EARTHQUAKE RESEARCH (2): Averting Disaster

Many steps could be taken (but usually aren't) to reduce the loss of life and property in earthquakes

BY JOHN H. DOUGLAS

Conclusion of a two-part series.

Liquefaction: Buildings in Niigata, Japan, sank into ground intact in 1964 quake.

Less than half the residents of the old Valencia Hotel in San Francisco's Mission District lived to tell about the great 1906 earthquake. Those that did reportedly stepped from the collapsed structure's fourth story directly onto street level. Next door, a more sturdily built apartment building did not collapse, but one news account vividly recalled its strange fate: "As though someone had struck it on top with a giant hammer, the entire building had sunk one story into the ground; you could walk right in at the second story." More important for the other residents of the city, just recovering from the direct effects of the quake, two arterial water mains under Valencia street had been shattered, cutting off water supplies to the downtown area that would soon be in flames.

Behind the tragedy of Valencia street lay the subject of an old parable, which would soon be given a new, technical name. The parable, of course, is the one about the man who built his house upon the sand: "Great was the fall thereof." The new name is "liquefaction" — a phenomenon in which large areas of wet, loose sandy soil literally flow like a liquid. After a quake, the ground surface in such a region appears frozen into waves, and the effect on buildings is that of quicksand.

The ground movement on Valencia street ranked among the worst in San Francisco because the area had been created by filling in an old creek bed, an ideal condition for liquefaction. When the 1906 earthquake struck, the loose, wet material began to quiver like a bowl of gelatin. Bare ground sank six to eight feet; streetcar rails were bowed into nearly yard-high arches; and the entire street "flowed" eastward some nine to ten feet.

By studying earthquake effects like these, and seeing how different kinds of buildings respond, researchers are slowly developing an understanding of how to lessen the destruction caused by quakes. Long-term forecasting (SN: 2/3/79, p. 74) can help spot those areas where such preparations are most needed. Studies of ground failure can help land-use planners steer contractors away from areas likely to experience liquefaction or landslides. Builders themselves are becoming more confident about being able to construct quake-resistant buildings, once likely ground motion is known. And the federal government has recently launched a national project to coordinate and encourage hazard reduction.

Because of the destructiveness of the 1906 quake, northern California has become the most intensively studied area in the United States in the search for ground failure patterns. Recently, the U.S. Geological Survey published a new study of the region (Professional Paper 993) and issued tentative zoning maps to indicate which areas would be most subject to hazard (Professional Paper 941-A).

Besides pointing out specific areas likely to experience liquefaction, the studies showed that the intensity of sideways thrusts due to a quake do not fall off as rapidly as expected the further one moves from a surface fault line. And peak shaking acceleration may be as large as the acceleration of gravity; that is, a building may momentarily experience the same force it would feel if it were built sideways out of the edge of a cliff. The greatest accelerations will occur where ground structure amplifies the tremors.

Geophysicist Robert D. Nason of USGS explains the results of these and similar studies: "The amount of shaking is about the same out to five miles on either side of a fault. The break itself may be only 20 feet wide, but tension is released from rocks along a strip five to ten miles wide. Thus it's not that much worse to build a house very close to a fault than to build it five miles away. In either case, the damage will be greatest where there's danger of liquefaction or landslides."

He goes on to explain that catastrophic ground failures, such as liquefaction, can occur even in relatively minor quakes: "A building constructed on water-saturated loose fill may be as badly damaged in a magnitude six quake as one built on solid ground experiencing a magnitude eight quake."

Already, studies of ground shaking, coupled with long-range forecasts of likely earthquake locations, have begun to save lives. As early as 1967, an analysis of the region around the Lower San Fernando Dam led engineers to lower the level of water behind it by nine feet. When an earthquake finally struck, in 1971, the dam did partially fail, and it is estimated that if the water had been left at its original height, total collapse and thousands of deaths would have resulted.

Given that an area is subject to earthquakes and that certain soils will fail completely, making them unsuitable for almost any kind of construction, how can engineers build structures on the remaining land to withstand the expected shaking? A leading authority in the field, Henry J. Degenkolb, a consulting engineer in San Francisco, gives a paradoxical answer.

