# Description of Work

## *ASSESS PAST PERFORMANCE OF STEEL BUILDINGS*

## Subtask 3.1.1 Collection of Data on Buildings Inspected Under the Los Angeles Inspection Ordinance

**Background**: It is the purpose of Task 3.1.1 to collect general data on buildings inspected under the Los Angeles Inspection Ordinance. This task is part of Task 3, whose goal is to document and assess the performance of welded steel moment frame buildings (WSMF) in past earthquakes and to provide means to evaluate and predict impacts in future earthquakes.

During SAC Phase 1, an extensive data base was developed that characterized the specific inspection results of buildings, focusing on damaged buildings. It was exploratory in nature and thereby incomplete for analysis purposes. Task 3 of SAC Phase 2 will supplement, and in some cases replace, this data set to provide statistically consistent, reliably characterized data that will allow the formulation of predictive models for damageability and economic impact for specific buildings and groups of buildings, evaluation of the efficacy current procedures for the inspection and evaluation of building conditions, based on Chapter 3 and 4 of the 1995 SAC Guidelines, and assessment of the impacts on the provision of repair related services within a community. The task will collect five distinct types of data: 1) general data for all of the buildings subject to the Los Angeles Municipal inspection ordinance; 2) specific engineering data for selected buildings that is as complete as practical; 3) data addressing the nature and reliability of the inspection process; 4) identification and documentation of damage to WSMF connections in other earthquakes; and, 5) documentation and characterization of the impacts of WSMF damage on selected construction service providers, financial institutions, and regulatory agenc ies.

Task 3.1.1 data collection will be limited to buildings for which the Los Angeles Municipal inspection ordinance applies. The data consistently determine building characteristics, inspection, damage, and repair. The data will include: the direct damage; inspection and repair costs; estimates of indirect costs such as business disruption; the underlying basis for design decisions; the financing alternatives considered; the economic and other trade-offs evaluated; and ad hoc strategies to minimize disruption and achieve cost savings. Data will be collected from the LA City files, telephone interviews with building owners, managers, consulting engineers and selected tenants.

**Objectives**: A systematic evaluation and development of elastic and nonlinear methods for performance prediction and evaluation of steel Ordinary Moment Frame buildings will be conducted with the following objectives:

1. Determine the reliability of existing performance prediction and evaluation procedures and design guidelines recommended by the other Task 5.5.2 and Task 5.5.3 investigators for OMFs and IMFs in different regions of seismic hazard. Determine the appropriate deformation limit states within the context of the reliability framework developed for the

SAC Phase 2 project. Develop other bias coefficients, if needed, as instructed by the Team Leader. Review current definitions and code requirements for OMFs and IMFs to evaluate their applicability. Develop appropriate characterizations for PR frames.

2. Investigate the reliability of using pre-Northridge welded moment connections, but with more ductile filler material, in regions of reduced seismicity. Determine the appropriate limit states and probability of exceeding these limits using the methodology consistent with those outlined in the reliability framework.
3. Develop analysis and design models for the use of bolted and other partially restrained connections in regions of reduced seismicity. Investigate the possibility and feasibility of using some of these connections for low-rise buildings in regions of high seismicity and mid- and high-rise buildings in regions of moderate and low seismicity. Where these connections are allowed, develop design procedures and acceptance criteria within the reliability framework developed for the SAC Phase 2 project. This will be closely coordinated with Task 7 subtasks results by the Team Leader.
4. In conjunction with other Sac Phase 2 investigators and the Performance Prediction and Evaluation (TAP), develop specific information for incorporation into both the State-of-the-Art Report on Performance Prediction and Evaluation and the **Seismic Design Criteria for Steel Moment Frames**.

**Task Description**: The study will focus on 2 three-story buildings and 1 nine-story building that have been designed for Seattle and Boston. One three-story building designed for a Los Angeles site will also be investigated. These frame designs will be modified to make them Ordinary.

