CHAMPIONS OF EARTHQUAKE RESILIENCE AWARDS

Organized by
the Applied Technology Council (ATC) and the Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE)

Applied Technology Council (ATC)

Founded in 1973, the Applied Technology Council aims to develop and promote state-of-the-art, user-friendly engineering resources and applications for use in mitigating the effects of natural and other hazards on the built environment. The corporate headquarters for ATC is located in Redwood City, California, with satellite offices in Atlanta, Georgia and in Arlington, Virginia. For more information, visit http://www.atcouncil.org

Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE)

Established in 1996, SEI advances our members' careers, stimulates technological advancement, and improves professional practice. SEI drives the practical application of cutting edge research by improving coordination and understanding between academia and practicing engineers. The mission of the Structural Engineering Institute (SEI) is to advance and serve the structural engineering profession. For more information, visit http://www.seinstitute.org

ATC&SEI

2nd Conference on Improving the Seismic Performance of Existing Buildings and Other Structures

Category:

Extraordinary Innovation in Development of a Community Earthquake Safety Program

Awarded to: City of San Francisco

for: Earthquake Safety Implementation Program

Award Citation:

San Francisco's *Earthquake Safety Implementation Program* (ESIP) which began in early 2012, evolved out of the key recommendations of the Community Action Plan for Seismic Safety (CAPSS), a ten-year-long study evaluating future earthquake impacts on San Francisco. The CAPSS findings, developed through the efforts of a broad range of community leaders, earth scientists, social scientists, economists, tenants, building owners, and engineers, are presented in the report series, *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco*, which present and address *Potential Earthquake Impacts*, *A Community Action Plan for Seismic Safety*, *Earthquake Safety for Soft-Story Buildings*, and *Post-earthquake Repair and Retrofit Requirements* (available online at www.sfgov.org/esip). The *Action Plan* was turned into the 50 tasks that the *Earthquake Safety Implementation Program* will be implementing over the next few decades. Since ESIP's inception, 14 pieces of earthquake safety legislation have been approved unanimously by the San Francisco Board of Supervisors. Task-related actions already completed include:

- The **soft-story mandatory retrofit ordinance**, which was signed into law by Mayor Lee on April 18, 2013, requiring (by the year 2020) the retrofit of 5,054 pre-1978 San Francisco wood-frame structures containing five or more residential units. having two or more stories over a "soft" or "weak" story, and housing approximately 15% of San Francisco's total population (and representing a significant percentage of the rent-controlled housing stock); related activities included an **earthquake retrofit fair** (attended by over 3,000 citizens and 160 vendors) to provide information about the mandatory retrofit program; and the passage of additional legislation to create a city-backed finance program and strengthen tenant protections for vulnerable populations.
- The **private school earthquake safety ordinance**, which was signed into law by Mayor Lee on October 1, 2014, to initiate the earthquake safety of 24,000 students, or one third of San Francisco's school age children, by requiring the seismic evaluation of all private school

buildings used primarily for the education and care of K-12 students or school administration that meet the building code definition of Educational "E" occupancy;

- Recommendations for **mitigation of chimney hazards**, which were completed in 2015; and
- A **building façade maintenance program** to protect passersby from earthquake-caused falling debris, which is currently undergoing the approval process.

San Francisco's *Earthquake Safety Implementation Program*, led by Patrick Otellini, is creating a broad range of earthquake safety programs that will not only greatly improve the earthquake resilience of San Francisco, but also serve as examples for other communities.

Category:

Extraordinary Innovation in Development of a Community Earthquake Safety Program

Awarded to: City of Los Angeles

for: Los Angeles *Resilience by Design* Program

Award Citation:

In December 2014, Los Angeles (LA) Mayor Eric Garcetti announced the release of the *City of Los Angeles Resilience by Design* report, which presented the recommendations of an ad-hoc Mayoral Seismic Safety Task Force to increase the City's resilience to future earthquakes. The goals of the project were to protect the lives of LA citizens during earthquakes, improve the capacity of the City to respond to the earthquake, prepare the City to recover quickly after an earthquake, and protect the economy of the City and all of Southern California.

