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Timeline of Precipitating Events, Discoveries, and Improvements in Earthquake Engineering, 1811-2004

Year	Event	Highlights of Event/Development in Earthquake Engineering
1811-1812	New Madrid earthquake (Missouri)	Three principal earthquakes occur over 3-month period. Extensive changes in ground configuration; chimneys destroyed in many parts of Midwest. Considered largest earthquake in modern history in continental United States. Effects felt as far east as Boston, Mass. Several people killed.
1886	Charleston earthquake (South Carolina)	Largest historical earthquake on East Coast of the United States occurs. More than 100 buildings are destroyed, 90 percent of buildings in Charleston damaged, nearly all chimneys down in the Charleston area; $5.5 million in damage; 60 people killed.
1890		First seismograph to record earthquake acceleration is developed.
1900		Fusakichi Omori develops the Omori scale of earthquake intensity: first scale relating ground motion (acceleration) to damage.
1906	San Francisco earthquake (California)	More than 700 people killed; property losses reach $400 million, mainly due to fire.
1923	Great Kanto earthquake (Tokyo)	One of the most devastating earthquakes in Japan occurs. More than 142,000 people are killed; 694,000 homes are destroyed. Immediate changes in the building code follow, including limiting building height to 100 ft.
1925	Santa Barbara earthquake (California)	13 people are killed, 65 injured; approximately $15 million in damage. Leads to development of seismic appendix in 1927 Uniform Building Code.
1928	Failure of St. Francis Dam (California)	Dam failure under static conditions establishes need for geologic evaluation of dam foundations.
1932		M.A. Biot develops concept of response spectrum for earthquake

		acceleration.
1932		John R. Freeman publishes book *Earthquake Damage and Earthquake Insurance*.
1933	Long Beach earthquake (California)	First recordings made of strong ground motion. Widespread damage is done to unreinforced masonry buildings—leads to widespread research in earthquake engineering. Earthquake leads to first substantive seismic design provisions: • Riley Act—Buildings are to be designed for 2 percent of gravity. • Field Act—Special seismic design requirements are set for schools.
1933	Tsunami (Japan)	Run-up of 30 m is observed at head of bay in Ryori Bay, Japan.
1946	Aleutian Islands earthquake and tsunami	Damage and loss of life occur in Hilo, Hawaii, and other islands. Scotch cap lighthouse destroyed in Alaska; run-up of 30 meters observed. Beginning of serious U.S. effort to understand various aspects of tsunamis. Disasters lead to initiation of Pacific Tsunami Warning Center and Alaska Tsunami Warning Center.
1948		First seismic probability map issued by Ulrich.
1948		First soil dynamics experiment is run at Harvard University.
1949		Earthquake Engineering Research Institute (EERI) is formed.
1952	Arvin-Tehachapi earthquake (California)	First damaging post-World War II earthquake in United States occurs. Significant damage to lifelines is sustained.
1952		The concept of earthquake design spectrum is introduced by George W. Housner.
1955		Experimental investigation of waves produced by submarine landslides is carried out.

1956		1st World Conference in Earthquake Engineering is held in Berkeley, California.
1958		First earthquake engineering research grants are funded by NSF.
1958	Lituya Bay earthquake and tsunami (Alaska)	Following 8.0-magnitude earthquake in Lituya Bay, a large aerial rockslide causes run-up of 520 meters on opposite slope. This is the largest run-up ever recorded.
1959		Recommended lateral force requirements are published, highlighting the importance of the structure period.
1960	Chilean earthquake	Possibly the largest earthquake in modern history occurs with a moment magnitude of approximately 9.2. This earthquake is critical in advancing the fields of plate tectonics and seismology. The earthquake generates a Pacific-wide tsunami. Approximately 2,000 people are killed by the earthquake and tsunami. Disasters initiated significant research on tsunamis, including numerical modeling of Japanese bays and harbors.
1964	Good Friday earthquake (Alaska)	Soil liquefaction and landslides lead to first zoning and land use regulations related to seismic hazards. Damage to short reinforced concrete columns leads to exploration of ductile detailing for concrete structural elements. Failure of precast concrete wall panels leads to research on cladding connection details. Damage to liquid storage tanks stimulates research on seismic performance of tanks. More than 120 people are killed by tsunami (106 in Alaska, 4 in Oregon, 12 in California). Nearly 2-meter run-up in Crescent City, California. Extensive damage highlights the importance of including tsunami effects in seismic hazard assessments. Earth science and engineering communities are mobilized to investigate the earthquake.
1964	Niigata earthquake (Japan)	Dramatic liquefaction-induced building failures occur. First documentation is made of liquefaction effects on lifeline

