Seismic Strengthening of Buildings in Los Angeles

By Michael Cochran, S.E., SECB, Dilip Khatri, Ph.D., S.E., Kevin O'Connell, S.E. and Doug Thompson, S.E.

Los Angeles is no stranger to earthquakes and, like other cities in California, has experienced extensive damage in previous seismic events, which has led to significant advancements in earthquake engineering. Some might say that L.A. has been the epicenter of seismic code development since the 1933 Long Beach Earthquake. Because of its long history with seismic events and their aftermath, Los Angeles has embarked in a leadership role to create a long-term program to educate the public, help building owners to seismically strengthen their buildings, and improve overall community resiliency after the next earthquake.

The impetus for this retrofit program started with a few articles published in the *Los Angeles Times* when a reporter got wind of a study being done at the University of California at Berkeley on non-ductile concrete buildings, which indicated that potential "collapse hazards" exist. This news spread like wildfire, and since then, the *Times* has been on top of this story with periodic coverage that has raised public interest in the topic of seismic strengthening and community resiliency. Mayor Eric Garcetti has issued a report to help improve the seismic preparedness of the city which addresses telecommunications, water system infrastructure, and building vulnerability. The report calls for proposed ordinances, several of which relate to buildings and structures:

1) Seismic Retrofit of Existing Wood-Framed Soft-Story Buildings
2) Seismic Retrofit of Existing Non-Ductile Concrete Buildings
3) New Cell Phone Communication Tower Design Requirements

The mayor created an Earthquake Technical Task Force, among several task groups, which brought together people from the City, Dr. Lucile Jones from the United States Geologic Survey (USGS), and structural engineers from the Structural Engineers Association of Southern California (SEAOSC). This task force provided advice and recommendations to Mayor Garcetti as the mayor's office went about writing a report that summarizes some of the city's vulnerabilities to a major seismic event: *Resilience by Design* (**www.lamayor.org/earthquake**).

The report, released in December 2014, covers major seismic risks to the city's infrastructure, and documents past disaster events that had serious impacts on other local economies. One fascinating observation is the effect that the 1906 San Francisco Earthquake had on California's demographics. Prior to that year, San Francisco was California's largest city (population approx. 400,000), but the earthquake and fire aftermath produced considerable migration south to Los Angeles as the U.S. population moved westward, approximately doubling the population from 150,000 to over 300,000 in the City in just four years. By 1920, the population of Los Angeles had surpassed that of San Francisco, making it the new economic center for California (*Figure 1*). After 100 years, San Francisco and the bay area have only recently, in the last two decades or so, been able to recover to a similar relative economic status with the development of Silicon Valley and the growth of powerhouse internet software/manufacturing companies like Apple and Google.

In a similar context, the economic damage to New Orleans from 2005 Hurricane Katrina is illustrated in *Figure 2* with a comparison to a similarly sized city with a similar economy and demographic, Nashville, Tennessee. The immediate financial loss suffered by New Orleans ($80 Billion) is exceeded by its lost potential financial gains over the next 7 years when compared with Nashville.

It has also been observed that when the immediate financial loss from the disaster approaches or exceeds the annual real growth domestic product of the community, it becomes very difficult to rebuild the community as existing resources (infrastructure, building stock, financial services, labor pool, available commodity goods and services, etc.) have been greatly depleted or wiped out. Resulting shortages greatly restrain the recovery effort, often for many years afterwards, as communities attempt to rebuild, in some cases from nothing. It has been ten years since Hurricane Katrina, and New Orleans has still not recovered to its original economic capacity.

The obvious conclusion in both of the above scenarios is that major disasters have long-term economic effects that can be irreversible, or at least take many decades to economically recover.

Los Angeles City and Los Angeles County have the largest population concentration (approx. 3.8 million/10.1 million respectively) in California and constitute a major economic hub within the state, which is a significant component of the United States gross domestic product (GDP) – approximately 10%. A major earthquake in the communities that make up the Los Angeles basin, or San Francisco bay area, could severely cripple the state economy and have a corresponding impact on the U.S. economic output. Mayor Garcetti's initiative to create a seismic strengthening program is a unique approach, different than that attempted by his predecessors, and reflects his willingness to take on a monumental challenge.

The agenda of the program covers many topics beyond just buildings. Telecommunication facilities, water delivery, and power substations are among the lifeline infrastructures that are also addressed in the Mayor's *Resilience by Design* report. But the seismic retrofit of both existing wood-framed soft-story buildings and non-ductile concrete buildings are of the most interest to the structural engineering community.

Wood-framed soft-story buildings and non-ductile concrete buildings are considered to have a high collapse potential during an earthquake, putting the occupants at great risk. The poor performance and loss of life in these existing building types during the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge Earthquakes have confirmed their vulnerability.