Recommendations presented in the *City of Los Angeles Resilience by Design* report and resulting actions already undertaken include:

- An historic **mandatory building retrofit ordinance**, unanimously approved by the LA City Council and signed into law by Mayor Garcetti on October 9, 2015, to ensure that approximately 13,500 pre-1980 soft first-story wood-frame buildings and an estimated 1,500 pre-1980 non-ductile concrete buildings are strengthened to prevent loss of life in the event of a major earthquake;
- Recommendations to **promote the use and understanding of seismic rating systems**, by rating and publicly displaying the ratings of all City-owned buildings, and to create a "Back to Business" program to expedite building inspections after earthquakes;
- A recommendation to **improve the resiliency of the LA water supply system**, including fortification of the aqueduct infrastructure and Department of Water & Power dams, replacement of older vulnerable pipelines with seismic-resilient pipelines; creation of alternatives to the use of the current water supply system for firefighting, and the creation of a Statewide Resilience Bond Measure to provide funds to invest in infrastructure resiliency; and
- A recommendation to **enhance the reliability of telecommunications**, including cell tower strengthening, installation of a city-wide solar powered Wi-Fi system to enhance communications following a disaster, protecting the electric power transmission system at

fault crossings to avoid cascading failures, and supporting the development and deployment of an advanced earthquake warning system in southern California.

The *City of Los Angeles Resilience by Design* report and the Program it created was developed by dozens of people under the direction of Lucy Jones of the USGS, who served as Science Advisor for Seismic Safety. Dr. Jones and the Mayor's Office held over 130 meetings with City Department staff, community members, private sector partners, and industry stakeholders, as well as subject matter and technical experts in the fields of building, engineering, and seismic resilience to inform the recommendations that would ultimately form the body of the report.

Category:

Extraordinary Innovation in Seismic Protection of Buildings and Lifelines

Awarded to: Association of Professional Engineers and Geoscientists of British Columbia, University of British Columbia's Earthquake Engineering Research Facility, and the British Columbia Ministry of Education

for: Development of Performance-Based Seismic Retrofit Guidelines for Schools

Award Citation:

Recently developed performance-based *Seismic Retrofit Guidelines* and a unique state-of-the-art web-based *Seismic Performance Analyzer* enable structural engineers to rapidly and consistently determine the seismic risk of existing buildings and optimize retrofits to achieve "life-safety" seismic performance. These *Guidelines* and companion *Analyzer* are now being used by the British Columbia Ministry of Education in a billion-dollar-plus seismic mitigation program for school buildings that has been designed to achieve a life-safety standard for schools by minimizing the probability of local structural collapse during a seismic event.

Developed by the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) and the University of British Columbia's Earthquake Engineering Research Facility, and documented in a nine-volume, 300+ page manual, these innovative *Guidelines* are being used to significantly minimize the risk of fatalities and serious injuries for the occupants of approximately 320 British Columbia schools. This translates to increased life-safety for approximately 150,000 school children, as well as approximately 7,500 teachers and school staff in British Columbia's high-risk seismic zones.

The companion *Seismic Performance Analyzer* accesses the program-developed database containing millions of non-linear incremental dynamic analyses for different structural systems and types of high-risk partition walls, for different site soil conditions, evaluated for three different types of earthquakes expected to occur in British Columbia. Users can rapidly and with province-wide consistency determine the seismic risk of an existing building, and optimize the extent and cost of new structural components required to achieve a life-safety seismic performance.

The use of the *Guidelines* by the structural community has proven to: relieve structural engineers from selecting earthquake ground motion records or carrying out non-linear analyses; offer the capability of mixing different new structural systems in combination with existing systems; be an effective way to utilize all available information on an existing building in the risk assessment; and be effective in selecting a very efficient, cost-effective retrofit scheme for a building.

The reduced cost of seismic retrofits compared to previous approaches; enables more school buildings to be upgraded, and made safer, within the available Ministry budget.

The British Columbia performance-based *Seismic Retrofit Guidelines* and companion *Seismic Performance Analyzer* began with planning, engineering design and research and resulted in cost-effective seismic assessment and retrofit strategies, followed by implementation across a large inventory of schools. The benefits achieved by this research and development effort are not limited to British Columbia, as the resulting methodologies and techniques can have tremendous positive impact on earthquake safety and retrofit worldwide.

Category:

Extraordinary Innovation in Seismic Protection of Buildings and Lifelines

Awarded to: Transbay Joint Powers Authority and Design and Construction Team

for: Transbay Transit Center, San Francisco

Award Citation:

The multi-billion Transbay Transit Center in downtown San Francisco is a landmark project. This innovative facility will be the centerpiece of a major urban development plan that embraces modern transportation solutions (including future high-speed rail) to create a sustainable and resilient community. The new Transit Center is the heart of this new neighborhood, which will include new tall office and residential buildings and will reshape San Francisco for the next century. The Transbay Joint Powers Authority, which is responsible for the financing, design, development, construction, and operation of the Transbay Program, is also engaged with the city to promote earthquake resilience of the Transit Center itself and buildings in the surrounding neighborhood.

