PRODUCT 3 - Nonstructural Performance Products

These products will form an important reference component of the PBSD guidelines. They will include information similar to that developed in the Structural Performance Products, but relating to nonstructural building components. They will also include the following concentrations:

- *Prediction of the demands on nonstructural components and the evaluation of their performance under these demands.*

  Just as forces on a structure are developed due to ground shaking and are affected by the interaction between the soil and the structure, nonstructural component demands are developed due to the building shaking and are affected by the interaction between the structure and the components. It will be necessary to study and develop methods by which these demands can be predicted. It will also be important to develop techniques for evaluating the performance of the components under these demands.

- *Testing and certification programs to bring uniformity to the design of manufactured components.*

  More so than buildings, modeling of nonstructural performance is difficult at best and needs to be supplemented with testing. The testing program will have to be broad enough to account for the placement of equipment and contents in different areas within various building types. It will also need to allow certification of equipment and contents bracing for an expected performance objective.

- *Post-earthquake data acquisition and analysis.*

  A detailed plan is needed for acquiring and analyzing performance data from future earthquakes. The nature of this data needs to be defined. Following a major earthquake, the data will be processed and compared to the Guideline provisions. The Guidelines will be modified in future editions by using lessons learned from performance of nonstructural components. This program is considered optimal for the effective development of PBSD.

- *Evaluation of nonstructural components in existing buildings*

  In addition to developing procedures for the installation of nonstructural elements in new buildings, it will be important to devise methods for assessing and increasing the performance of components already installed within existing buildings.

The nonstructural performance products will be developed by a team of design

professionals, scientists, equipment manufacturers and researches expert in the behavior of nonstructural components. Testing agencies will be employed as part of the certification program. User groups will be brought in to develop goals and strategies and to assist in the verification process.

Successful development of the NPP will require outside funding of testing. A comprehensive program will cost millions of dollars and will be an ongoing effort. Funding identified herein must be augmented by research dollars provided by industries and manufacturers which have a stake in the performance of nonstructural systems.

Task 3.1 Identify initial parameters and current state of the art

Task 3.1.1 – Identify nonstructural components and their impacts on performance

Description:

The team will identify the various types of nonstructural components and systems that are vulnerable to loss. It will utilize existing efforts in this area. In addition to looking at individual components, a goal will be to understand how the components fit together into systems (i.e. pumps and fans are parts of a chiller system), and what the effects of damage to one component means to the system. Identifying weak links in systems is important. The team will then identify what systems are typically present in various building types, and what the weak links are when considering overall building performance.

Another focus of this task will be to identify the scope of the Nonstructural Performance Products. The team will determine the detail with which issues of design, installation and maintenance of nonstructural components will be evaluated.

Personnel: Design professionals, Material suppliers, Owners

Priority: Essential
Budget: $250,000
Duration: 2 years

Task 3.1.2 – Evaluate effectiveness of current nonstructural and contents installation standards and practice

Description:

With the list of components and systems from task 3.1.1, the team will identify information on performance in past earthquakes. It will catalogue and quantify performance of components and systems by themselves and in relation to overall building performance, in terms of capital and contents loss and down time. The team will compare the effectiveness of different designs of the same components. Issues which play the greatest role in performance will be prioritized (i.e. anchorage design vs. installation quality, equipment ruggedness, etc.). A goal will be to assess the current state of the art and identify gaps in existing knowledge.

Personnel: Design professionals, Material suppliers (Researchers, Owners)

Priority: Essential
Budget: $300,000
Duration: 2 years

Task 3.1.3 – Develop a research plan to advance the state-of-the art

Description:

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task with the Plan, considering public and private resources.

Personnel: Researchers, Design professionals, Material suppliers

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 3.2 – Develop analysis and design methodologies

Task 3.2.1 – Quantify nonstructural performance levels

Description:

Working with the performance definitions developed in the **SPP**, the team will quantify nonstructural performance levels using appropriate parameters (drift, damage, loss, business interruption, casualties, etc.).

The goal in this task is to set the performance parameters so that the evaluation and design methodologies developed in later tasks can be targeted to definitive numerical quantities.

Personnel: Design professionals, Researchers, Material suppliers (Government agencies)

Priority: Essential
Budget: $350,000
Duration: Throughout the project

Task 3.2.2 – Develop demand prediction methodologies

Description:

The team will develop processes to calculate the demands on nonstructural components based on their location within various building types. It will identify and describe in measurable terms the parameters that have the most important effects on these demands (height above grade, building stiffness, anchorage, etc.). The goal is to be able to extrapolate from the basic building acceleration, velocity and displacement characteristics, the effects on nonstructural components.

Personnel: Design professionals, Material suppliers, Researchers

Priority: Essential
Budget: $450,000
Duration: Throughout the project

Task 3.2.3 – Develop analytic methodologies for achieving performance levels

Description:

The team will fill in the gaps in existing knowledge identified in earlier tasks. Research will consist primarily of analytical efforts. The team will identify promising new techniques and devote research to making them applicable to the PBSD framework. A forum will be held, bringing together design professionals and manufacturers to discuss design and analysis methodologies.

Following this, a strong effort will be made to develop design and analysis methodologies, consistent with the efforts in the **SPP**.

A focus will be on developing modeling or other techniques to lend consistency to design and analysis. Modeling will account for the range of computer applications currently available and anticipated in the future. It will also account for the financial investments various design engineers are able to make in obtaining modeling technology.

Personnel: Design professionals, Researchers, Material suppliers (Government agencies)

Priority: Essential
Budget: $850,000
Duration: Throughout the project

Task 3.2.4 – Coordinate design and analysis methods with SPP

Description:

The team will compare the design and analysis methods of the **SPP** and **NPP** to ensure that they are compatible and that they lead to the same measures and prediction of performance. The team should check that the level of reliability is similar between the two and that structural and nonstructural performance measures can be combined to form overall performance goals for buildings. The team will also make a focused effort to describe the functions of the **SPP** and **NPP** in relation to the overall goal of PBSD and of the guidelines. A task will be to describe building behavior from both points of view in technical and financial terms and identify where structure and nonstructure overlap or come in conflict.

Personnel: Design professionals, Researchers, Material suppliers

Priority: Essential
Budget: $150,000
Duration: Throughout the project

Task 3.3 – Establish separately funded testing and data collection programs

Task 3.3.1 – Establish comprehensive testing and certification protocols

Description:

The team will catalogue all relevant testing information to date. It will identify gaps in this knowledge with respect to nonstructural component effects on building performance. Research programs will be developed and established to fill these gaps.

A distinction will be made between component "ruggedness:" the ability of the piece of equipment to stay together in a functional black box, and "anchorage:" the ability of the equipment to remain where it was installed.