The creation of the LA Mayor's task groups to look at the threat of loss of life and impact on the economy from building failures in the aftermath of an earthquake afforded the local structural engineering community the opportunity to offer their technical advice on how to improve the performance of these buildings. An important distinction has to be made when participating in a task group such as the Earthquake Technical Task Force. As structural engineers, we can provide the professional technical expertise on how to help mitigate building failures during earthquakes and discuss associated risks associated with doing nothing. But this is where our advice typically needs to stop when working to develop a mandatory or voluntary seismic retrofit ordinance to be adopted by a local jurisdiction.

Besides the technical engineering aspects of any ordinance, there are also the economic, social, and political aspects that must be considered by the government jurisdictions. As engineers, we typically want to see hazard mitigation methods implemented as soon as possible. Here is where we have to learn patience. Time frames for adoption and implementation of any seismic retrofit ordinance have to be left in the hands of the local government officials and staff to determine the amount of time it will take to get community buy-in regarding adopting such ordinances. As the costs increase for any mandated seismic retrofit, the time frame for compliance must also increase so as not to immediately impact building valuations, and building owners need time to strategize the best methods for mitigating the earthquake hazard given their particular property.

There will be occasions when the local jurisdictions decide *not* to move forward on adopting and implementing any mandatory seismic retrofit ordinances. This has been the case in Los Angeles for many years, since the 1994 Northridge Earthquake, with the City only able to adopt a voluntary seismic retrofit ordinance for several vulnerable building types. In such cases, the only thing the structural engineering community can do is attempt to further educate the general public about the seismic risks and the necessity for adopting mandatory seismic retrofit ordinances. Ultimately, the general public has to buy-in to implementing mandatory seismic retrofit ordinances, as elected government official's work on behalf of their communities and cities.

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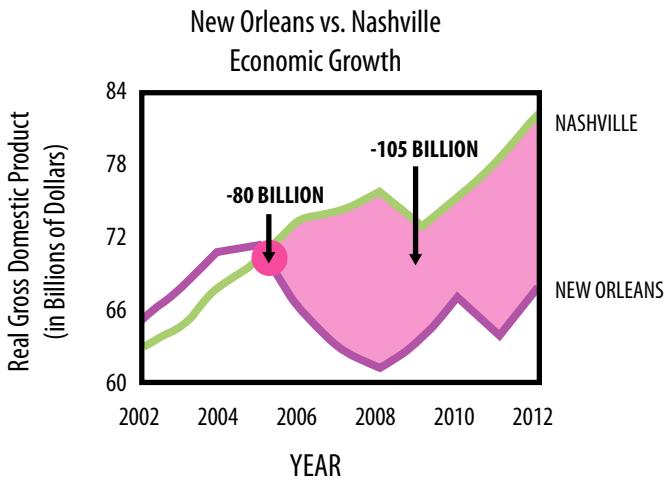

Figure 2. The Gross Domestic Product of Nashville, TN and New Orleans, LA Metropolitan area per year. Data Source: U.S. Bureau of Economic Analysis, Google Data (Los Angeles City Resilience by Design Report, 2014).

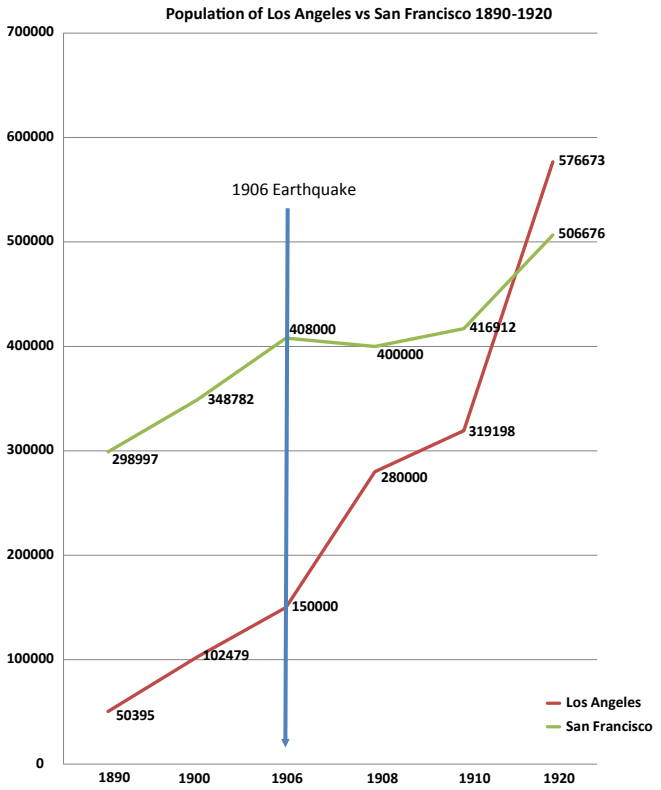

Figure 1. The population of the cities of San Francisco and Los Angeles (U.S. Census Data). The population of Los Angles grew fourfold in the decade after the 1906 earthquake struck San Francisco (Los Angeles Resilience by Design Report, 2014).