The Transbay Transit Center building consists of six levels: (1) Train Passenger Platform Level, (2) Lower Concourse Level, (3) Ground Level, (4) Second Level, (5) Bus Deck Level (elevated), and (6) Roof Park Level. The Train Passenger Platform Level and Lower Concourse Level are the below grade levels referred to as the Train Box, which is concrete construction. The above grade structure is a steel framed building, consisting of steel Special Moment Frames (SMF) in the transverse direction (north-south) and Eccentrically Braced Frames (EBF) in the longitudinal direction (east-west) created by inclined exterior pipe columns (and an edge girder) to allow space for bus lanes on the ground level. Typically, the interior columns for the superstructure are transferred at the Ground Level by steel transfer girders that are 6 feet or deeper.

The design of the Transbay Transit Center building employed a performance-based approach using non-linear analysis tools and accommodated unique architectural features while meeting a tailored seismic performance target. Innovative aspects of the design process included:

- Consideration of three ground motion performance levels—motions having a 50-year (frequent earthquake), 975-year (rare earthquake), and 2476-year (very rare earthquake) return period;
- State-of-art nonlinear soil/structural interaction analyses to determine the seismic input to the structure, a finite element geotechnical analysis of the site to simulate site mitigation

measures to prevent undermining of neighboring buildings, and an unprecedented real-time geotechnical instrumentation network;

- The establishment of acceptance criteria for deformation-controlled actions based on fragility studies and verified with full-scale cyclic tests; and
- The confirmation of plastic hinge (fuse) performance of the steel moment frame connections and EBF link beams (which are larger than those tested in the past) through full scale cyclic testing at the University of California, San Diego.

Stringent requirements set forth by the Transit Joint Powers Authority governed the design of this landmark building. Photos are available at http://www.transbaycenter.org/media-gallery/image-gallery.

Category:

Extraordinary Innovation in Seismic Protection of Buildings and Lifelines

Awarded to: San Francisco Public Utilities Commission (SFPUC)

for: SFPUC's Water System Improvement Program

Award Citation:

Initiated in 2002, the San Francisco Water System Improvement Program (WSIP) is a $4.8 billion dollar, multi-year capital program to upgrade the San Francisco Public Utilities Commission's regional and local water system, which extends 167 miles from the Hetch Hetchy Reservoir to San Francisco and crosses the Calaveras, Hayward, and San Andreas Faults. Financed by a San Francisco voter-approved bond measure and supported by the 26 wholesale customer agencies represented by the Bay Area Water Supply and Conservation Agency (BAWSCA), the program will deliver capital improvements that enhance the Commission's ability to provide reliable, affordable, high quality drinking water in an environmentally sustainable manner to 2.6 million people in the greater San Francisco Bay Area. The program consists of 83 projects to repair, replace and/or upgrade major portions of the water system, including treatment facilities, pipelines, tunnels, dams, reservoirs and tanks—35 local projects located within San Francisco and 48 regional projects, spread over seven counties from the Sierra foothills to San Francisco. Currently, the Program is approximately 90% complete. Examples of key seismic projects* within the program include

- the replacement of the 220-ft high Calaveras Dam to address seismic deficiencies with the existing dam;
- the construction of several new water tunnels, including the 3.5-mile-long New Irvington Tunnel and the new 5-mile-long Bay Tunnel (first tunnel under San Francisco Bay) to provide system redundancy to increase seismic and delivery reliability;
- seismic and other upgrades to both the Sunol Valley Water Treatment Plant and the Harry Tracy Water Treatment Plant to increase the maximum delivery rate of these plants for up to 60 days after a major earthquake; and
- several projects to increase reliability of water transmission across major fault crossings, including a unique project where two of SFPUC's large-diameter regional pipelines cross the Hayward fault – the project utilizes an articulated concrete vault and secant pile walls to

absorb energy, and ball/slip joints and pipe supports with sliding mechanisms to release energy during large fault displacements.

The program also included the development of performance criteria for system-wide service after earthquakes, with short-term (24 hour) and long-term (30 day) levels of service goals for seismic reliability. Short-term service goals are based on delivering basic service (average winter month delivery) of 215 million gallons per day within 24 hours after a major earthquake, assuming that no significant repairs are performed during that period. The long-term performance criteria are based on making temporary repairs to restore average day delivery of 300 million gallons per day to customers. Photos are available at https://drive.google.com/folderview?id=0B9xlqjpm2PBLak5taGdEeVJhR0k&usp=sharing.