The team will identify *sources of funding* for extensive testing. These sources will include equipment manufacturers, owners, insurers, government agencies, etc. This may include developing collaborative efforts between equipment buyers and equipment manufacturers, for example. The team will develop a consensus on the technical description of testing protocols. The team will develop a means of obtaining certification of tested equipment for various seismic regions, building types and usage, and locations within buildings. If financially feasible, some testing should be conducted within this task to calibrate certification parameters.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Optimal (does not include funds for extensive testing)
Budget: $1,000,000
Duration: 5 years

Task 3.3.2 – Establish a post-earthquake data collection and analysis program

Description:

The team will *establish* a program for collecting nonstructural performance information after an earthquake. This will be coordinated with the efforts in the **SPP**. Existing earthquake performance data will be reviewed for its usefulness and as appropriate will be assembled and catalogued into a database. The team will develop ways to distill and use this information and identify where gaps remain. A workshop will be held to identify the types of information that are the most valuable. The team will develop data collection forms, binders, instructions and databases in preparation for use. It will establish a methodology for creating and maintaining a team of inspectors and will hold seminars on a regular basis to train them. A focus will be to identify how the collected information will be used within the development and refinement of the PBSD Guidelines. The team will identify sources of funding for post-earthquake data collection, so that these groups may be approached in a timely fashion after a damaging event.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 3.3.3 – Establish a program for developing innovative nonstructural design

Description:

The team will *establish* a program for encouraging manufacturer's to develop innovative nonstructural designs that take advantage of the performance-based criteria developed within this project. The team will identify sources of funding to implement this program. Implementation will include offering incentives for use, marketing the program and tracking its success.

Personnel: Design professionals, Material suppliers, Owners, (Government agencies)

Priority: Optimal
Budget: $300,000 (includes only the establishment of the program framework)
Duration: 1 year

Task 3.4 – Develop documents and reports for use in PBSD Guidelines

Description:

This task will occur at milestones within the research plan developed in Task 3.1.3 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the **RMP** and **SPP** will occur to insure that information is presented in a consistent manner. The team will coordinate verification studies to be run on the analysis and design methodologies. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team of Task 3.1.3 to set out the goals for the next phase of research.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Essential
Budget: $500,000
Duration: Throughout the project

Challenges

- *Analysis and modeling*

  Developing modeling and analysis techniques for nonstructural systems will be a very challenging effort. The complexity of these systems may overwhelm the capacity of most office computer systems. Reliable methods for estimating the performance of these elements, however, is vital to reaching higher levels of overall building performance. As with the **SPP**, software engineers may need to be consulted and retained to develop programs which can model piping, equipment, ducts, and other elements which have the potential to cause significant loss.

- *Performance levels and damage states*

  Understanding a component's anchorage to the structure is only one half of the challenge of nonstructural systems. Being able to reliably estimate the "ruggedness" of the piece of equipment is also important. A major effort will be required of design professionals and equipment manufacturers to find ways to define equipment fragility and to test for and design ruggedness into equipment.

- *Administration*

  Peer review and plan check of equipment anchorage is a novel concept and will need acceptance from building officials. This will require a major effort to write provisions for their use and to educate and train them on the subject.

- *Education and Incentives, Cost*

  Full scale testing of equipment will prove to be a monumental and very expensive effort that will require funding from multiple sources. Convincing owners and manufacturers to pay for this testing will be a challenge.

  With the idea of certification of equipment will come issues of liability for performance. It will be difficult to convince manufacturers to warrant their equipment and contractors to be responsible for installation. Owners may be able to provide incentives to convince these stakeholders that certification is in their best interests.

- *Data Acquisition*

  As with the **SPP**, similar challenges will be faced in obtaining useful information and maintaining the data collection program.

PRODUCT 4 – Risk Management Products

These products will provide financial information for the Stakeholders' Guide and the PBSD Guidelines. The goal will be to identify cost-benefit and other models by which PBSD can deliver the most benefit to the users. The products will have three main areas of focus:

- *Methodologies for quantifiably defining performance objectives in terms of expected loss, risk and stakeholder tolerance.*

  The work will utilize the efforts of the **SPP** and **NPP**. It will consider issues of damage costs, loss of operation, risk tolerance, etc., with the expectation of obtaining realistic design goals for stakeholders.

  Minimum performance objectives will be established, considering the broader social and economic drivers that affect planning, design and construction decisions. An effort will be made to consider the effects on building performance of elements outside the building envelope, such as infrastructure, utilities and other lifelines.

- *Identifying and minimizing uncertainties in the PBSD process.*

  A key to obtaining wide use of PBSD is developing more reliable and accurate analysis and design methodologies. Uncertainties, error and randomness must be related numerically through reliability measures to the methods developed in the **SPP** and **NPP**. Ways need to be found to minimize these sources of inaccuracy. Risk associated with building performance should be quantified in relation to other activities (such as fire, building maintenance, revenue, etc.). Methods for more accurately identifying risk and reaching acceptable risk levels need to be developed.

- *Developing cost/benefit and other financial analysis models.*

  The philosophy behind PBSD centers on being able to choose from a range of performance objectives, to reliably meet the financial goals and risk tolerance of the stakeholders. Techniques for determining and optimizing cost-benefit ratios and other financial representations of construction are important to achieving implementation. Non-engineering groups need to have a complete understanding of PBSD and its benefits. It is also important for design professionals to understand the concepts of risk management.

  An effort will be made to emphasize the broader global planning opportunities that PBSD presents for reducing economic and social losses to communities, regions and states. The RMP should provide the basis for economic and social rating systems for buildings.

Task 4.1 – Quantify performance objectives

Task 4.1.1 – Match performance levels with hazards to develop performance objectives

Description:

The team will take the performance levels and hazards developed in the **SPP**, **NPP** and **RMP** and combine them in order to understand expected performance over measurable and meaningful timespans (building life, a typical mortgage, careers, etc.). The team will select performance objectives for various building types, occupancies, construction eras, etc, and develop performance expectations for these buildings over their lifetimes. A focus will be to define the goals that owners and design professionals can utilize for capital planning and design purposes.

Personnel: Design professionals, Researchers, Owners, Financial interests

Priority: Essential
Budget: $350,000
Duration: 1 year

Task 4.1.2 – Develop minimum performance objectives considering social and economic drivers

Description:

The team will identify the various social and economic drivers that affect decisions about designing to a particular performance objective. The team will evaluate issues of cost, safety, construction duration, building function, etc. and will consider how each affect the various stakeholders. The goal will be to establish a set of minimum performance goals that protect the interests of all the parties involved in the building environment and provide for the protection of the public welfare. The team will discuss minimum performance standards for external elements that affect building performance, such as infrastructure, utilities and lifelines.

Personnel: Design professionals, Researchers, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $350,000
Duration: 1 year

Task 4.1.3 – Quantify performance in terms of loss and risk

Description:

The team will develop a set of acceptable risk levels quantified in terms of loss (capital, lives, down time, etc.), considering building type, usage, age or other parameters. It will link performance objectives with these acceptable risk levels. Risk will be defined in agreed upon terminology with varying levels of reliability. The team will define a set of maximum loss thresholds for each performance objective. The Stakeholders' groups will be tapped to provide input. A methodology will be developed to convert loss into financial terminology.

Personnel: Design professionals, Researchers, Financial interests, Owners, (Other stakeholders)

Priority: Essential
Budget: $400,000
Duration: 4 years

Task 4.2 – Develop financial modeling tools

Task 4.2.1 – Develop a research plan to advance current risk evaluation methods

Description:

The team will gather existing information on risk analysis and financial modeling methods and identify gaps in current knowledge. A strong effort will be made to use available information so that future research funding can be most efficiently spent. The current state of the art should not define the scope of this project or limit the direction research might take, but rather allow researchers to avoid unnecessary duplication of effort.

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task with the Plan, considering public and private resources.