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In the cases of the proposed wood-framed soft-story building ordinance and the non-ductile concrete building ordinance, the Mayor's office task groups did something different than had been done before while developing seismic retrofit ordinances. They engaged the stakeholders, including the apartment building and commercial office/retail/manufacturing building owners, to understand their concerns and get their input regarding seismically retrofitting their buildings. These owners were specifically targeted since their buildings have high occupancy loads. *This was a fundamental change in approach*, as now the building owners were becoming part of the development process, instead of being typically placed in a reactionary position where they may be uninformed about the issues and have to respond to city mandates. Having all parties involved in the initial conversations has led to better developed ordinance language, with a greater chance of successful adoption.

The Mayor's report also addresses adopting a voluntary rating system for estimating individual buildings' earthquake performance.

The voluntary building rating system is designed to encourage building owners to invest in their existing facilities and to consider new construction that exceeds current minimum building code requirements. This will likely make their buildings able to be re-occupied and put back in use sooner after a major earthquake, and thereby help the overall community recover faster.

A building rating system informs the community about building risks such as earthquakes related hazards. It creates a system that evaluates new and existing buildings based on three separate dimensions: Life Safety, Damage (Repair Cost), and Recovery (Time to Regain Basic Function). A rating can be given for each dimension. The concept is to "encourage" building owners to design new buildings to a higher performance level or to perform seismic retrofit projects voluntarily. Strengthened facilities will be more desirable to the earthquake-aware public and their tenants than older buildings that are still vulnerable or new buildings that are not designed to higher performance standards.

An offshoot of such a rating system is that the community can have a better understanding of their building stock's vulnerabilities to natural hazards such as earthquakes. This information allows the community to be able to formulate preparedness plans to help reduce the impact when the next earthquake occurs, and implement recovery plans after an event to help the community recover faster economically.

To encourage the residents of Los Angeles City to pursue *voluntarily* rating of their own buildings, the Mayor's office is proposing to lead by example and is tentatively looking to have some city-owned buildings rated for earthquake performance. The city has consulted with the United States Resiliency Council (USRC) regarding how the city's building department might proceed in rating city-owned buildings. More information about the USRC, building rating systems, and getting one's building professionally rated can be found at (**www.USRC.org**).

Ordinance Status

The mayor's office is currently working through the details of the ordinances identified in his report with the City Council, and has the goal to adopt and implement them into law before the end of this year. This program initially created quite a stir locally, putting structural engineers in the center of the discussion with owners, public officials, and the general public through extensive coverage by the *Times* and public town-hall meetings around the city. The ordinance adoption process by any jurisdiction can be lengthy, as the ordinances usually must pass through both economic and legal due-diligence reviews by a series of the jurisdiction's own internal committees.

Preliminary drafts of the building seismic retrofit ordinances recommended in the Mayor's *Resilience by Design* report were submitted to the Los Angeles City Council in January 2015. The ordinance requiring construction of new cellular communication towers to be designed for an importance factor of 1.5 passed rather quickly, and was adopted in March 2015. In September 2015, both the wood-framed soft-story building and non-ductile concrete building ordinances were heard by the City Council and forwarded to the city attorney's office for final review. It is anticipated the City Council will vote on the approved ordinance language from the city attorney's office sometime in October.

SEAOSC has been actively involved with the mayor's office and the Los Angeles City Building Department to provide support in developing the technical engineering recommendations for these seismic retrofit ordinances. The seismic retrofit ordinance compliance timelines, currently under consideration by the City Council for implementation, range from five years for wood-framed soft-story buildings to thirty years for non-ductile concrete buildings. It seems like a long time, but the big issue with earthquakes is that we simply do not know when the next "big one" will hit, and without moving forward towards better performing buildings and a more resilient community, we will be no better off than if we did nothing. We can't afford to do nothing.▪

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City Council Update

On October 9, 2015, the Los Angeles City Council adopted both the mandatory Wood-Framed Soft-Story seismic retrofit and the mandatory Non-Ductile Concrete Building seismic retrofit ordinances. The Los Angeles City Department of Building and Safety now begins the task of implementing both of these ordinances, and notifying the building owners identified as owning either of these two types of buildings that they are required to comply with these mandatory ordinances. It is likely that first notices will be sent out to the building owners towards the end of this year or the first few months in 2016.