Community Resilience through Mandatory Retrofit Ordinances

What is the Role of the Structural Engineer?

By Erica Fischer, P.E., Keith Porter, P.E., Ph.D., and Elaina J. Sutley, Ph.D.

Disasters are occurring with increasing severity and frequency [NOAA 2018]. Communities are also shifting design objectives to consider building functionality. As the severity increases and the design objective shifts, design standards generally rise with higher strength levels and stricter detailing requirements. With each code revision that raises safety levels, and/or incorporates increasing disaster intensity, a higher percentage of the existing building stock is deemed insufficient to meet the current design standards. The result is extraordinary federal, state, and local government spending on both disaster recovery and disaster preparation. For example, the Cascadia Subduction Zone, a roughly 622-mile (1,000 km) megathrust fault off the coast of British Columbia, Washington, Oregon, and Northern California, was discovered in the late 1980s. This means that structures in Oregon and Washington designed and built before this time were not designed to resist the forces that could be imposed on a structure in a potential magnitude 9.0 earthquake due to the rupture of this fault. Many buildings in lower Manhattan, Miami, and the Florida Keys are not designed for the flooding experienced over the last ten years. The increased frequency of disasters prevents communities from fully recovering before they are subjected to the hazard again. At the time of this writing, the island of Puerto Rico has only begun to recover from Hurricane Maria, yet the island was forced to prepare for the next hurricane season.

Governments face the choice of either paying to recover from disasters after the fact or implementing pre-disaster mitigation to avoid damage and loss in the first place. Extensive studies performed by the National Institute of Building Sciences' Multihazard Mitigation Council [MMC, 2017] have shown that, on average, every dollar spent to mitigate existing public-sector buildings before a disaster saves six dollars in property losses, additional living expenses, business interruption, indirect economic losses, and the value of avoided deaths, injuries, and instances of post-traumatic stress disorder. MMC found that it is more economical to spend money on pre-disaster mitigation and retrofit buildings for the new level of hazards rather than responding after a disaster. MMC also found that design of new buildings to exceed certain requirements of the 2015 I-codes can also prove cost-effective, saving on average \$4 for every \$1 in additional construction cost for new construction. Pre-disaster mitigation and retrofits could reduce sheltering and relocation needs for households, maintain business continuity, and prevent disruption to education either through school building damage or emergency sheltering use of the facility. Pre-disaster mitigation also can be planned and undertaken at a predictable, practical rate, rather than being suddenly and urgently required because of an unpredictable disaster. Cost effective, controlled mitigation results in a more stable social, economic, and political fabric of a community.

Some communities adopt mandatory retrofit programs for classes of vulnerable buildings. Often these retrofits do not bring old buildings to current code levels, but instead aim to reduce the danger posed by well-known weaknesses in common, vulnerable building types. Other than understanding structural vulnerabilities, it is important to ask "what is structural engineering's role in mandatory retrofit ordinances?"

Destruction in Armatrice, Italy, following an earthquake in 2016.

For example, many California communities have required mandatory strengthening of parapets and other elements of unreinforced masonry bearing-wall buildings, as opposed to the much costlier effort to demolish the buildings or to replace their structural systems to meet current code. Other examples of seismic vulnerabilities addressed by mandatory retrofit programs include soft-story conditions on apartment buildings, roof-to-wall connections on tilt-up concrete buildings, and strengthening of older reinforced concrete buildings. Decisions about what well-known deficiencies to mitigate, and how to do so, often seem to be driven by the knowledge that the deficiency exists, that it threatens safety, and that certain mitigation measures can be affordably implemented. That is not to say that these mandatory ordinances are driven by rigorous cost-benefit analysis or other canonical decision processes. More often, they seem to show an intuitive, ad-hoc decision-making process.