Personnel: Financial interests, Researchers (Design professionals, Owners)

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 4.2.2 – Develop financial life cycle and damage cost models

Description:

The team will use the structural and nonstructural performance acceptability criteria in the **SPP** and **NPP** to calculate life-cycle and annualized losses relative to each performance objective. Combinations of performance objectives will be evaluated to help users minimize overall life-cycle and damage costs. The team will extrapolate costs for individual buildings, to look at classes of buildings and regional implications for cities, states and the federal government. Costs of repair, business interruption and casualties will also be developed. The goal is to quantify expected losses in a manner that stakeholders can use in long term capital planning. Example applications will be developed. The information developed within this and other tasks should also form the basis for building rating systems, which will integrate structural and nonstructural quality with financial and social performance measures.

Personnel: Researchers, Financial interests, Owners, Government agencies

Priority: Essential
Budget: $650,000
Duration: Throughout the project

Task 4.2.3 – Define cost-benefit relationships for improving performance

Description:

The team will develop tools by which the costs of different retrofit measures (existing buildings) or design criteria (new buildings) can be weighed against the expected reduction in loss and life-cycle costs. A comparison of individual components will be necessary (such as bolting down a wood building vs. bracing sprinkler pipes). The combination of components into design systems will also be considered. Cost-benefit relationships need to be developed in ways that can be calculated by design professionals and are meaningful to owners and financial interests. Cost-benefit ratios should be applicable to individual buildings or portfolios. The goal should be to provide owners with methods for performing economic loss management of their facilities. Efforts will be made to look at how this can be expanded to a regional basis.

Personnel: Design professionals, Researchers, Financial interests, Owners, Government agencies

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.2.4 – Calibrate financial models

Description:

The team will develop a series of example applications and will calibrate and compare them against current design techniques. Calibration parameters will include cost, duration, responsibility, liability, etc. The team will establish subgroups to carry out these studies, and will develop a standard reporting method by which the results can be quantitatively compared. If the team decides that the results diverge too significantly from existing methodologies, revisions to the procedures will be made, or a schedule for incremental application of the procedures will be developed. The team will develop methodologies to project costs and other data into the future. In this way, the information can function as a capital planning tool.

Personnel: Design professionals, Researchers, Financial interests

Priority: Essential
Budget: $500,000
Duration: Throughout the project

Task 4.2.5 – Develop cost-effective design strategies

Description:

With information from previous tasks the **SPP** and the **NPP**, the team will develop strategies to improve performance based on building class, usage, location, etc. The team will consider components and systems, identifying which individually and which combinations typically will provide the minimum expected life-cycle cost involving tradeoffs between the initial cost and potential damage costs. The information will be presented in a manner that is usable by engineers for design and will give owners and financial interests a numerical valuation of the money spent. The team may use information obtained in past earthquakes, coupled with testing research previously done.

Personnel: Design professionals, Researchers, Financial interests, Owners

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.3 – Educate users about risk management concepts

Description:

The team will establish a program to teach stakeholders about risk management. Representatives of lending agencies, insurance and financial institutions and researchers will write papers and create tools to apply the concepts developed in the above tasks. The team will hold workshops and seminars to discuss this information. The goals for design professionals, contractors, material suppliers and building officials are to recognize that PBSD involves choices about risk, and to be able to use the risk management tools provided in the Guidelines. For building owners, the goal is to bring awareness of how these tools fit in with current risk management techniques they use when purchasing space, making renovations, considering deferred maintenance, etc. A strong effort will be made to identify ways to coordinate current risk analysis techniques used by owners and financial institutions (probable maximum loss, ratings, etc.) with these new tools.

Personnel: Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.4 – Identify legal implications of PBSD

Description:

The team will contract with attorneys to address the legal implications of moving towards PBSD oriented building codes. The team will develop a list of issues that need to be evaluated, including: liability in the event of unexpected performance, cost allocation, long-term responsibility for the building or components, definitions of terms such as "significant," "reliable," etc. The goal will be to develop strategies to make

PBSD more attractive to stakeholders from a legal standpoint.

Personnel: Attorneys, Design professionals, Financial interests, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $250,000
Duration: 2 years

Task 4.5– Develop documents and reports for use in PBSD Guidelines and Stakeholders' Guide

Description:

This task will occur at milestones within the research plan developed in Task 4.2.1 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the **SPP** and **NPP** will occur to insure that information is presented in a consistent manner. The team will coordinate verification studies to be run on the analysis and design methodologies. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team for Task 4.2.1 to set out the goals for the next phase of research.

Personnel: Design professionals, Researchers, Financial interests, Owners, (Government agencies)
Priority: Essential
Budget: $400,000
Duration: Throughout the project

Challenges

- *Analysis and modeling*

  A major effort will be required to develop financial tools relating costs to structural and nonstructural performance. This will require close collaboration between design professionals and Financial interests.

- *Acceptability*

  It will be important to define acceptable risk. The challenge will be in quantifying stakeholders' tendencies to be either risk adverse or risk tolerant. A key to successful implementation of PBSD is the ability to match a design with the owners' risk tolerance.

  Considering broader social and economic factors affecting a building -- such as a hospital remaining functional to treat injuries within the community, or even of a grocery store being able to provide emergency food supplies after a damaging event -- will complicate the consideration of minimum performance objectives and liability.

- *Data Acquisition*

  A challenge will be to obtain useful information on performance versus loss and performance versus design and construction costs. A major effort may be warranted to cost estimate example designs using the PBSD procedures. This information will be needed to calibrate cost models.

- *Reliability*

  Identifying uncertainties in quantifying costs, damage, hazard and risk will be a major challenge. New methods for integrating engineering design and analysis with financial and social modeling will need to be developed and tested.

PRODUCT 5 – PBSD Guidelines

The Guidelines form the most important product resulting from this project. They distill the information developed in the **SPP**, the **NPP** and the **RMP** into the application document used by design professionals, manufacturers, government agencies and building officials in design and construction. These guidelines can form the basis for the next generation of building codes and earthquake resistant design practice. When implemented, these guidelines should permit economical design that can reliably attain desired seismic performance.

The Guidelines will have to be broad in scope yet deep in level of detail. They need to be usable by a wide range of design professionals. They will focus on:

- *Selecting and quantifying performance objectives, including cost performance.*

  A set of consistent performance levels for new and existing buildings is essential. To be useful and reliable, predictors of structural and nonstructural performance must be characterized in a manner that can be understood by building owners.

- *Defining minimum and standard performance objectives.*

  Although the concept of performance based design permits owners to specify custom objectives for each building, presumably codes will need to have a single set of minimum and standard objectives used for enforcement purposes. These will need to be defined and incorporated into the performance objectives. They should be based on considerations of acceptable risk and should be based on input from multiple stakeholders. In addition, the desired reliability level in achieving these objectives needs to be specified.

- *Characterizing performance and hazard levels consistent with the objective.*

  The performance objectives must be quantified in engineering terms. This includes defining specific acceptable damage levels for various elements, both structural and nonstructural as well as permissible global behavior of the structure itself. Characterization of ground motion will also be important.

- *Performance prediction and evaluation methods.*

  The methods in the guidelines will facilitate design of structures of any configuration for any desired performance and can be used to calibrate building codes for new buildings or develop new codes. Methodologies used for evaluation and retrofit of existing buildings can also be calibrated. Lastly, the financial industry can use the guidelines as a basis to develop methods of ranking the design performance of buildings for underwriting purposes.