Category:

Exceptional Public- and Private-Sector Research and Development Programs

Awarded to: Pacific Earthquake Engineering Research (PEER) Center and Los Angeles Tall Buildings Structural Design Council

for: Development of Guidance and Procedures for the Seismic Design of Tall Buildings

Award Citation:

The Pacific Earthquake Engineering Research (PEER) Center's *Guidelines for Performance-Based Seismic Design of Tall Buildings* (2010) and the Los Angeles Tall Buildings Structural Design Council's *Alternate Procedure for Seismic Analysis and Design of Tall Buildings Located in the Los Angeles Region, A Consensus Document* (2005) were developed to address the design of many buildings that were taller than what was covered in the provisions of the prescriptive building code - because these taller buildings fell beyond the provisions of the code, they were each being designed with their own criteria.

These two guidelines were developed considering the seismic response characteristics of tall buildings, including relatively long fundamental vibration periods, significant mass participation and lateral response in higher modes of vibration, and a relatively slender profile. Following their publication, these landmark documents have been used for the seismic design of all major tall buildings in San Francisco, Los Angeles, Seattle and other west coast cities. The documents incorporate many new and innovative state-of-the-art features and have substantially advanced the practice of building seismic design. For example:

- The methods they prescribe have facilitated the development and implementation of new innovations in tall buildings, including capacity design of coupled core-wall buildings, buckling-restrained brace (BRB) damped outrigger systems for concrete core walls, and innovative mega-bracing systems that employ viscous dampers with inelastic BRB fuses;
- The provisions for peer review and building instrumentation, as required by Los Angeles, have served to advance the professional practice of earthquake engineering and risk mitigation.

- The documents have provided a framework that employs nonlinear dynamic analysis to evaluate the structural performance for service-level and maximum-considered-earthquake (MCE) level earthquakes, helping to formalize the latest thinking on how to characterize earthquake ground motions, systematically conduct nonlinear dynamic analyses, and evaluate design acceptance criteria.
- Methods that were formalized in these documents serve as a model for new procedures for nonlinear dynamic analyses in the FEMA-funded 2014 *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* that have been adopted for the forthcoming update to ASCE 7, *Minimum Design Loads for Buildings and Other Structures* (2016 edition).

More than 50 new tall buildings in Los Angeles, San Francisco, San Diego, and Seattle have been analyzed designed using these state-of-the-art guidelines, enhancing the response predictability and resilience of these important structures.

Category:

Exceptional Public- and Private-Sector Research and Development Programs

Awarded to: Federal Emergency Management Agency (FEMA)

for: Development of FEMA P-58 *Seismic Performance Assessment of Buildings Methodology* and companion *Performance Assessment Calculation Tool* (PACT)

Award Citation:

In 2012, the Federal Emergency Management Agency (FEMA) published the FEMA P-58 documents, *Seismic Performance Assessment of Buildings, Volume 1 – Methodology*, *Volume 2 – Implementation Guide*, and *Volume 3 – Supporting Electronic Materials and Background Documentation*, along with a companion electronic *Performance Assessment Calculation Tool* (PACT). Prepared by the Applied Technology Council and based on the framework for performance-based seismic engineering developed by the Pacific Earthquake Engineering Research (PEER) Center, the methodology has been developed for use in performance-based seismic design of new buildings and the retrofit of existing buildings. Results are expressed as probability distributions for potential casualties, repair costs, repair time, and posting of unsafe placards. Assessments can be conducted for shaking of a specified intensity; a specified earthquake scenario (i.e., magnitude-distance pair); or considering all earthquakes that may occur over a specified interval of time along with the probability of their occurrence.

The companion *Performance Assessment Calculation Tool* (PACT) can calculate and parse results by structural and nonstructural performance groups, direction, story level, and realization for each performance measure, including repair cost, repair time, casualties, and unsafe placarding. PACT also provides a range of options for viewing assessment results, and printing hard-copy reports.

In contrast to the current design approach of simply providing a code-compliant design, which most engineers expect to perform well for safety, but poorly for losses and downtime, the FEMA P-58 methodology is a game-changer because it will completely transform the way that structural engineers design buildings, because it can predict the important performance metrics (loss, downtime, and safety), and because the building design can be tuned specifically to meet those metrics. FEMA's foresight in identifying the need for the methodology and in promoting, funding, and overseeing its development over a 10-year period, at a cost of more than $12 million, are a remarkable testimony to FEMA's dedication to and perseverance in seismic hazard reduction.