2008 SCEC REPORT

Management of SCEC's Participation in the Tall Buildings Initiative

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INTRODUCTION

The Pacific Earthquake Engineering Research Center is actively pursuing a research agenda in support of the development and application of alternative design concepts for earthquake engineering of buildings, as described in the Tall Buildings Initiative (Moehle, 2006). The Southern California Earthquake Center is pursuing a research agenda that will provide earthquake ground motion simulation capabilities to support this cutting-edge earthquake engineering of buildings. The City of Los Angeles, the City and County of San Francisco, and other communities simultaneously are confronted with a boom in the construction of highrise buildings that involve a variety of unusual configurations, innovative structural systems, and high performance materials. Various jurisdictions, with the active involvement of peer review committees, are considering performance-based methods to assess the adequacy of these new designs. These parallel efforts create a timely opportunity for collaboration to improve and increase the application of performance-based designs for tall buildings, thereby assuring that new highrise construction meets intended safety and performance objectives, ensuring safe and usable buildings after future major earthquakes.

High occupancy levels, associated safety considerations, and interest in re-occupancy following an earthquake are leading to rethinking of ground shaking hazards. As a minimum, a building must be safe for rare (low-probability, long-return period) ground shaking demands, and must remain safe for significant aftershocks. However, there is increasing concern that serviceability for more frequent events ought to be considered as well; in a performance-based design, how should serviceability be treated? Many of these buildings have deep foundations, and questions arise about whether the ground motion is input at the grade level, at the base, or some average. Finally, in view of the very long vibration periods of tall buildings, special treatment of design ground motions is needed to ensure they are representative in their damage potential, including proper duration and long-period energy content, so designs based on them will safely represent anticipated effects of future earthquakes.

The selection, scaling and spectral modification of ground motion time histories to represent a design response spectrum has a large impact on the results of nonlinear analyses using these time histories, indicating the need to establish rational procedures for time history selection, scaling and modification. The earthquake shaking hazard that dominates in many important jurisdictions is associated with larger magnitudes and closer distances than are available in data bases of strong motion recordings. Validated seismological methods will be used to generate ground motion time histories that incorporate near-fault rupture directivity effects and basin effects, and thus appropriately represent the duration and long period energy content of these large design events.

OVERALL WORK PLAN OF THE TALL BUILDINGS INITIATIVE

The following overall work plan of the Tall Buildings Initiative is taken from Moehle (2006) and is presented here as a means of conveying the scope of the project as a whole.

Task 1 - Establish and Operate the Tall Buildings Project Advisory Committee

Select members for the advisory committee, including experts and representatives from the seismology, geotechnical engineering, structural engineering, and building regulation communities. Convene the T-PAC to initiate the project, define operating procedures, and advise on scope, tasks, and investigators. Meet on a regular basis to review ongoing work and recommend revisions in tasks as well as recommend new tasks. Seek expanded participation and funding as appropriate. Serve as an overall project quality control board, ensuring that main findings of this project have achieved consensus of the T-PAC prior to release.

Task 2 - Develop consensus on performance objectives

Using an appropriate methodology, develop a consensus on performance objectives, and document methodology and performance objectives in a final report. Considered performance objectives should include serviceability and safety margin. Deliberations should include conventional performance objectives and alternative ways of expressing objectives. Alternative performance considerations may include reparability and reoccupancy. Final objectives should clearly define confidence levels associated with objectives. Some analysis of socio-economic impacts associated with tall building performance should be considered.

Task 3 – Assessment of ground motion selection and scaling procedures

Conduct analyses of multistory building models subjected to a large number of earthquake ground motions to determine the native statistics of the responses, and compare results with results obtained using various proposed ground motion selection and modification procedures. Document methodology and results in final report. Work to be conducted in coordination with the PEER working group on ground motion selection and scaling. Buildings models to include two core wall models (of different heights) and two frame models (of different heights). Building models preferably based on actual building projects, preferably the models (perhaps slightly modified) from the actual projects. Collect statistics on important design parameters including roof drift, interstory drift, floor accelerations, moment profiles, shear profiles, collector forces, etc.