- *Means of verification.*

  The various analytical procedures used to evaluate performance and demonstrate acceptability, together with suitable modeling rules and prescriptive requirements on configuration and detailing must be verified. The uncertainty inherent in each of these procedures for buildings of different sizes, types, and configurations, and for different performance levels must be quantified. While a minimum level review is essential, a broad program of verification will be optimal.

- *Procedures for installing and maintaining nonstructural components and contents in buildings.*

  This information will focus on the issues related to installation and maintenance of nonstructural components. Not least among these is the division of responsibilities and liability between the component manufacturer and installer. As the design engineer observes building construction, equipment installation should also be observed for compliance to the manufacturer's specifications.

- *A technical commentary serving as backup for the Guidelines.*

  No matter how well stated in the PBSD Guidelines, the rationale and history behind the provisions will be subject to the interpretation of the engineers and building officials employing them. A comprehensive commentary is necessary to give these users a fuller picture of PBSD and direction when implementing it. The commentary should also include a series of example applications of the guidelines.

The Guidelines will involve major participation from all stakeholders, including design professionals, researchers, manufacturers, owners, financial institutions, building officials and governing agencies. A comprehensive program of verification will require input and involvement from a broad range of users. Technical writers and code officials will also be employed to produce the highest quality document.

The guidelines will be developed in phases. The first, or the 25% phase, will include a basic framework for the Guidelines, to be filled in with research and tools from the **SPP, NPP** and **RMP**. Review by the Guidelines teams at this stage will focus on refining or changing the direction of the technical research efforts for these products. The next phases at 50% and 75% will continue to take information from the technical products and flesh out the Guidelines, again returning comments to refine the research. The 100% phase will consist of final review, formatting, wordsmithing and publication. An important task within the Guidelines product is to develop this phasing further and to coordinate overall efforts with the steering committee.

Task 5.1 – Reach consensus on Guidelines format and development process

Description:

The main goal of this effort will be to reach a consensus on the format of the Guidelines, and to develop a conceptual framework. The team will also establish a procedure for taking the information from the **SPP, NPP** and **RMP** and writing the guideline provisions.

Personnel: Design professionals, Researchers, Material suppliers, Contractors, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 5.2 – Develop design and analysis provisions

Task 5.2.1 – Develop systematic design and analysis processes

Description:

Using the analysis and design methodologies defined in the **SPP** and **NPP**, the team will create design and analysis processes that take a building through concepts into final design, identifying major steps along the way. Procedures will be developed for new and retrofit conditions. The team will develop minimum performance objectives to be included in the standards based on the economic and social drivers developed in the **RMP.** A focus will be on developing modeling guidelines to lend consistency to the design and analysis process. The team will work closely with the verification team in Task 5.3, to ensure that the provisions are tested and are acceptable. This team will be responsible for suggesting refinements or changes to the technical product research as necessary to accommodate the provisions. A goal should be to minimize this as much as possible, to maintain the schedule and budget. The committees will write the provisions using consistent and appropriate language, figures, equation styles, procedures for implementation, etc.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies, (Financial interests)

Priority: Essential
Budget: $1,200,000
Duration: Throughout the project

Task 5.2.2 – Write a technical commentary to support the Guidelines

Description:

The team will write a technical commentary to support the information in the PBSD Guidelines. It will develop the format of the commentary to track the outline of the Guidelines. The goal of the commentary is to give specific background on the development of the procedures within the Guidelines and to explain the concepts in technical terms. It should also contain many references to allow users to obtain additional guidance. The team will consider the

advantages of discussing the broader implications of decisions that were made in the Guidelines (financial, political, based on reliability, etc.). The team will have the commentary reviewed for accuracy by a panel of experts set up by the Steering Committee. This panel will include members of the **SPP, NPP** and **RMP** teams.

Personnel: Design professionals, Researchers,

Priority: Essential
Budget: $500,000
Duration: 2 years

Task 5.2.3 – Develop administrative guidelines for building officials

Description:

The team will establish administrative provisions for the use of PBSD by building officials. It will detail the process by which buildings, including structural and nonstructural components, are reviewed, plan checked and field inspected. The team will also develop tools for building officials to ease the burden of reviewing PBSD design. The team will consider the benefits of third party plan check and peer review and other means of streamlining the process while maintaining quality

Personnel: Design professionals, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $200,000
Duration: 1 year

Task 5.3 – Implement a verification program

Task 5.3.1 – Run examples to check accuracy of provisions

Description:

The team will establish subgroups to verify the accuracy of the design and analysis procedures. The subgroups will create and test a series of parametric examples. The team will set up a means by which the results of the testing can be checked for accuracy and acceptability. The team will identify and make necessary changes in the procedures in cooperation with the technical product teams.

Personnel: Design professionals, Researchers, Building officials,

Priority: Essential
Budget: $600,000
Duration: Throughout the project

Task 5.3.2 – Compare resulting designs and costs against current methodologies

Description:

The team will evaluate the effects of the resulting guidelines on each of the major stakeholders, looking at costs, level of effort and responsibility. A series of example applications will be developed and compared against current design techniques. The various methods that are developed will be calibrated against each other. Calibration will consider at least: the effort to implement, resulting

performance and expected construction costs. Information from the **RMP** will be incorporated into the calibration study. The team will establish subgroups to carry out these studies, and will develop a standard reporting method by which the results can be quantitatively compared. If the team decides that the results diverge too significantly from existing methodologies, revisions to the procedures will be made, or a schedule for incremental application of the procedures will be developed.

Personnel: Design professionals, Researchers, Financial interests

Priority: Essential
Budget: $400,000
Duration: Throughout the project

Task 5.4 – Develop procedures for quality control during construction

Description:

The team will write a set of guidelines for maintaining quality during construction. Information on reliability and uncertainty developed in the **SPP** and **NPP** will be used to evaluate the various stages of construction. The team will address such issues as material fabrication and inspection, installation, testing, uniformity in construction practices, field changes, etc. The goal is to provide a clear statement about the need for a high level of construction quality, and to provide standard procedures to attain this quality. It may be desirable to permit different levels of quality control based on expected performance or on building usage, etc.

Personnel: Design professionals, Contractors, Material Suppliers, Owners, Building officials

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 5.5 – Develop a plan for verifying nonstructural component design and installation

Description:

The team will develop a standard format for checking the adequacy of nonstructural component and system design, manufacture and installation. Much like peer review and inspection procedures for the structure, this system will be designed to track nonstructural elements through a similar process. The team will establish a system for identifying and training qualified inspectors and reviewers. The team will use the information developed in the **NPP** to make easier reevaluation of existing components and determine expected performance.

Personnel: Design professionals, Contractors, Material suppliers, Building officials

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 5.6 – Publish guidelines and create an adoption process

Description:

The team will set up milestone deliverables at 25%, 50%, 75% and 100% and will describe the content to be included in each. It will establish and implement a final review and adoption process. A peer review procedure will be established at each milestone. A technical writing team will be created and a consensus reached on the style and voice of the guidelines. The Guidelines will be written and reviewed. A small team of reviewers will focus on the presentation of the information, both graphically and textually.