The ad-hoc nature of past retrofit ordinances raises many questions. At the 2018 ASCE Structures Congress in Ft. Worth, Texas, an expert panel discussed the challenges associated with developing mandatory retrofits, after which the panelists and session attendees participated in break-out discussions. During the discussions, participants examined several issues:

- Who pays for the retrofit?
- How does a community ensure that vulnerable populations are not left behind and do not end up living in the most vulnerable buildings in a community?
- Who decides what buildings have mandatory retrofits and what performance level are these buildings retrofitted to?
- How can society consider all of the different stakeholders and their potential biases?
- What is the risk that is accepted by the public when we do not retrofit unsafe, structurally deficient buildings?
- How can costs and benefits be equitably shared by the various stakeholders?
- How can society incentivize mandatory retrofits?
- What is the role of the structural engineer in developing mandatory retrofit ordinances?

For brevity, we have chosen three of these questions to explore and provide discussion within this article.

What Risk is Acceptable to the Public?

What risk does the public prefer? Let us first narrow the question by considering the breadth of risk measures one could discuss. Public and proprietary catastrophe risk analyses commonly measure risk in terms of collapse, life-threatening structural damage, fatalities and nonfatal injuries, and several measures of monetary loss.

Which of these measures matter most to the public? First: who is the public? Davis [1991] and Davis and Porter [2016] argue that "the public should be understood as including all those anywhere whose lack of information, technical knowledge, ability, or conditions for adequate deliberation renders them more or less vulnerable to the power that engineers wield on behalf of client or employer. The public is a collection or aggregate rather than an organized body. Unlike an electorate or corporation, it has interests, but no decision procedure – no will of its own." ASCE's Code of Ethics supports this conclusion, in that the Code of Ethics clearly distinguishes the public from the individual engineer, the engineer's employer, and the employer's client, and holds paramount – above the rest – the health, safety, and welfare of the public, that is, over the interests of the other groups.

So, which risk metrics matter most to the public? The FEMA P-58 project may represent the first attempt to identify "those aspects of earthquake-related risk that are of most concern to… stakeholders." Its authors held a workshop in 2001 to decide which measures to focus on as they developed a second generation of performance-based earthquake engineering procedures (Applied Technology Council, 2002). The workshop discussion assumed that life safety was provided and, therefore, the risk metrics discussed were financial loss, business interruption time, and building re-occupancy.

Davis and Porter (2016) present a large (800-person) public-opinion survey of adults in California and the central United States. The survey focuses solely on the perceptions and preference of the public for the seismic performance of new buildings. The survey asks which of a narrower set of risk metrics mattered most to the respondents. Respondents cared most about the total number of community casualties (deaths and injuries) in a large earthquake.

In answer to the question of the level of fatality risk that is actually placed on the public in a large metropolitan earthquake, ShakeOut and HayWired (among other earthquake scenarios) suggest fatalities could reach thousands and nonfatal injuries could reach hundreds of thousands. With regards to what the public prefers, Davis and Porter (2016) suggest that the majority of respondents think that new buildings ought to be at least occupiable after a large urban earthquake. Davis and Porter (2016) findings suggest that respondents would be willing to pay the likely additional cost to achieve that level of performance. This performance level is in stark contrast with what the building code intends to provide, which is essentially life safety (via a low collapse probability), even if buildings cannot be quickly, or even economically, repaired. Thus, the level of risk accepted by the public when we do not retrofit unsafe, structurally deficient buildings is a level that is much higher than the public's preference.

Who Benefits from Mandatory Retrofits and Can Costs Be Shared?

The benefits of retrofits can accrue to occupants, owners, lenders, local jurisdictions, and anybody who visits or does business directly or indirectly with them. Depending on the intended increase in performance level, retrofits save lives, avoid search-and-rescue costs, reduce or avoid repairs, reduce business interruption costs, reduce insurance costs and claims, preserve tax revenues, and reduce costs for emergency sheltering. The less damage a disaster causes, the more likely there will be sufficient resources available to recover from it, the quicker the recovery, and inherently the more resilient the community grows.