		structures. First demonstration of successful implementation of ground improvement occurs.
1967		U.S. West Coast and Alaska tsunami warning system is established.
1967	Caracas earthquake (Venezuela)	Damage to reinforced concrete frames leads to understanding of the importance of continuity of reinforcement in frames.
1968		The first large U.S. shake table is constructed at the University of Illinois, Urbana-Champaign.
1969		Gonzalo Castro articulates principles of soil liquefaction.
1969		National Academy of Sciences prepares report on state of knowledge and research needs for earthquake engineering.
1970		The first comprehensive earthquake loss scenario is developed by S.T. Algermissen and K.V. Steinbrugge.
1971	San Fernando earthquake (California)	Earthquake leads to passage of Alquist-Priolo Earthquake Fault Zonation Act in California, which requires geologic investigations to restrict housing construction across active faults. Damage to bridge structures leads to new bridge design code and to ductile detailing in bridges. Damage to reinforced concrete hospitals results in new requirements for ductile seismic detailing of reinforced concrete hospitals. Following the collapse of upstream portion of San Fernando Dam in this earthquake, major programs for seismically resistant design of earth dams are implemented. First ground acceleration in excess of 1 gravity recorded.
1971		H.B Seed and I.M. Idriss develop simplified procedure for assessing liquefaction potential.
1972		Applied Technology Council initiates ATC 003 effort, which is the first comprehensive seismic design document based on modern dynamic analysis principles.

1973		First conference held on microzonation for liquefaction hazard identification.
1975		U.S. Army Corps of Engineers initiates national dam inspection program.
1976	Tangshan earthquake (China)	More than 500,000 people are killed by dam failure and collapse of unreinforced masonry construction.
1976		Geotechnical site factors are incorporated into Uniform Building Code.
1976		First national seismic hazard maps with explicit and consistent probabilities of exceedance are developed by S.T. Algermissen and D.M. Perkins.
1977		In response to San Fernando earthquake of 1971, Congress passes the Earthquake Hazards Reduction Act (Public Law 95-124) to "reduce the risks to life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program." To accomplish this, the act establishes the National Earthquake Hazards Reduction Program (NEHRP).
1980		Geotechnical centrifuges are first used for earthquake experiments.
1983	Tsunami (Japan)	Tsunami generated in Japan Sea results in large loss of life and damage to harbors and ships on west coast of Japan and South Korea. Numerical simulations of tsunami propagation and run-up are studied extensively in Japan.
1985		First base-isolated building is constructed in the United States, the Foothill Communities Law and Justice Center in Rancho Cucamonga, California.
1985	Mexico City earthquake (Mexico)	Strong local ground motions due to a distant earthquake source result in more than 8,000 people killed and over 50,000 left homeless.