Personnel: Design professionals, Researchers, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $600,000
Duration: Throughout the project

Task 5.7 – Develop a means for future revisions

Description:

After the guidelines are completed, the team will assess the project and identify future goals, research efforts, etc. that will build upon the work completed. The team will write a framework for the next generation of PBSD related projects. The goal of the task is to provide a plan for the continuing evolution of PBSD. The team will establish a procedure for updating the guidelines

Personnel: Design professionals, Researchers, Government agencies

Priority: Optimal
Budget: $150,000
Duration: 1 year

Challenges

- *Analysis and modeling*

  Developing general methods for design and performance prediction will be a challenge when considering varying performance objectives. The procedures must be relatively easy to implement yet still provide higher reliability than current design methodologies and be reasonably economical.

  Procedures for nonstructural design and analysis will have to be greatly expanded from current standards. This will require a major effort on the part of the product team.

  Because modeling will play a more significant role in PBSD design than it currently does, standards for computer aided design will be necessary. These standards need to insure consistency while allowing creative flexibility.

- *Reliability*

  The incorporation of reliability methods into design procedures will be a challenge. Design professionals will need to begin to think in terms of probability, uncertainty and risk. Quantifying these terms in relation to traditional structural engineering concepts will be difficult but important.

- *Administration*

  As with any adoption process, acceptance from the stakeholders will be one of the most difficult challenges. It will require political and diplomatic skill to bring each of the parties into enthusiastic agreement. The teams should consider using professional facilitators and negotiators to build a strong consensus about the PBSD Guidelines and their use.

- *Example applications*

  It will be a challenge to develop realistic, understandable examples of the application of the guidelines that will achieve sellable conclusions and encourage the use of PBSD.

PRODUCT 6 – Stakeholders' Guide

The Stakeholders' Guide will serve to educate the non-engineering audience about the benefits of PBSD. It will be their reference and planning tool much as the PBSD Guidelines serve a similar purpose for the engineering community. The Guide needs to be written in a non-technical style, and emphasize graphic presentation. The financial information should be presented in a way that will be useful to owners and financial professionals. It needs to communicate the concept and application of PBSD to these primary stakeholders. It will include the following components:

- *Background on codes and performance based design.*

  The Guide should give background on the history of code development and the reasons for moving toward performance based design. It should describe in general terms the principles of PBSD and its benefits over current methods. The goal is to show stakeholders that this move is necessary and that performance based design standards are in their financial and business interests.

- *Financial and other benefits of using PBSD.*

  Tables, charts, equations, examples and text, should convey the advantages and appropriate uses of PBSD in terms of financial and other models. Adoption will require that the document include the issues that stakeholders see as concerns and benefits. It will need to specify and quantify these benefits and provide a mechanism for making incremental changes to current practice.

- *Guidance for implementing PBSD.*

  The owner and financial professionals need to be guided through the process of implementing PBSD. Much more than in current practice these stakeholders will form an integral part of the design team. They must assist in making decisions about the direction of a project and be involved throughout its implementation.

- *Example applications of PBSD*

  The guide will contain example applications of the guidelines, covering structural and nonstructural design, and financial planning issues. The examples will contain technical information for the design professionals as well as nontechnical information for building owners and financial interests.

Task 6.1 – Define content and format of Stakeholders' Guide

Description:

The team will convene a series of workshops with stakeholder representatives to create the format and content of the Stakeholders' Guide. The team will determine the level of complexity of the information and equations presented. The goal is to layout the format for the guide so that it is usable to a non-technical audience. A strong effort will be made to involve owners and financial representatives, as these will be the primary users of the information. Another goal is to be able to quantify the level of effort that will be required of these groups in the planning, design and construction processes, in terms of cost and time. A consensus about the style of presentation will also be reached.

Personnel: Design professionals, Researchers, Financial interests, Owners, Contractors, Material suppliers, Building officials, Government agencies, Legal professionals

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 6.2 Present and explain financial modeling techniques

Description:

The team will present and explain the financial modeling tools developed in the Guidelines and the Risk Management Products. In the same manner as the Guidelines these tools should be presented with different levels of complexity, so that the user can employ the most appropriate to a specific situation. The technical and financial research will have been done as part of the **RMP**. In this task the goal is to provide descriptions of and practical ways to employ these tools.

Personnel: Design professionals, Researchers, Financial interests, Owners

Priority: Essential
Budget: $300,000
Duration: Throughout the project

Task 6.3 – Describe the design and construction process

Description:

As with the Guidelines, the team will develop a road map to move from the concept stage to completion of construction, identifying major steps along the way. Retrofit and new design will be considered. The responsibilities and qualifications of each of the stakeholders (including owners and design professionals) throughout the design and construction process will be identified and described. The team will review these responsibilities and evaluate their effects on the groups. The team will prepare the information using

language, figures, equation styles, procedures for implementation, etc., consistent with the Guidelines. The team will consult with legal professionals to evaluate possible changes in liability.

Personnel: Design professionals, Owners, Financial interests, Building officials, Government agencies, Legal professionals

Priority: Optimal
Budget: $250,000
Duration: 2 years

Task 6.4 – Develop examples for the guide

Description:

The team will develop a series of examples for the financial and engineering application of PBSD, which will serve as teaching and reference tools. The team will set up a verification means and check the examples for accuracy and acceptability. The examples will include photographs and other graphic aids to increase understanding of the process.

Personnel: Design professionals, Researchers, Financial interests, Owners

Priority: Essential
Budget: $400,000
Duration: 2 years

Task 6.5 – Develop a plan to maintain or monitor the designed performance objective

Description:

The team will identify maintenance needs for nonstructural components, based on type, function, age, etc. It will develop a program that owners can follow, similar to deferred maintenance or tenant improvement, for maintaining the performance quality of existing equipment. A similar program will be developed to maintain and monitor the overall structural performance goals of a building throughout its life, accounting for changes in occupancy, advancements in the state of the art, structural modifications, etc. This information will be published as part of the Stakeholders' Guide. The team will prepare educational material to inform owners, contractors, and others about the procedures for maintaining a building's designed performance.

Personnel: Design professionals, Contractors, Manufacturers, Owners

Priority: Optimal
Budget: $250,000
Duration: 1 year

Task 6.6 – Publish the stakeholders' guide

Description:

The team will set up milestone deliverables at 25%, 50%, 75% and 100% and will describe the content to be included in each. It will establish a final review and adoption process. The team will also include a nontechnical background and history of the PBSD process and of current code evolution. The goal will be to show the non-engineering audience the need for PBSD and the expected changes with respect to the current design and construction practice. A peer review procedure will be established at each milestone. A writing team will be created and a consensus reached on the style and voice of the guide. A small team of reviewers will focus on the presentation of the information, both graphically and textually. This group will have the responsibility, along with the steering committee of ensuring that the presentation compliments the Guidelines themselves.

Personnel: Design professionals, Financial interests, Owners, Government agencies, Outside experts in information outreach

Priority: Essential
Budget: $400,000
Duration: Throughout the project

Task 6.7 – Develop a means for future revisions

Description:

The team will set up dates for considering revisions to the Guide and a procedure for doing so.

Personnel: Design professionals, Owners, Financial interests, Government agencies

Priority: Optimal
Budget: $100,000
Duration: 1 year

Challenges

- *Cost*

  Turning PBSD into a reality will require substantial investments of time and money by all stakeholders. Stakeholders will need to be convinced that spending money up front will be in their long-term financial interests. Lessons should be taken from other successful efforts, or from other countries such as Japan.

