

Bracing for Disaster: Earthquake Resistant Architecture and Engineering in San Francisco, 1838–1933

**Stephen Tobriner, Heyday Books, Berkeley 2006.
Reviewed by Roger Bilham**

After every major earthquake nowadays, a SWAT team of engineers saturates the epicentral region armed with cameras and notebooks to record the story of what went wrong—and more importantly, what went right—with structures exposed to violent shaking. They must move fast to document vital evidence before it is lost to repair or demolition. Successes are incorporated into new building practices, and the construction industry is alerted to failed methods.

In Chapter 8 of Steven Tobriner's superb book on the nuts and bolts of San Francisco's buildings, he leads an imaginary Earthquake Engineering Research Institute (EERI) team through the damaged city hours after the 1906 earthquake. The fires on that fateful morning have yet to take hold, and although the roads are congested with spectators and debris, his team bravely bicycles through block after block, taking notes and photographs. The team's final report blames foundation failures, weak materials, and poor assembly for structural failures. But the report also describes earthquake-resistant structures—many of them constructed from reinforced masonry or wood—that rode out the shaking, and it reports with dismay on the unkind and thoughtless savagery to otherwise intact structures caused by falling chimneys and toppled masonry from neighboring buildings.

Tobriner's imaginary team has taken 100 years to write its report, but there are good reasons for this. The Seismological Society of America and the EERI had yet to be founded, and although Tobriner's ancestors were there, none of the city's architects or engineers were able to wander through the quake-torn streets before fire and the dynamite used to create fire-breaks destroyed much of the evidence for or against structural damage to brick buildings, wooden structures, sidewalks, and underground pipes. But the most remarkable thing about this engrossing book is that we find that San Francisco at the turn of the last century was a city largely ready for anything Nature had in store. Many of San Francisco's buildings were already prepared for a good shaking and surfaced by materials thought to resist fire; the city's streets were populated by dozens of fire engines and firefighters ready for action. So what went wrong? In a masterful job of engineering sleuthing based on photos, engineering drawings, and eyewitness statements, Tobriner has pieced together a conspiracy of misfortunes not envisaged by architects before 1906. And what a tale it makes!

His book dispels numerous myths about the 1906 earthquake. Many of us have thought of San Francisco as an unsuspecting duck vulnerable to a pot shot from a lurking killer

quake. In fact, due to earthquake damage in the preceding several decades, the city was home to numerous earthquake-resistant buildings, many of which survived the 1906 earthquake only to succumb to the fire. Some have survived to the present, and others have been dismantled (with great difficulty) to make way for new construction. Tobriner and his colleagues reverently watched the dismantling of some of the survivors—tough cement, steel bands and bolts, iron framework, keyed brickwork laid in thick courses—and note a host of experimental solutions to a persistent menace.

Even though the engineers who specified these experiments in earthquake resistance were not quite sure what happened in an earthquake, many of them had grasped the basic notions from the way in which buildings had been shaken in earlier earthquakes with increasing severity, in 1851, 1856, 1863, 1865, and 1868. They recognized that parallel layers of bricks separated more easily than sequenced cross-layers (Flemish bond), and that it was essential to hold buildings together in a tight elastic embrace of high-tensile steel so that the independent motions of the buildings' massive parts would not destroy the whole. They also recognized that damage was ubiquitously worse in the former swamps and infilled bays downtown and near the shores. Solutions involved monolithic foundations, steel-frame structures, steel-banded masonry, and tie-bars. These structures were tested by moderate shaking in 1892, 1893, and 1898 that left many complacent that the city had nothing to fear.

The section on the earthquake itself is a gripping and informative read. The clinical details of mechanical, political, and hydraulic failure and thwarted success are so much more interesting than the sensational but patchy tales of the earthquake that have hitherto been available. In some places it takes a real San Franciscan to follow the road nomenclature as the firefights unfold, but an abundance of labeled maps and figures are there to guide a Mongolian farmer or a diligent schoolboy from Hemel Hempstead to grasp the geography of the city.

Reinforced concrete had yet to be incorporated in San Francisco's buildings, but when it was introduced after 1906 it became a major contributor to suppression of the second of the city's nightmares—fire. The 1906 fire was the last straw. In the mid-nineteenth century the fires of San Francisco were a far bigger headache than earthquakes for architects, investors, and most of all, insurance companies. Insurance paid for rebuilding substantial parts of the city not once but after several fires, including the one that followed the earthquake of 1906. The temperatures in these fires were sufficient to crumble poor quality brick, soften iron, and burn boardwalks and wharves. Buildings that in isolation would have resisted fire had no hope when surrounded by incendiary neighbors. In 1906, fire-resistant buildings ignited from within when windows damaged by shaking and dynamiting digested embers that kindled rapidly through inner ventilation shafts. Some insurance companies

refused to honor fire insurance, and others fell back on escape clauses such as “no fire insurance shall apply to an earthquake-damaged building.”

Numerous anecdotal entries in Tobriner’s book add spice to his engineering insights. To cite just a few: Redwood was considered not just fire resistant but nonflammable. Heinrich Schliemann, a Sacramento gold dust merchant who later became the archaeologist who excavated the precious metals and bricks of Troy “to gaze on the face of King Priam,” comments scathingly on the lack of fire resistance of cast iron and bricks in 1851 San Francisco. Mark Twain describes the ground waves and multiple shocks of the 1865 quake. Tobriner’s analysis of some better known anecdotes of San Francisco is just as fascinating. For example, he discusses the missing report on the 1868 Hayward earthquake that was rumored to have been destroyed by a city anxious to attract investment (Tobriner concludes the report simply never was written by a committee—like many nowadays—too busy with other matters) and the myth that 1906 rubble-fill was responsible for lateral spreading of the Marina District in the 1989 Loma Prieta earthquake (the region was carefully filled with selected offshore aggregate and hosted an earthquake-resistant pile-supported world-expo building before its present development).

But the real joy of this book, despite its revealing and insightful engineering for real engineers, is that it translates earthquake resistance into something we can all understand. We learn not just about the mechanics of buildings, but about the workings of the mind of the engineer. It is really very odd

that our public buildings, unlike cars, are never replicated. Each structure is different, not so much to satisfy the quest for architectural uniqueness but for reasons of footprint, soil conditions, sky access, and function. Earthquake resistance must be calculated from scratch for all major structures and in many cases simulated in computers to ensure that the right combination of stiffness, elasticity, and damping has been achieved. Any reader who needs to answer questions from the public about earthquake engineering will get a lot out of this book. Anyone interested in the history and future of construction in San Francisco will find this essential reading. Anyone intrigued by the labyrinth of dams, pipes, pools, and pumps that now augments the water supply of the city to prevent multiple lacerations of supply lines in a future earthquake will find the answers here.

There’s scarcely a page without a picture, and these visual constraints hold the text to its theme of science and engineering rather than—as so often has happened—letting it drift into sensationalism and speculation. I liked best the black and white photos that have been colored to illustrate what fell from where and to where, and there are numerous before and after pictures thanks to the prodigious holdings of the Bancroft Library at the University of California, Berkeley. The author and the library are to be congratulated on conspiring to make this remarkable imagery come to life. It’s a marriage made in heaven between an able engineer who obviously enjoys getting at the root of mechanical problems and a library with a photographic memory of two centuries of development, shaking, and conflagration. ☒