Current Situation of Performance-Based Earthquake Engineering and its impact on California society relative to Sustainable "Green" design impacts

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Centered in Berkeley, California the Pacific Earthquake Engineering Research Center (PEER) is a major U.S. regional engineering research center established in 1997 by the State of California and the United States National Science Foundation. PEER's mission is to develop and disseminate performance-based earthquake engineering (pbee) technology throughout the Western USA in general and California in particular. PEER's main product, pbee, is a revolutionary new structural engineering design methodology that goes beyond traditional prescriptive design procedures and current building code force-based approaches. Pbee design decisions are based on expected consequences of earthquakes in terms of life safety or immediate occupancy, protection of structures and their contents, and the ability to use facilities after earthquake events. It does this by predicting likely facility performance in terms of drift, natural periods of oscillation, and casualty damage, dollar loss, and disruption of functions. This information allows the designer in coordination with facility owners to make better decisions about the effectiveness of various alternatives in controlling those consequences. As a result, pbee can be more efficient from a construction standpoint, perform more predictably, and be more reliable as a risk management tool than traditional, prescriptive-only design methods. In the long run pbee will result in safer, more reliable structures with lower life-cycle costs. The following is previous and projected casualty losses from specific earthquake throughout the world:

Causalities and Losses from Specific Earthquakes and Earthquake Scenarios

	Earthquakes	Deaths	Injuries	Property Damage & Economic Loss
Previous	1971 Sylmar, CA Earthquake (EQ)	65	2,400	$0.5 billion
	1989 Loma Prieta, CA EQ	62	3,757	$10 billion
	1994 Northridge, CA EQ	57	9,000	$20 billion
	1995 Kobe, Japan EQ	>5,500	>26,000	$250 billion
Projected	Scenario 7.0 Hayward fault, CA	>4,000	>25,000	$100 billion
	Scenario 7.4 event on the Puente Hills fault, Los Angeles, CA	3,000-18,000	56,000-268,000	$80-250 billion
	Repeat of the 1906 San Francisco, CA EQ	800-3,400	23,000-62,000	$90-120 billion
	Scenario 7.0 Newport-Inglewood fault, Long Beach, Los Angeles, & Orange County, CA	2,000-6,000	20,000	$200 billion

Source: California Seismic Safety Commission

To address all of this, PEER has so far applied pbee via certain client entities an apparent impressive looking number of achievements throughout the State of California. Strong examples of these include the following:

Example #1: The Bay Area Rapid Transit (BART) system was constructed in the 1960s and 1970s. Built to seismic standards considered high for the time, recent research indicates that the system has both life safety and post-earthquake operability deficiencies. PEER helped develop a cost-effective program using performance-based procedures to meet life safety objectives and shorten times for restoration of train service after earthquakes.

Example #2: The earthquake safety and sustainability of California's institutions of higher learning have also benefited tremendously from the use of performance-based earthquake engineering and PEER's research results. In 1997, the University of California at Berkeley (UC) embarked on an aggressive program to upgrade seismically deficient buildings using PBEE. Costs for these improvements were substantially less than bringing UC's buildings into compliance with older, prescriptive, force-based codes for new buildings. UC was able to be more flexible in its allocation of funds, meet its budget, tailor its building performance objectives, and spend its retrofit funds more efficiently with PEER's help.

Example #3: PEER has also developed the OpenSees computer program for simulating the complex performance of structural systems in earthquakes. OpenSees has become a widely accepted, web-based application for analyzing structures under various loading conditions.

These good examples of pbee usage are often limited to specific niche area sectors of the California professional community. At large however, overall general impact of pbee is not as impressive. A recent rough unofficial survey of the number of pbee building designs that went through the building departments of three of California's largest cities have indicated the following: Los Angeles: 0; Long Beach: 6; San Francisco: 2.

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Thus in spite of pbee's benefits, this survey would apparently indicate that approximately 1% of the new California buildings have been designed so far using pbee. By other unofficial surveys and accounts, approximately 10 to 15% of the practicing structural engineers have so far heard of pbee, and of these approximately 5% have used pbee in their design practices. What's more, the current 2001 California Building Code (CBC) does not address pbee. Building department plan checkers are often not familiar with pbee and have to hire special consultants to perform the plan checking. In addition the design plans would need to be peer reviewed. This in turn would result in pbee costing more currently for design than conventional code-based design methods. Design cost increases are estimated at from 50 to 100%, depending on the practitioner's "learning curve." Given the further lack of pbee knowledge by most building owners, this in turn puts the pbee structural engineer at a distinct competitive disadvantage in the highly competitive design market. Given that design contracts are usually tendered separately from construction contracts, the end result is that rank and file structural engineers tend to shy away from using pbee even though pbee is more advanced and can result in significant structural-portion construction cost savings (25%).