Task 4 - Synthetically generated ground motions

Using validated broadband ground motion simulation procedures, generate ground motion time histories in San Francisco and Los Angeles for large earthquakes on the major faults in the region. The time histories will be simulated for geographic areas of specific interest for San Francisco and Los Angeles. These broadband simulated time histories are to contain long period effects such as rupture directivity effects and basin effects that are specific to the fault geometry and geological structure of the regions.

Task 5 – Review and validation of synthetically generated ground motions

Conduct review of procedures and results obtained in Task 4, with purpose of establishing a validated reference set of synthetically generated broadband ground motions. Develop final report documenting procedures used to generate motions as well as validations procedures. Provide digital set of validated synthetic ground motions.

Task 6 - Guidelines on selection and modification of ground motions for design

Using findings from Tasks 3 through 5, write guidelines for selection and modification of ground motions for design of tall buildings. Apply recommendations to virtual sites in San Francisco and Los Angeles to demonstrate procedures and to establish a sample set of validated ground motions that can be used in subsequent research or for design of tall buildings.

Task 7 - Guidelines on modeling and acceptance values

Develop practical guidance for nonlinear modeling of tall buildings in reinforced concrete (priority) and steel, whose methodology and findings will be documented in a final report. Include recommendations for stiffness, strength, deformation capacity, hysteretic models, and implementation in software for nonlinear dynamic analysis. Provide guidance on appropriate use of overstrength parameters, capacity reduction parameters, etc. for capacity design. Work with experienced consultants to ensure focus on key components and systems that affect earthquake response and design, including modeling of podium force transfer. As appropriate, conduct analyses to validate procedures.

Task 8 – Input ground motions for tall buildings with subterranean levels

Prepare interim report describing the state of the art and practice for definition and input of ground motions for tall buildings with embedded foundations. Define additional needed studies as appropriate. Rely on past analytical and empirical studies. Work with experienced engineer familiar with tall building configurations and analysis procedures. Also, identify any other major issues to be investigated for foundation design of tall buildings.

Task 9 – Presentations at conferences, workshops, seminars

Implement a vigorous outreach program to engage a broad group of stakeholders and end users in the program, so it is well known among key stakeholders and end users, and so it is aware of and responsive to needs of those stakeholders and end users.

WORK ACCOMPLISHED IN THIS SCEC PROJECT

The main work accomplished in this SCEC Project was in relation to Task 4 – Synthetically Generated Ground Motions. The objective is to ensure that the simulated broadband ground motion time histories for use in the design of tall buildings in Los Angeles and San Francisco, are generated in ways that meet the engineering needs of the project; are accepted for use by the earthquake engineering community as represented by Project Advisory Committee and its technical subcommittees; and are modified in appropriate ways when subjected to procedures for scaling and spectral matching for engineering application. The work involved coordination of SCEC and USGS broadband ground motion simulation activities, and the transfer of suitable subsets of the simulated ground motion time histories to the TBI Project.

The time histories were simulated for geographic areas of specific interest for San Francisco and Los Angeles. These broadband simulated time histories contain long period effects such as rupture directivity effects and basin effects that are specific to the fault geometry and geological structure of the regions. The time histories that have been provided include the following sets.

Puente Hills Blind Thrust Earthquakes

Robert Graves generated suites of time histories for the Puente Hills Blind Thrust scenario earthquakes (Graves and Somerville, 2006). The broadband time histories were calculated at sites on a 1 km square grid centered over the fault planes and extending out to about 60 km. Digital sets of simulated ground motion time histories were provided to the TBI for review.

Northern San Andreas Earthquakes

A large group of investigators lead by Brad Aagaard (Aagaard et al., 2008) generated suites of long period ground motion time histories for 1906 San Andreas scenario earthquakes. Documentation of the simulations and data files is provided in Aagaard et al. (2009). Robert Graves incorporated short period ground motions into these long period simulations to make them broadband. Examples of the broadband simulations are shown in Figure 1. Digital sets of simulated ground motion time histories were provided to the TBI for review.

Southern San Andreas Earthquakes (ShakeOut)

A group of investigators lead by Robert Graves (Graves et al., 2008) generated suites of broadband ground motion time histories for scenario earthquakes on the Southern San Andreas fault as part of the ShakeOut Exercise.

Hayward Fault Earthquakes

A large group of investigators lead by Brad Aagaard is now developing suites of time histories for scenario earthquakes on the Hayward Fault.

