Description of Work

Topical Investigations on Performance Prediction and Evaluation

Sub-Task 5.5.4 Develop Recommended Procedures for Performance Prediction &Evaluation of Steel Moment Resisting Frame Buildings

Background: As part of Task 5.5, models for predicting the behavior of steel moment frames must be developed. These models must be directly usable by practicing engineers, but they must be of sufficient sophistication and complexity that they can incorporate all of the available data on expected building performance. They must incorporate knowledge gained from the results of detailed analytical studies and experiments on connections, materials testing and model development, and all system performance analyses. As such, this task will be based in large part on other topical investigations of Task 5 and the testing work in Task 7. In addition, data collected and analyzed from actual building performance in past earthquakes will be used to calibrate any models developed. Modeling procedures to be developed under this task must consider a performance-based design format. Sub-Task 5.5.2 investigates elastic analysis methods, and Sub-task 5.5.3 addresses nonlinear methods. Sub-Task 5.5.5 will develop design requirements for Ordinary (low ductility) moment frames. This Sub-Task will pull together results from Sub-Tasks 5.5.1, 5.5.2, Sub-Task 5.5.5 and the System Performance and Connection Performance Teams, and develop consistent and reliable recommended procedures for performance prediction and evaluation of steel moment frames. Part of this Sub-Task will verify the results of all of these procedures through design type calculations and application of the previous work. The results of Task 5.5.4 will contribute to the accomplishment of the following objectives specified in the Project Work Plan:

- Develop design and analytical procedures that will assure satisfactory steel moment frame performance during an earthquake and
- Develop **Seismic Design Criteria for Steel Frame Construction**

Objectives: This task will combine the results of the elastic and inelastic analysis and evaluation methods developed under Sub-Tasks 5.5.2 and 5.5.3 and the methods developed under Sub-Task 5.5.5 for ordinary (low ductility) frames. This will be done within the reliability framework that has been established. Verification studies will be conducted to ensure that a uniform level of safety is achieved by each method for different correction types and building configurations. It will be verified that the issues of balancing the target reliability and performance of the structure to the uncertainty in seismic hazard, structural model, system force and deformation capacities and the design process have been properly accounted for and that this has been accomplished within the reliability framework developed for the SAC 2 project.

This Sub-Task will address the following objectives:

1. Based on results from the SP Team and the PPE Team a recommendation will be made as to what is the “most accurate” method of modeling and analyzing a frame structure considering various hysteretic behavior, effective damping, and participation of gravity frames. The best model will then be used to establish bias factors which will be combined with bias factors developed in Sub-Tasks 5.5.2, 5.5.3, and 5.5.5.
2. Based on information developed by the SP Team on the effect of connection fractures on system behavior and capacity, and by the CP team on the behavior of gravity connections, the reliability, or safety, of damaged frames will be evaluated. Reductions in safety margin for frames under various conditions of damage will be investigated. This information will be used by the Guideline writers to develop guidelines as to when a damaged building should be judged unsafe for further occupancy, and when an undamaged building needs upgrading.
3. The behavior of frames designed by the 1994 UBC (approximately equivalent to the 1988 UBC), 1997 UBC and 1997 NEHRP provisions will be investigated to determine the annual probability of exceedance for the Immediate Occupancy and Incipient Collapse States of the nine SAC model buildings. This will be used by Guideline writers to determine if current provisions for new construction should be adjusted by requiring greater strength and/or stiffness.
4. The behavior of frames designed to the provisions of the 1973 UBC, 1979 UBC and 1988 UBC (1988 & 1994 S/B are about the same) will be investigated to determine the annual probability of exceedance for the Immediate Occupancy and Incipient Collapse of the nine SAC model buildings. This will be used by the Guideline writers to determine the level of safety and economic protection inherent in existing building stock and serve as a basis for making recommendations for upgrades.
5. Results from the SP and CP teams to determine if weak panel zones, strong-beams and weak columns, weak column splices, and other features will result in substantial decrease in safety margin and will be used to develop indicators for a “rapid evaluation” methodology such as FEMA 178.
6. The effects of structural redundancy on frame reliability will be investigated in conjunction with the efforts of the SP team. As a part of this objective, the effectiveness of the redundancy coefficient given in the 1997 UBC will be evaluated.
7. Working with the Task 3 team, an attempt will be made to develop a crude economic loss prediction model as a function of building configuration, age and other characteristics vs. MMI and as a function of structural analysis of response to various ground motion inputs.

Several elastic and nonlinear methods of analysis for frames with different connection types will be developed and evaluated under the other Sub-Tasks of Sub-Task 5.5. Information from the System Performance (SP) and Connection Performance (CP) Teams will be used throughout these activities. One goal of this project is to develop methods that will result in a uniform level of safety regardless of the method used. Bias factors will be developed for each method in conjunction with Sub-Tasks 5.5.2, 5.5.3, and 5.5.5. Part of the work under this Sub-Task will be to verify the consistency of the proposed methods using selected design-type calculations. These case studies will be chosen with the guidance of the PPE Team Leader, the PPE TAP, The Project Directors

for Topical Investigations and Product Development and Selected Lead Guideline Writers. It is expected that some of this work will be done near the end of the SAC Phase 2 Project.

The analysis and evaluation procedures will be calibrated for the Immediate Occupancy Performance Limit, or equivalent, so that the results will be consistent with observed performance reported by the Task 3 Team, Past Performance of Steel Buildings. Again, the specific cases studied will be chosen with the guidance of the PPE Team Leader and TAP, the Project Directors for Topical Investigations and Product Development and Selected Lead Guideline Writers.

It is expected that near the end of the research phase of the SAC Phase 2 project a few areas that have not been adequately addressed in the design-evaluation matrix will be revealed. This might be related to building configurations, connection types, frame irregularities, material type or other parameters. Limited additional design case studies will be performed to address these gaps. The cases studies will be chosen under the guidance of the PPE Team Leader and TAP, the Project Directors for Topical Investigations and Product Development, and selected Lead Guideline Writers.

Deliverables: Material developed under this Sub-Task will be incorporated directly into the **State of the Art Report on Performance Prediction and Evaluation**. Since most of the actual work is not specifically identified, it is not known at this time whether a formal report will be required or desired. A summary of results will be prepared by the Investigator for evaluation by the PPE Team Leader and TAP and the Project Directors for Topical Investigations and Product Development. If so desired, the summary report will be expanded and developed into a publishable final report.

Task Management and Review: This Sub-Task is supervised by James Malley, Project Director for Topical Investigations. The Performance Prediction and Evaluation (PPE) Team Leader and TAP will provide oversight and an advisory role on the conduct of the research and will review, provide specific comments and evaluate all reports and recommendations. Team Leaders and selected members of the Systems Performance TAP and Connections Performance TAP will also review and evaluate this work. It is expected that the subcontractor/consultant selected for this Sub-Task will be responsive to issues and concerns raised by the Project Director, TAP and other reviewers. The subcontractor shall be responsible for regularly reporting progress and difficulties to the PPE Team Leader and the Project Director for Topical Investigations.

Target Audience: The work products of this Sub-Task will be directly used by Performance Prediction and Evaluation Team and the guideline writers working on the SAC Phase 2 project. There will also be a need to integrate these results with the various other investigations throughout the progress of the program. They will also be of interest to Topical Investigation Team Leaders for System Performance and Connection Performance. The results of this sub-task will be used to develop the State of the Art Report on Performance Prediction and Evaluation. It is expected that the results will also be of great interest to the general profession and research community.