Two crucial caveats of retrofits, stemming from the same attribute, must be addressed: retrofits are expensive and, without coupling appropriate funding mechanisms, retrofits can exacerbate the intersection of physical and social vulnerabilities in a community that will ultimately lead to unequal disaster impacts and differential recovery rates across cross-sections of communities (Sutley 2018).

Mandatory retrofits increase employment opportunities in the construction industry, including material suppliers, construction trades, construction contractors, structural engineers and architects, and the banks and other lenders that finance the work. On the other hand, in many cases, mandatory retrofits are viewed as a burden to building owners, who work to oppose them before they can be implemented. If not appropriately explained, even the general public can work against efforts to develop mandatory retrofit ordinances. In Portland, the public started a petition in response to the development of a mandatory ordinance to retrofit unreinforced masonry bearing-wall buildings. This petition (**https://saveportlandbuildings.com**) asks for more equitable solutions so that social disparities do not become exacerbated through a mandatory retrofit ordinance.

Communities have choices to make when examining resilience and hazard mitigation. There are many options. Two of them include (1) re-zoning to remove people and infrastructure out of the most hazardous geographic areas of the community (i.e., moving people out of floodplains and away from active faults), and (2) retrofitting buildings and other structures within the hazardous regions to better withstand the hazard. These decisions can be easier in some communities than others depending on financial resources, political engagement, and available land. Rezoning to reduce flood damage is more straightforward than rezoning to reduce damage from earthquake shaking.

The cities of Boulder, Colorado, and Nashville, Tennessee, purchased land in the floodplain from private owners after floods in those communities in 2013 and 2010, respectively. The land was converted to green space. In Nashville, it was managed by non-governmental organizations and non-profit corporations. In the case of seismic hazards, however, rezoning has limited application: one can rezone to avoid building across mapped active faults, as in the case of California's Alquist-Priolo special studies zones, but not to avoid shaking.

When communities can practically address mitigation through zoning, mitigation is equitable, at least superficially, in that all groups, including vulnerable populations, are prevented from living in high-risk regions of a city. However, it may be that more flood-prone areas are those that cost less, in which case more impoverished populations may be moved and wealthier ones not. One can see this imbalance in equity as either more beneficial for the poorer populations (because their long-term risk is reduced to a greater extent) or more harmful (because they suffer the greater short-term disruption).

Another way to promote mitigation is through incentives: tax breaks and grants, for example. Both the California Earthquake Authority (**www.earthquakebracebolt.com**) and the City of Portland (**https://bit.ly/2CToDtd**) have provided mitigation grants to owners of single-family dwellings, although not to owners of multi-family units. When supporting funding mechanisms are not provided, tenants often absorb the cost through substantial increases in rent. Rent increases can lead to gentrification and hurt vulnerable populations, particularly low income and older adults and renters who cannot afford higher rent payments. Rent increases push low-income renters out, leaving them to seek what is left of affordable housing, often consisting of un-retrofitted buildings in their home city, or permanent relocation to other, more affordable cities.

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Thus, while the benefit of mandatory retrofitting is realized community-wide through decreased damage, disruption, and casualties, and minor spikes in the construction industry, the initial costs also need to be realized equitably. New financial mechanisms are imperative. It is not only up to public entities. Private insurance companies and banks can share the cost with building owners. Insurance companies often provide premium incentives for increasing safety through retrofits, such as the incentive program offered by the California Earthquake Authority, thus offsetting to some degree the owner's retrofit cost. Similarly, the National Institute of Building Sciences is working to develop a resilience mortgage with a lower interest rate for risk remediation.

What is the Role of the Structural Engineer?