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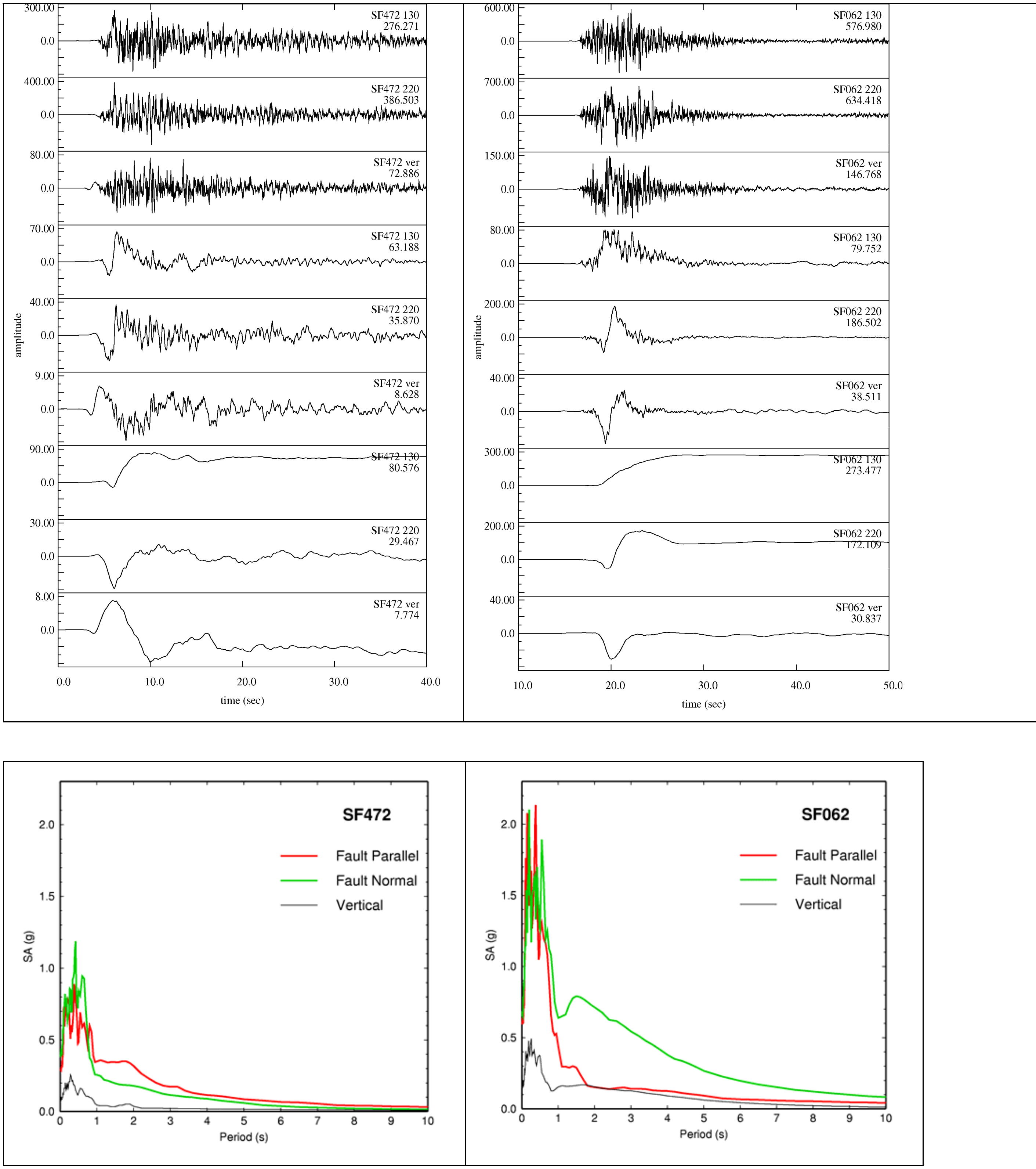

Figure 1. Time history (top) and response spectrum (bottom) of ground motions in San Francisco (left) and Santa Rosa (right) in the 1906 San Andreas earthquake. From top: acceleration, velocity and displacement for each of three components, in cm/sec^2, cm/sec, and cm respectively. Component 130 is fault parallel and 220 is fault normal. Source: Graves, 2006.