Thirty Years after the Northridge Earthquake: Impact on Seismic Steel Design and Construction in the U.S.

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Year 2024 marks the 25th anniversary of the Chi-Chi Earthquake in Taiwan, which also coincides with the 30th anniversary of the Northridge, California Earthquake in the U.S. A number of devastating earthquakes have occurred in urban cities around the world in the past 30 years. Nevertheless, major cities in high seismic regions of the U.S., especially the West Coast, have been fortunate not to be challenged. The current seismic design and construction practice, especially for steel buildings, is significantly impacted by the lessons learned from the Northridge Earthquake. This presentation highlights the impact and some important changes to steel research, design, and construction practice in the U.S. due to this event.

Although the Northridge Earthquake caused a widespread damage to bridges and buildings of different construction and material types, what surprised the engineering community was the brittle weld fracture of beam-to-column moment connections in about two hundred multistory steel buildings that use Special Moment Frames, a type of system thought to be one the best to resist earthquakes. To address the unexpected failure of this class of construction, a federally funded study (SAC Joint Venture) involving several university researchers, practicing engineers, and experts in different disciplines worked together for more than six years to address this issue (Hamburger and Malley 2019).

The first change to the engineering community is the mentality on weld fracture. Prior to the Northridge Earthquake, it is not uncommon that researchers conducting related experimental research would put the blame on welders fabricating the test specimens when fracture occurred. It was realized after the Earthquake that all parties involved, especially researchers and designers in the author's view, played a very important role on the robustness of welded connections under seismic loading. The second change is the way that experimental research is conducted. Prior to the Earthquake, researchers would fabricate and test small-size connection specimens for adoption into design codes and then apply to real construction. After realizing that it is not appropriate to extrapolate such experimental results to much larger welded connections due to the size effect, reduced-scale testing is discouraged, and such test results are always viewed with suspicion in the U.S. nowadays.

Some steel mills in the U.S. started changing the process of making steel shapes in the early 1980s. It wasn't until after the Earthquake did the engineering community realize that the associated change in steel strengths not recognized in design at the time also played an important role on the observed weld fracture. As a result, a new steel grade (ASTM A 992) was introduced as the default material for steel construction nowadays. Recognizing the critical role of the welded joints, American Welding Society issued a new welding code (AWS D1.8) specifically for seismic applications.

The regulation of the so-called "prequalified connections" for steel moment frame construction is another outcome of the Earthquake. Unlike the pre-Northridge practice, connections for use in seismic moment frame need to be prequalified through testing. For this purpose, AISC publishes a design standard (AISC 358), which contains 11 connection types so far. For adoption into this design standard, each connection has been scrutinized by a panel of experts. The Earthquake also triggers a wave of innovation on proprietary connections, a phenomenon not seen before the Earthquake; these connections were mainly developed by the design profession, not from academia. Six of the 11 connections in AISC 358 are of this nature. Aside from moment connections, development of buckling-restrained braces (BRB) for braced frame applications, for example, is also primarily triggered by the Earthquake as structural designers were looking for alternative, reliable seismic structural systems. The Earthquake accelerated the adoption of new seismic force systems into the AISC Seismic Provisions (AISC 341); buckling-restrained braced frame that is widely used in the past twenty years is a good example.

A span of three decades after the Northridge Earthquake also sees an advocacy of community seismic resilience (NIST 2021). The building seismic design philosophy is in the process of transitioning from life safety to post-earthquake functional recovery. To address this need, several proprietary steel connections and yielding energy dissipation devices have also been developed. It is interesting to note that, based on the author's observation, the use of this kind of devices appears to be more common in Taiwan than in the U.S.

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