		Research initiated on local soil amplification effects, particularly basin effects. Nonductile, reinforced concrete structures exhibit poor performance. Mixed performance of cross-braced steel structures leads to new research.
1989	Loma Prieta Earthquake (California)	Good performance of reinforced masonry buildings is confirmed. Poor performance of open first stories (storefronts, garages) leads to upgrade recommendations for this condition. Poor performance of older steel bridges leads to major upgrades and replacements. Collapse of nonductile reinforced concrete bridges confirms poor seismic performance of this structure type. Upgraded nonductile concrete bridges perform with marginal success. Poor performance of some wharf structures results in recommendations for wharf upgrades. Studies of performance of structures on various soil types leads to refinement of soil factors in building codes. Gas and water pipelines rupture in liquefiable soils. Landslides cover 15,000 square kilometers. Successful performance of improved ground is confirmed. Seismic Hazards Mapping Act passes in California, requiring geologic and geotechnical investigations to mitigate seismically induced liquefaction and landslide hazards.
1992	Tsunami (Nicaragua)	First formally organized international field survey (United States, Japan, Nicaragua) takes place.
1992	Flores Island tsunami (Indonesia)	Loss of life and damage occur in Indonesia. Damage pattern at Babi Island is investigated experimentally, theoretically, and numerically.
1993	Okushiri Island (Japan)	Loss of life, complete destruction of town are caused by tsunami and fire. Leads to awareness of destructive potential of overland flow for triggering co-tsunami fires.
1994	Northridge earthquake	Costliest natural disaster in U.S. history ($30 billion).

	(California)	Collapse of wood-frame buildings with open parking garages at ground level results in code changes and renewed research on wood-frame buildings. Brittle fracture of connections in welded steel moment frames leads to extensive research programs on evaluation and upgrade of existing steel moment frames and design of new steel moment frames. Good performance of recently upgraded unreinforced masonry buildings is confirmed. Poor performance of tilt-up concrete panel buildings results in upgrade recommendations and new code provisions for this structure type.
1995	Kobe earthquake (Japan)	Earthquake is costliest natural disaster in world history ($100 billion). First comprehensive set of strong, near-field ground motion records from a single event creates new opportunities for research into near-fault effects. Fractures and collapses of steel frames lead to reexamination of steel design codes and practices in Japan and confirm importance of ongoing welded steel moment frame research in United States. Widespread failures of bridges lead to reexamination of bridge design codes and practices in Japan and shed new light on bridge design provisions and practices in the United States. Extensive damage caused by soil liquefaction and lateral spread places new emphasis on research into prediction of liquefaction potential and techniques for mitigating liquefaction hazards. Japanese government invests significantly in new and existing experimental facilities for earthquake engineering research. Several collaborative programs between United States and Japan are established.
1995	Manzanillo tsunami (Mexico)	Large earthquake off Pacific coast of Mexico results in tsunami in city of Manzanillo. Large currents cause damage to port. Photographs of depression waves bring about studies of leading waves of nearshore tsunamis.
1998		FEMA issues first set of comprehensive guidelines for seismic design that incorporate principles of performance-based seismic design (PBSD): NEHRP Guidelines for Seismic Rehabilitation of Buildings (FEMA 273).

1998	Tsunami (Papua New Guinea)	One of the most devastating tsunamis in the past century occurs; run-ups are as high as 15 m, and more than 3,000 people are killed or missing. The tsunami accelerates research in the area of underwater landslide generation.
1999	Izmit earthquake (Turkey)	More than 16,000 people are killed by the collapse of improperly constructed buildings. Bearing capacity-type failures occur in soils not considered liquefiable by existing criteria, leading to criteria revision. Successful performance of improved ground at industrial facilities is confirmed.
1999	Chi-Chi earthquake (Taiwan)	Near-fault effects and large fault displacements are observed. Successful use of ground improvement at port facilities is confirmed.
2000		Earthquake risk reduction in developing countries is a central theme of 12th World Conference in Earthquake Engineering; a consensus declaration is made that developed countries are not doing enough to help reduce the risk.
2001	Bhuj earthquake(India)	Deaths of at least 13,800 people from collapse of modern, multistory reinforced concrete and poorly reinforced masonry structures highlight need to ensure compliance with building codes. Satellite imagery reveals huge subsided areas inundated with surface water from liquefaction. Deep basin effects contribute to structural collapses.
2001	Nisqually earthquake (Washington)	Liquefaction-related damage harms port structures under weak shaking. Areas improved with ground treatment technologies perform successfully.
2002	Denali earthquake (Alaska)	Despite large (>6 m) horizontal ground displacements, Trans-Alaska Pipeline suffers minimal damage and no product loss.
2004		NEES equipment sites are slated to be operational