- *Administration*

  The Stakeholders' Guide will need to function well with the PBSD Guidelines. Owners and other non-engineering stakeholders will primarily use the former while design professionals will use the latter. Each, however, must lead to complimentary results that meet the needs of all parties. Close collaboration of both teams will be important. This will present special challenges for each because of the differences in their training and expertise.

- *Education and Incentives*

  A focus of the Guide will be to make the concepts of risk and reliability understandable to all parties. PBSD incorporates reliability-based design, a concept that design professionals often only consider peripherally. Owners and Financial interests, however, use risk management on a regular basis. It will be a challenge to communicate to design professionals that uncertainty must be included in their design approaches, and to convince owners that there are limits on what can be known or anticipated regarding building performance.

Interrelation of Products

It is important to consider the six products as interrelated. It will not be possible to develop PBSD by isolating each as an independent project. This section describes some of the necessary relationships between the products and identifies key crossover lines between the various product teams.

The Technical Reference Products

The **SPP, NPP** and **RMP** will contain the bulk of the research, analysis and testing necessary to develop PBSD guidelines. Generally, these efforts will be developed concurrently throughout the project. However, there are some important commonalties that should be developed first, including:

- *Development of performance levels and global acceptability criteria.*

  This is necessary to establish a common basis for analysis and the development of the standards. Prior to the start of focused research, the three teams should reach a consensus on the definitions of performance and acceptability.

- *Hazard quantification and prediction.*

  The identification of hazard parameters impacts all three products and should be consistent between them. Researchers and design professionals developing this information will to some extent be working concurrently with the structural, nonstructural and risk teams. Before these teams make assumptions regarding hazard evaluation and characteristics, however, agreement on these issues is needed. This will require greater interaction between design professionals and scientists.

- *Reporting methodologies.*

  Each product should report information in a consistent manner, to make the eventual synthesis into the Guidelines and Stakeholders' Guide easier. Reporting formats should be developed at the beginning of the project. Milestones should be put in place to compare progress and track that basic assumptions are consistent between the groups. It will be the function of the steering committee to make sure that each team is meeting its schedule. However, several members of the technical product teams will likely be part of the Guidelines teams as well. Conflicts about fundamental goals and reporting styles may create problems in the development of the Guidelines.

The End Use Products

The PBSD Guidelines and the Stakeholders' Guide are the products that will ultimately be used to implement PBSD. They need to compliment and supplement each other, not duplicate information, and work toward the same overall goal. To this end, both teams working together should perform several tasks.

- *Set goals with stakeholders.*

  While each product will be developed for somewhat different audiences, many of the goals will be the same. Each of the goals identified by the stakeholders should be accounted for in one or both of the products. Stakeholders' forums should be held with the product teams early on and regularly throughout the project, to make sure that no important goal is missed.

- *Develop document outlines.*

  To insure that these products do not miss information or undesirably duplicate it, the outlines for each should be developed in a unified setting. Planning sessions should be held to make sure that both will be compatible.

- *Coordinate example applications.*

  Because of the tight overall project schedule, much of the efforts for these two products will be done concurrently. At the point when the Guidelines are technically complete, the two teams should meet to agree on the content and style of the examples to be included in the Stakeholders' Guide.

Hand over between the Technical and End Use Products

The project schedule requires that work be done in a manner that moves forward quickly. Obviously, developing accurate, reliable and acceptable information is of utmost importance. The quality of the products should not be sacrificed to meet the schedule. However, since the consensus process typically involves compromise and reevaluation, valuable time may be lost if the end use products are begun before substantial progress is made on the technical products. To make the hand over more efficient the following tasks should be performed:

- *Convene technical acceptance workshops.*

  Before the process of distilling the technical products into the end use products at each phase (25%, 50%, 75% and 100%) begins, review should be implemented to "sign-off" on the former. A representative group of stakeholders needs to come to agreement that significant research has been completed and that there is enough information to begin developing the Guidelines. If substantial research is needed during the writing of the guidelines, this could snowball, causing reworking of all the technical products. This is to be avoided.

➢ *Check that the technical products are on the right track:*

At milestones during the technical product development, the members of the end use product teams should confirm that the right information is being produced to facilitate development of the guidelines. To this end, early in the development of the technical products these teams need to prepare outlines of the end use products, so that they or the steering committee can see that work is moving on the right track.

Development of Education Program

Two keys to the success of the education program will be having valuable information published in an understandable and exciting way, and recruiting experts to present this information. It may be unrealistic to assume that the members of the product development teams will be most suited to lead these efforts.

➢ *Translate technical material into easy to understand educational and promotional material.*

The team responsible for developing the education program will meet with representatives from the other product development teams to identify material which would be useful. They will work together to prepare technically accurate information while at the same time, keeping the product beneficiaries in mind. The representatives will review material developed by the team for accuracy.

➢ *Recruit and train experts to present educational material*

The education teams will identify people who are gifted in presenting and teaching, and have a strong knowledge of the PBSD products. These people may not be members of the other product development teams. If this is so, the teachers will need to have close interaction with the product team members to fully understand the concepts that need to be conveyed. The team will develop teaching and presentation programs and train the teachers on presentation methods. The teachers will eventually receive feedback from the seminars they give. The education team will use this information to refine the program.

An effort should be made to bring the concepts of PBSD into universities, so students in engineering, architecture and construction management programs will be familiar with and embrace PBSD concepts when they enter their professions.

Conclusion

Few lives have been lost in major American seismic events, in buildings designed under modern codes. The economic losses in recent earthquakes, however, have put a strain on communities, owners, lenders, insurers, governments and building users. It must be said, too, that none of these events have been of a level that would typically be considered catastrophic. Temblors with a magnitude similar to the 1812 New Madrid or 1906 San Francisco earthquakes will likely result in losses that are several times larger than anything previously experienced if they occur in a densely populated area.

There has been much miscommunication between design professionals, owners and financial institutions about the performance that buildings built to modern codes are expected to deliver. This has led to higher than appropriate expectations by owners.

Owners, however, must be able to make reliable financial decisions about a building's seismic performance. Their long-term capital planning strategies require that seismic risk be translated into meaningful, quantifiable terms. Engineers need ways to design buildings with a predictable level of performance that can be adjusted to meet the owner's needs.

Performance based seismic design represents a bold new strategy for reducing earthquake losses. It focuses on the economic goals of building stakeholders and integrates financial modeling with the latest engineering research. This *Action Plan* lays out a rational, cost-effective and achievable program for establishing and implementing PBSD in a manner that will benefit each of the groups with a stake in the built environment.

The organization of this project around six "products" insures that the critical areas of research and implementation are addressed. It breaks the overall effort into manageable units and produces valuable, self-contained material at regular intervals. It brings together a diversity of opinions, interests and expertise to produce robust and widely acceptable guidelines. The products themselves will rely upon various media to most effectively disseminate information.

The tasks within each product are designed to address the major challenges that will arise, and provide clear guidance for the development teams. Establishing a steering committee and education program insures that administration and promotion of the project are top priorities.

The budget and schedule are both ambitious. However, flexibility is built into each product by recommending essential and optimal funding levels. Tasks are devoted to *finding* sources of major funding for long term research, testing and education efforts, with the intention of spreading these costs throughout the stakeholder community.

The process of building design and construction must undergo a significant change if it is to meaningfully reduce the potential for disastrous earthquake losses. This *Action Plan* represents a major step towards fulfilling the potential of PBSD and reaping its benefits.