**The following questions should be among those considered by the Investigator:**

- Do the R values in NEHRP 1997 appropriate for design of Intermediate and Ordinary Steel Moment Frames properly account for the seismic demands within the reliability framework established for this project?
- Do weak panel zones and/or weak columns seriously compromise the functionality of these frames during earthquakes?
- How should demands on column splices and base plate connections be evaluated?
- What limitations should be placed on local flange buckling, panel zone strength and weak-column strong-beam systems?
- Which partially or fully bolted connections provide adequate strength and stiffness for seismic loads?
- What requirements in terms of strength and stiffness of bolted connections should be included in the code for each performance level?

*Objective 1*: The effects of relaxing the SMF restrictions on local buckling, column vs. beam strength and panel zone strength and stiffness will be investigated. Analytical and design models will be developed to account for these phenomena. Evaluation and design methods developed for FEMA 273-274 (ATC-33) will be evaluated and modified as needed to result in reliable frame behavior. The Investigator should use information and results from the System Performance Team (SPT) and the Connection Performance Team (CPT). Other Investigators on the Performance Prediction and Evaluation Team (PPET) will also provide information. The focus should be on linear

design and evaluation procedures verified by static (FEMA 273) and dynamic nonlinear analyses. The nonlinear methods determined in Task 5.5.3 should also be investigated. These Performance Prediction and Evaluation models are to be evaluated within the reliability framework established for the SAC Phase 2 project. Close coordination will be provided by the Team Leader.

FEMA 273 does not use the terms Special or Ordinary Moment Frames. The requirements for moment frames are continuous based on whether local buckling, lateral torsional buckling or panel zone behavior controls the design. The feasibility and practicality of this approach should be investigated.

This study will require re-designing one of the perimeter frames for 4 different buildings, based on the model buildings designed for this project. They are the 3-story buildings designed for the Boston, Seattle, and Los Angeles sites and the 9-story building designed for the Boston site. Deformation limit states for each site based on the reliability framework should be determined. This may require determining dynamic pushover analyses for these buildings. Curves representing the probability of exceeding target deformation limits will be developed. Instructions based on the reliability framework will be provided by the Team Leader. Bias factors determined in Subtasks 5.5.2 and 5.5.3 will be modified if necessary.

*Objective 2*: A large number of tests of pre-Northridge connections have been done prior to and after the Northridge Earthquake. These tests have been done on members of different sizes and/or connections made with a variety of welding procedures. These tests should be reviewed from the perspective that some combinations of member sizes, welding procedures and seismic hazard will result in reliable and satisfactory performance. Information from the SP Team on seismic demands and the CP Team on deformation and strength capacities will be needed to complete this objective. Special attention should be given to the procedures within the reliability framework for determining proper deformation limit states.

*Objective 3*: Bolted connections are popular in many regions of the U.S. because of their economy and ease of construction. These, however, are primarily used in regions of low to moderate seismicity. Some of these are considered to be partially restrained connections. FEMA 273 includes specific design and analysis procedures for frames that utilize these connections. These should be evaluated and modified, as necessary, to result in practical and reliable frame designs. Information on seismic demands will be provided by the SP Team, and connection strength and deformation capacities will be provided by the CP Team. The Investigator should work closely with the Investigators working on Sub-Tasks 5.5.2 and 5.5.3. Special attention should be given to the procedures within the reliability framework for determining proper deformation limit states.

*Objective 4*: The investigator will supply recommendations and supporting data to other members of the Phase 2 Project, including the Guideline Writers and Team Leaders to be considered for use in the development of project deliverables, such as **Seismic Design Criteria for Steel Moment Frames**, as well as, the State-of-the-Art Report on Performance Prediction and Evaluation. Close coordination with the appropriate Guidelines Writers will be required throughout the development of such recommendation.

**Deliverables**: A final report will be written that will summarize the results of this investigation. It will address the theoretical and practical basis for the various procedures developed and proposed for use in other parts of the project. Issues of balancing target reliability and performance

of the structure to the uncertainty in the seismic hazard, structural model, system forces and deformation capacities and the design or evaluation process will be addressed. Interim reports to the Performance Prediction and Evaluation TAP will also be required. This objective will be completed in conjunction with analysis results provided by the SP team.

**Task Management and Review**: This subtask is supervised by James Malley, Project Director for Topical Investigations. The Performance Prediction and Evaluation (PPE) 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 subtask 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 PPE Team Leader and the Project Director for Topical Investigations.

**Target Audience**: The work products of this subtask 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.