As with pbee, **sustainable a/k/a Green design** also began in the early to mid-1990's. Its principal sponsor has been the United States Green Building Council (USGBC) headquartered in Washington, D.C. This program addresses the fact that in the U.S. buildings account for 65% of electricity consumption, 36% of total energy use, 30% of greenhouse gas emissions, 30% of raw material use, 30% of waste output (or 136 million tons/year), and 12% of potable water consumption. The USGBC's mission is to promote the design and construction of buildings that are environmentally responsible, profitable, and healthy places to live and work. In order to define, qualify, and certify green buildings, the USGBC created the LEED system. LEED, which stands for Leadership in Energy and Environmental Design. LEED encourages a holistic approach that guides an integrated and collaborative design, construction, and O&M process throughout the building's life cycle. Typically Green buildings cost between 1 and 5% more to design and construct but the overall benefits outweigh the costs. Benefits of Green buildings include reduced operating expenses including significant lower utility costs (30 to 50% typical), decreased occupant vacancy rates, increased productivity, improved occupant performance (student performance increases in day-lighted schools), reduced worker absenteeism, retail sales increase with daylighting of store spaces, and general increased health and happiness of workers. The following are the LEED certified point ranking system: Certified: 26 to 32 Points: Silver: 33 to 38 Points; Gold: 39 to 51 Points; and Platinum: 52 + Points (69 Possible).

As such the City of Long Beach is constructing its first LEED-Silver new building, namely MacArthur Branch Library. This 16,000 square-foot state-of-the-art library is currently 80% completed and features many sustainable developments including but not limited to waterless urinals, daylighting of the interior, recycled material usages, low VOC paints, no CFC hvac refrigerants, water efficient landscaping, low runoff storm water management, optimized mechanical energy performances, urban and brownfield redevelopment, public transportation access, and a sustainable design education display for the public.

The impact and growth in the United States of sustainable "Green" design has been phenomenal. As opposed to only a handful of pbee-designed public buildings, there were over 5,000 registered and certified buildings in 2006. This accounts for over half a billion square feet of space. To add to this there are now over 35,000 LEED accredited professionals. Today, there is widespread popularity of Green design by a growing number of designers, owners, managers, and elected officials.

Why has green design taken off while pbee hasn't? The different approaches of U.S. engineers vs. U.S. architects may offer a clue. Engineers tend to be more cautious with the public and with their peers, so much so that often they are waiting for the "other parties" before making policy decisions. For example, when a new methodology is developed by a center such as PEER, engineers tend to then organize selective ad hoc committees who would present the new method to national institutions such as FEMA pursuant to establishing new guidelines. Later these guidelines may become engineering standards via such institutions as ASCE. Official building code committees may also then be established. By this slow methodical process, the time required for a newly developed design method to become part of an adopted building code may be 10 to 15 years. For example today even though we are presently using the 2001 CBC, the stipulations are really the 1997 Uniform Building Code. For sustainable design, architects have taken a totally different path. By first establishing a strong dynamic organization such as the USGBC, which established good connections, green architects have deftly and effectively led and accelerated not only the development of green design but also its usage via deft public outreach, education, and training. This approach has been so successful that green architectural professionals have forced the building departments and code committees to "catch up."

Architects' more proactive and aggressive general approach stands in stark contrast with engineers' more cautious approach. First of all the green design subject matter is more tangible to the average person compared to earthquakes, which are less understood and sporadically occurring in nature. Secondly public attention is consistent for green design, especially in this day and age of increased pollution and Global Warming; whereas the attention on earthquakes diminishes non-linearly with the passage of time after the last major event. For example in California there were several major earthquakes in the 1990's, which in turn resulted in very strong public attention and concern for earthquakes and earthquake safety at the time. Presently, after over 13 years since the last major earthquake (Northridge 1994), public attention appears very low. In order to rectify this, we civil engineers need to change our thinking and adopt new holistic strategies and approaches including a) adopting more aggressive, less cautious approaches, b) leading and not following, c) learning better marketing, outreach, and public relations skills, d) thinking more populously, e.g. working with decision makers and elected officials in establishing special tax incentives and benefits for profession design use of pbee, and e) thinking more idealistically about the human occupants who're at greater risk by not having pbee design in their structures and buildings. Finally, instead of asking the question "why use performance-based earthquake engineers," we engineers should really be asking "why are we not yet using pbee."