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Performance based Design Workshop Participant List July 27-28, 1998 San Diego, California

Daniel Abrams
Professor
University of Illinois
1245 Newmark Civil Engineering Lab
MC 250
205 N. Mathews Avenue
Urbana, IL 61801-2397
Tel. 217/333-0565
Fax 217/333-3821
E-mail d-abrams@uiuc.edu

S. Ahmad
American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Tel. 248/848-3700
Fax 248/848-3700
E-mail SAhmad@aci-int.org

Dan Alesch
Professor
University of Wisconsin
Rose Hall, Suite 324
2420 Nicolet Dr.
Green Bay, WI 54311-7001
Tel. 920/465-2355
Fax 920/465-2791
E-mail: aleschd@uwgb.edu

Randall Allen
Director of Design and Construction
State of Missouri
Office of Administration
301 West High Street
P. O. Box 809
Jefferson City, MO 65102
Tel. 573/751-4174
Fax 573/526-3665
E-mail
allenr@mail.oa.state.mo.us

Donald Anderson
Senior Geotechnical Engineer
CH2M Hill
777 - 108th Avenue NE
Bellevue, WA 98004-5118
Tel. 425/453-5000
Fax 425/462-5957
E-mail
danderso@ch2m.com

Alfredo Ang
Professor
University of California
Dept. of Civil & Environmental Engineering
4157 Engineering Gateway
Irvine, CA 92697-2175
Tel. 714/824-8528
Fax 714/824-5051
E-mail: ahang@uci.edu

Christopher Arnold
President
Building Systems Development
P. O. Box 51950
Palo Alto, CA 94303
Phone 650/462-1812
Fax 650/462-1817
E-mail chrisarno@aol.com

Deborah Beck
Real Estate Board of New York
12 East 41st Street
New York, NY 10017
Tel: 212/532-3100
Fax 212/779-8774

Vitelmo Bertero
Professor Emeritus
1106 Colusa Avenue
Berkeley, CA 94707
Tel. 510/231-9586
Fax 510/527-8178

Michael Bocchicchio
Assistant Vice President
Facilities Administration
University of California
Office of the President
1111 Franklin Street, 6th Floor
Oakland, CA 94607-5200
Tel. 510/987-0777
Fax 510/987-0752
E-mail:
mike.bocchicchio@ucop.edu

Lawrence Brugger
ICC Building Performance Committee
3131 Donnie Ann Road
Rossmoor, CA 90720
Tel: 213/977-6446
Fax 213/977-6468

Jacques Cattan
American Institute of Steel Construction
1 East Wacker Drive, Suite 3100
Chicago, IL 60601-2001
Tel. 312/670-5430
Fax 312/670-5403

C. Allin Cornell
Professor
Stanford University
Terman Engineering Center
Stanford, CA 94305-4020
Tel. 650/854-8053
Fax 650/854-8075
E-mail:
cornell@ce.stanford.edu

Craig Comartin
President, Comartin-Reis
7683 Andrea Avenue
Stockton, CA 95207-1705
Tel: 209/472-1221
Fax: 209/472-7294
E-mail:
comartin@comartin-reis.com

Anthony Court
Vice President
Curry Price Court Structural & Civil Engineers
444 Camino del Rio South #201
San Diego, CA 92108
Tel. 619/291-2800
Fax 619/291-0613
E-mail: cpceng@aol.com

Chuck Davis
Esherick Homsey Dodge and Davis
2789 25th Street
San Francisco, CA 94110-3597
Tel. 415/285-9193
Fax 415/285-3866

Greg Deierlein
Professor
Stanford University
Dept. of Civil & Environmental Engineering
Terman Engineering Center – M 4020
Stanford, CA 94305-4020
Tel. 650/723-0453
Fax 6500/723-7514
E-mail:
ggd@cive.stanford.edu

Bruce Ellingwood
Johns Hopkins University
Dept. of Civil Engineering
3400 N. Charles Street
Baltimore, MD 21218
Tel: 410/516-8443
Fax 410/516-7473

Jeffrey Gee, AIA
Director of Design & Project Management
University of California
2000 Carleton Street
Berkeley, CA 94720-1380
Phone 510/643-9363
Fax 510/642-7271
E-mail
gee@dofm.berkeley.edu

S. K. Ghosh
Portland Cement Association
1811 Cree Lane
Mt. Prospect, IL 60077
Tel: 847/297-5640
Fax 847/297-9144
E-mail skghosh@aol.com

John Gillengerten
John A. Martin & Associates
1212 S. Flower Street
Los Angeles, CA 90015
Tel. 213/483-6490
Fax 213/483-3084
E-mail: JGjama@aol.com

Michael Hagerty
Chief Engineer
City of Portland
Bureau of Buildings
1120 SW 5th, Room 930
Portland, OR 97204
Tel. 503/823-7538
Fax 503/823-7692
E-mail
hagertym@ci.portland.or.us

Ronald Hamburger
Senior Vice President
EQE International, Inc.
1111 Broadway, 10th Floor
Pakland, CA 94607
Tel. 510/817-3100
E-mail: roh@eqe.com

Robert D. Hanson
Senior Earthquake Engineer
University of Michigan/
FEMA CA-1008-DR
74 North Pasadena Avenue
Parsons Bldg. West Annex,
Room 308
Pasadena, CA 91103
Tel. 626/431-3079
Fax 626/431-3859
E-mail:
robert.hanson@fema.gov

Gary Hart
University of California at
Los Angeles
Civil & Environmental
Engineering Dept.
5731 Boelter Hall
Los Angeles, CA 90095-
1593
Tel: 310/825-1377
Fax: 310/206-2000
E-mail ghart@ucla.edu

Perry Haviland, FAIA
Building Standards Seismic
Safety Advisory Committee
Haviland Associates
Architects
27 Embarcadero Cove
Oakland, CA 94606
Phone 510/532-6996
Fax 510/532-6998

Frederick Herman
City of Palo Alto
250 Hamilton
P. O. Box 10250
Palo Alto, CA 94303
Tel. 415/329-2550
Fax 415/3229-2240
E-mail:
fred_herman@city.palo-
alto.ca.us

William Holmes
Vice President
Rutherford & Chekene
Consulting Engineers
303 Second Street, Suite
800 North
San Francisco, CA 94107
Tel: 415/495-4222
Fax 415/546-7536
E-mail:
wholmes@ruthchek.com

John Hooper
Skilling Ward Magnusson
Barkshire Inc.
1301 Fifth Avenue, Suite
3200
Seattle, WA 98101-2699
Tel. 206/292-1200
Fax 206/292-1201
E-mail: Jdh@skilling.com

Laurence Kornfield
Chief Building Inspector
City and County of San
Francisco
Dept. of Building Inspection
1660 Mission Street, 3rd
Floor
San Francisco, CA 94103-
2414
Tel. 415/558-6244
Fax 415/558-6474

Wilfred Iwan
Professor/Director
Earthquake Engineering Research Laboratory
California Institute of Technology
223 Thomas Laboratory
Pasadena, CA 91125
Tel. 626/395-4144
Fax 626/568-2719
E-mail:
wdiwan@cco.caltech.edu

James Jirsa
Professor
University of Texas
Ferguson Structural Engineering Lab
10100 Burnet Road, PRC Bldg. 177
Austin, TX 78758-4497
Tel: 512/471-4582
Fax: 512/471-1944
E-mail:
jirsa@uts.cc.utexas.edu