The business of developing seismic retrofit laws and ordinances is difficult because nobody possesses both the technical knowledge and authority required to know what is possible and appropriate. Policy decisions are the domain of elected officials, who often set objectives and the broad outlines of methods in law, and then delegate implementation details to regulators. The problem is that most policymakers and most regulators lack engineering knowledge of disaster risk – they do not understand the size of the problem, whether there is a solution, what the options are, how much they cost, and how much good they can do. Engineers can estimate risk, identify mitigation options and the ways in which we can estimate risk, and calculate costs and benefits. However, engineers seem to have set the standard lower than the public's preferences, as evidenced by the gap between the building code's seismic performance objectives for new buildings (mostly life safety) and the public's apparent preference for buildings to withstand earthquakes and remain occupiable. The public's preferences are often balanced with or opposed by engineers' clients (such as developers and real estate investors) who are not representatives of the public, because of cost. How can engineers contribute meaningfully to practical solutions? The next section reviews the role of structural engineers in two efforts to develop mandatory retrofit ordinances.

Examples of Retrofit Ordinances

San Francisco Soft-Story Ordinance. In 2015, San Francisco implemented the first mandatory aspect of its Earthquake Safety Implementation Program (ESIP), requiring mandatory evaluation and retrofit of high-occupancy soft-story wood frame dwellings. That element of ESIP grew out of two important actions by structural engineers. In 2006, Pat Buscovich, a San Francisco professional engineer, gave an interview to a reporter at the local newspaper, the *San Francisco Chronicle* [Smith, 2006], recounting how soft-story wood frame buildings were known to represent a significant risk to San Francisco housing. Mr. Buscovich added that city officials and the engineering community had known about the problem at least since the 1989 Loma Prieta earthquake almost 20 years prior, but had done little to solve the problem. Engineers provided options and cost/benefit information. Representatives of the public identified the risk measures they cared about and, together, the engineers and public representatives made the policy recommendation. Finally, the San Francisco Board of Supervisors and the San Francisco Department of Building Inspection defined the scope, timeline, and implementation details of the mandatory ordinance. Each group contributed the best of their expertise, stayed in their own lane, and did not try to intrude in the domain of the others.

Los Angeles Resilience by Design. The 2008 ShakeOut scenario [Jones et al. 2008] highlighted several problem areas with existing buildings. As part of ShakeOut, Krishnan and Muto (2008) showed that a large southern California earthquake could realistically cause the collapse of several older high-rise steel-frame buildings. Their study was peer-reviewed by several highly regarded structural engineers. Similarly, Taciroglu and Khalili-Tehrani (2008) reminded ShakeOut participants of older nonductile concrete buildings that could collapse as well. Other studies addressed problems with telecommunications, oil and gas pipelines, fire following earthquake, water supply, railways, hospitals, and other topics.

Partly in reaction to ShakeOut, Los Angeles Mayor Eric Garcetti solicited help from USGS seismologist and local earthquake celebrity, Lucy Jones. Within a 1-year timeline, a mayoral task force that Jones led held more than 100 meetings with numerous engineering and other stakeholder groups. Of the many problems Los Angeles could address, the task force selected four problems to solve: pre-1980 non-ductile reinforced concrete buildings; pre-1980 soft-first-story buildings; water system infrastructure (including its impact on firefighting capability); and telecommunications infrastructure. The task force recommended detailed programs to mitigate risk in all four areas. In 2015, the City of Los Angeles passed Ordinance 183893, requiring the retrofit of pre-1978 wood-frame soft-story buildings and non-ductile concrete buildings. It also adopted seismic standards for new cellphone towers that require new freestanding cellphone towers to be built to the same seismic standards as public safety facilities, i.e., with an earthquake importance factor of 1.5. The Los Angeles Department of Water and Power has begun to implement an infrastructure resilience program, including the installation of new pipe at a critical tunnel and targeted pipe replacement to construct a resilient backbone grid of earthquake-resistant pipe.

Conclusion

In both examples above, structural engineers provided advice on the nature of the problem, the degree of risk, available mitigation options, and costs and benefits. This information allowed the public and their elected officials to make decisions that balanced public protection and economy. Communities looking to implement retrofit ordinances can look to these locales, the processes they followed, and the selection of participants with particular expertise as examples to follow. Structural engineers should continue to understand existing physical vulnerabilities and be capable of communicating the accepted risk of not retrofitting to their clients.▪

The online version of this article contains references.
Please visit **www.STRUCTUREmag.org**.

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