lack of integration of non-structural and structural code requirements into one code, the lack of specific information regarding the performance of non-structural elements causes the ATC to be very vague in both specifying requirements for seismic design and giving the designer information on the choices available. This leaves the designer and client generally in the position of deciding the extent of implementing seismic design principles in the work and does nothing to generate new design ideas because critical parameters for design are unknown.

Based on these findings, the integration of seismic design principles into the design process could be greatly facilitated by writing a new code that incorporates requirements for both non-structural and structural components in one code which the ATC has attempted but not succeeded in doing. The use of these requirements in providing for life safety and building durability could then be made much more helpful by introducing more parameters for design which would be the result of in-depth investigation of the performance of components during seismic activity. The outline and commentary on specific code provisions are placed in Appendix C as a reference.

5.4. THE ADOPTION OF CODES

The opening statements of this report suggested that while technical knowledge in seismic hazard mitigation was substantial and increasing, assimilation and utilization particularly in the East was not far advanced. This appears true even though organizations already exist which disseminate hazard mitigation information. To paraphrase their March 1981 newsletter, the Academy for Contemporary Problems established a Natural Disaster Recovery and Mitigation Resource Referral Service in September 1980. The service "is part of a project to improve the dissemination of research results..." Its primary purpose is to disseminate pertinent and practical information on mitigation to state and local public officials. The message to the officials is that if the local government has recognized (or experienced) a natural hazard, the Academy has a library containing information and case studies describing prevention and management procedures. However, as our research experience has shown, we cannot assume the current perception of eastern seismic hazard will prompt officials to contact the Academy in regard to earthquakes. Much less can we expect local officials to initiate a process to adopt better codes, to mitigate against earthquake damage.

5.4.1. Coalition of architects, engineers, contractors, etc.

If we take the proposition that architects should use their initiative to promote integration , and follow that with the proposition that architects will find it difficult to commit their clients to mitigation techniques unless these are required by building codes, then the third step in the integration process is the campaign to draft and adopt practical non-structural provisions in local codes. Since most municipalities follow the BOCA or UBC standards, perhaps these models ought to stress the need for local bodies to determine the level of and means to provide acceptable seismic safety. However, the primary effort would still be made at the local level, where an "acceptable" level of mitigation would have to be defined and implemented.

Whether based locally, regionally, or nationally, there must form a coalition of architects, engineers, economists, and contractors to pursue the ultimate adoption of improved codes. Such a team would have two tasks in regard to each specific locality or region in which it worked: first, to assemble the knowledge base for a comprehensive presentation of seismic issues relavant to that geopolitical unit, and second to initiate and pursue with the local governmental body, negotiations in which these issues are discussed and evaluated.

For each geopolitical unit, the knowledge to be presented would include:

1. The historical seismicity of the area and its geological and seismic relation to major historic epicenters in the East.
2. The earthquake forces which could originate in or travel to an area and descriptions of damage states that could result.

3. The translation of those damage states into life loss and dollar amounts in property damage.
4. Possible secondary short-term economic effects.
5. The annual probability of disruptive occurances.
6. The economic utility of lowering the risk.
7. The moral and social arguments to ensure some level of safety.

The team would also have to explain how existing codes may be inadequate and suggest the contents and organization of new provisions which would be addressed to architects and contractors as well as structural engineers.

5.4.2. Negotiations with state and local legisltors

With this knowledge developed to the best extent possible and with the team fully prepared to present it, the local governmental officials should be engaged. The points to make in the negotiations would be:

1. The threat to public safety and the general welfare
2. The availability of a viable technology
3. The existance of model codes
4. As best as can be determined, the financial incentives in implementing mitigation measures
5. How to finance the cost of administrative action

The thrust of the coalition's argument would be that given the geological condition of the Eastern U.S. with respect to the attenuation of shock, and given the magnitude of historical seismic events in the east, major urban centers considered co-regional with the historic epicenters should consider themselves in eventual jeopardy. Further, since these urban centers and their inhabitants are not likely to disappear within the forseeable future the local government must make the operational assumption that an earthquake will occur during the lifetime of all new structures and existing structures which by virtue of their market or historic value have an extended lifetime.

Given the magnitude of historic seismic events, and evidence of the intensities produced over the felt radius from their epicenters, a prediction of expected seismic force should be made for the purpose of establishing the design seismic loads.

Therefore structural and non-structural provisions which can resist such loads should be enacted. If high intensity shocks are to be expected as a matter of policiy the target level of safety is to protect against collapses and lifeloss. If moderate shocks are to be expected, major damage should be prevented, if minor shocks are expected, the community should either protect itself against minor disruptions or accept the costs of insurance coverage.

5.4.3. Local public approvals process

Such a presentation, of course, would not be sufficient to effect change. To achieve a local approval there would also have to be a campaign for community support. There would have to be affidavits from technical experts, insurers, and mortgage lenders. There would have to be letters of support from profesional organizations, trade associations, agency heads and legislators.

The point of the campaign would be to earn the support of departmental directors, council persons, and mayors or city managers. As a practical matter, any legislation which would amend local codes would require the prior support of senior governmental executives in order to give the draft legislation any weight. The amendments themselves should be written, with the coalitions as consultant, by staff of the local building department, or county health department.

Elected officials, code administrators and department heads will weigh such legislation against the possible impact on property owners and developers. As stated above, the adoption of a code following the ATC tentative provisions would not seem to indicate significant increases in building cost, and as reported, the cost of housing production in most eastern regions should not be severly impacted. Nontheless, the implications of adopting such seismic legislation would have to be communicated to the interested private sector. Therefore community meetings or public hearings would probably be part of the approval process.

Thus the coalition's two-fold task would be to take the initiative in disseminating pertinent knowledge of the seismic hazard and mitigation techniques in a locality, to educate the public and private sectors in order to dissipate concerns about the economic and political liabilities of new seismic codes and to work with local officials in guiding the local approvals process which would result in the adoption of new local seismic ordinances.