Gerald Jones
1100 West 122nd Street
Kansas City, MO 64145
Tel. 816/942-3167
Fax 816/941-8743
E-mail:
ghjones@prodigy.net

Helmut Krawinkler
Professor
Stanford University
Dept. of Civil Engineering
Terman Engineering Center
Stanford, CA 94305-4020
Tel. 650/723-4129
Fax 650/723-7514
E-mail:
krawinkler@ce.stanford.edu

George Lee
Director
MCEER
SUNY at Buffalo
100 Red Jacket Quadrangle
Box 610025
Buffalo, NY 14261-0025
Tel. 716/645-3391
Fax 716/645-3399
E-mail
gclee@acsu.buffalo.edu

H. S. Lew
National Institute of Standards and Technology
Building and Fire Research Lab
Building 226, Room B168
Gaithersburg, MD 20899
Tel: 301/975-6060
Fax: 301/869-6275
E-mail: hsl@nist.gov

Michael Mahoney
Senior Geophysicist
FEMA
National Earthquake Program Office
500 "C" Street SW, Room 416
Washington, D.C. 20472
Tel. 202/646-2794
Fax 202/646-3990
E-mail:
Mike.Mahoney@fema.gov

Hank Martin
American Iron and Steel Institute
11899 Edgewood Road, Suite G
Auburn, CA 95603
Tel. 530/ 887-8335
Fax 530/887-0713
Hmartin@steel.org

Andrew Merovich
President
A. T. Merovich & Associates, Inc.
1163 Francisco Blvd., 2nd Floor
San Rafael, CA 94901
Tel. 415/457-0932
Fax 415/457-1718
E-mail:
atmerovich@aol.com

Jack Moehle
Professor & Director
Pacific Earthquake Engineering Research Center
1301 S. 46th Street
Richmond, CA 94804-4698
Tel. 510/231-9554
Fax 510/231-9471
E-mail:
moehle@eerc.berkeley.edu

Vilas Mujumdar
Chief
Division of the State Architect
Office of Regulation Services
1300 I Street, Suite 800
Sacramento, CA 95814
Tel. 916/445-1304
Fax 916/327-3371
E-mail
vmujumda@dgs.ca.gov

Paul Murray
Structural Engineer
Stanley D. Lindsey & Assoc. Ltd.
1801 West End Avenue, Suite 400
Nashville, TN 37203-2509
Tel. 615/320-1735
Fax 615/320-0387
E-mail: pmurray@sdl-nash.com

Farzad Naeim
Director
Research/Development
John A. Martin & Associates
1212 S. Flower Street
Los Angeles, CA 90015
Tel. 213/483-6490
Fax 213/483-3084
E-mail:
farzad@johnmartin.com

Hidemi Nakashima
Visiting Scholar
PEER Center
1301 South 46th Street
Richmond, CA 94804-4698
Tel. 510/231-9597
Fax 510/231-9471
E-mail
hidemi@ppp.bekkoame.or.jp

Maryann Phipps
Principal
Degenkolb Engineers
225 Bush Street, Suite 1000
San Francisco, CA 94104
Tel: 415/392-6952
Fax 415/981-3157
E-mail:
mphipps@degenkolb.com

Chris Poland
President
Degenkolb Engineers
225 Bush Street #1000
San Francisco, CA 94104
Tel: 415/392-6952
Fax: 415/981-3157
E-mail:
cpoland@degenkolb.com

Maurice Power
Principal Engineer
Geomatrix Consultants
100 Pine Street, Suite 1000
San Francisco, CA 94111
Tel. 415/434-9400
Fax 415/434-1365

Andrei Reinhorn
Professor
SUNY at Buffalo
Civil Engineering
Department
231 Ketter Hall
Buffalo, NY 14260
Tel. 716/645-3491 x 2419
Fax 716/645-3733
E-mail:
reinhorn@eng.buffalo.edu

Evan Reis
Vice President, Comartin-Reis
356 King Street
Redwood City, CA 94062
Tel. 650/725-7016
Fax 650/723-7444
E-mail:
reis@comartin-reis.com

Robert Reitherman
Executive Director
CUREe
1301 S. 46th St.
Richmond, CA 94804-4698
Tel. 510/231-9557
Fax 510/231-5664
E-mail:
reitherm@nisee.ce.berkeley.edu

Mike Riley
National Institute of Standards & Technology
Earthquake Equipment Group
Route 270 & Quince Orchard Rd.
Building 226, Room B158
Gaithersburg, MD 20899
Tel. 301/975-6065
Fax 301/869-6275

Dan Rogers
Stanford University
University Facilities Projects
655 Serra Street, 2nd Floor
Stanford, CA 94305-6114
Tel. 650/723-3928
Fax 650/725-9475

Ronald Sack
Director
National Science Foundation
Division of Civil and Mechanical Systems
4201 Wilson Blvd., Room 545
Arlington, VA 22230
Tel. 703/306-1360
Fax 703/306-0291
E-mail: rsack@nsf.gov

Phillip Samblanet
Structural Engineer
National Concrete Masonry Association
2302 Horse Pen Road
Herndon, VA 20171-3499
Tel. 703/713-1900
Fax 703/713-1910
E-mail
PSamblanet@NCMA.org

Sheila Selkregg
Planning Director
Municipality of Anchorage
Community Planning and
Development
632 West 6th Avenue,
Room 210
Anchorage, AK 99501
Tel. 907-343-4303
Fax 907-343-4220

Paul Somerville
Senior Associate
Woodward-Clyde Federal
Services
566 El Dorado Street
Pasadena, CA 91101
Tel. 626/449-7650
Fax 626/449-3536
E-mail pgsomer0@wcc.com

John Theiss
208 St. Georges Drive
P. O. Box 102
St. Albans, MO 63073
Tel. 314/458-2453
Fax 314/994-0722 (EQE)
E-mail: jct29@aol.com

Stephen Toth
Chief Engineering Officer
Teachers Insurance &
Annuity Ass'n/College
Retiremt. Equities Fund
730 Third Avenue
New York, NY 10017-3206
Tel. 212/916-4445
Fax 212/916-6207
E-mail stoth@tiaa-cref.org

Bill Tryon
Wells Fargo Bank
540 Oak Street
Petaluma, CA 94952
Tel. 707/773-2868
Fax 707/773-2879
E-mail:
tryoncw@wellsfargo.com

Susan Tubbesing
Executive Director
EERI
499 - 14th Street, Suite 320
Oakland, CA 94612-1934
Tel. 510/451-0905
Fax 510/451-5411
E-mail: eeri@eeri.org

Fred Turner
Staff Structural Engineer
California Seismic Safety
Commission
1900 K Street #100
Sacramento, CA 95814
Tel: 916/322-4917
Fax: 916/322-9476
E-mail: fredt5@aol.com

David Tyree
Regional Manager
American Forest & Paper
Association
1080 Mesa Road
Colorado Springs, CO
80904
Tel. 719/633-7471
Fax 719/633-7439
E-mail: dptyree@aol.com

Nabih Youssef
President
Nabih Youssef & Associates
800 Wilshire Blvd., Suite
510
Los Angeles, CA 90017
Tel: 213/362-0707
Fax 213/688-3018
E-mail: nyoussef@gnn.com

☆ U.S. GOVERNMENT PRINTING OFFICE: 2000-522-300/95079