On the one hand, he says, "There's a lot we don't know"; present building codes are based on "a peculiar mix of experience, theory, some testing and best judgments." On the other hand, he says, even in the days before much of our present knowledge and technology had been developed, "none of the big buildings failed in the 1906 quake. They performed excellently."

A self-styled "earthquake chaser," Degenkolb has surveyed the damage caused by many of the great earthquakes that have occurred in recent years. "The final test is to forget all the theory and see how and why buildings were damaged," he concludes. "Almost every improvement in the code came from this, not research." And if there is one lesson that stands out from such experience, with all its surprises, he says it would be that buildings must be made more ductile.

The concept is simple, the application difficult. Obviously a building needs to be flexible, that is, when pushed to one side, it must be able to snap back into place. But if a building were *too* elastic, energy would not be dissipated and it would whipsaw in a quake. The danger can be especially great in a skyscraper whose natural period of oscillation is near that of the ground motion. In such a case, even the strongest flexible materials, like steel, can be strained beyond their yielding point.

What prevented such whipsawing in the large buildings that survived the great San Francisco quake, Degenkolb says, was heavy masonry walls between the elastic steel beams. While the beams provided flexibility and strength, the masonry prevented wild oscillations by deforming slightly but permanently as a structure swayed from side to side. The motion thus resembled that of a ductile stick of taffy more than that of a more elastic stick of rubber.

Ironically, as building technology rapidly developed after World War II, Degenkolb says, this extra element of safety was lost because the importance of ductility was not fully recognized. A new style of skyscraper — with light "curtain walls" — became popular, and building codes were not altered to assure their ductility. The elastic strength of a steel frame was judged sufficient.

Now, even this elastic strength has sometimes been compromised, when solid steel beams have been replaced by concrete columns only reinforced by steel bars. Degenkolb says that columns with straight steel bars have proven too brittle; a helical winding of steel is needed in addition, to make the concrete more ductile.

Ductility requirements were eventually added to the California building code in 1973, but thousands of buildings constructed under the old code remain, and the cost of replacing or strengthening them appears prohibitive. Says Degenkolb, "Every engineer in the state knows what's going to happen." In the worst cases, he says such buildings may simply "pancake."

Although California has at least tried to update its building codes in line with new information concerning earthquake hazards, most other states have not. Some 39 states, with a total population of 70 million people, are considered subject to "major or moderate earthquake hazard," and by next year roughly $2.3 trillion of construction will be "at risk." Yet most state and local authorities have done little to ameliorate the hazards. Most building codes in the eastern part of the United States have not incorporated even the standards long practiced in California, so that many build-

Steel and mortar building that withstood the San Francisco quake and still stands.

Caracas apartment building with concrete pillars that "pancaked" in 1967 quake.

Concrete pillars with vertical steel rods (left) are brittle and may fail in an earthquake. Ductile concrete pillars (right) with additional helical steel windings have proved more durable.

Photos: Henry J. Degenkolb

ings have almost no resistance to quakes.

When asked what would happen if an earthquake the size of those that struck Missouri in the last century were to occur now, most experts simply blanch. "Destruction from St. Louis to Memphis," they murmur. "Great liquefaction potential." Then they change the subject.

In short, no one really knows. The locations of active faults in the East aren't known; neither are the likely recurrence intervals for quakes, nor the possible effect of even an accurate prediction given long in advance. All that seems certain is that major quakes can occur in at least three Eastern regions (SN: 2/3/79, p. 75) and that people in none of these areas are even as well prepared as Californians. And, despite their preparation, if a great earthquake were to strike Los Angeles now, the death toll is expected to be greater than 10,000, with property damage of more than $20 billion.

After years of inaction, the federal government has finally launched a major campaign to increase public awareness of earthquake hazards throughout the country. The Earthquake Hazards Reduction Act of 1977 provided a framework for action along half a dozen lines and established a Federal Emergency Management Agency (FEMA) to coordinate these efforts. To find out how work is progressing, SCIENCE NEWS interviewed Charles C. Thiel, head of the Earthquake Hazards Reduction Coordinating Group of the Office of Science and Technology Policy — the interim organization responsible for implementing the Act and helping set up FEMA (SN: 7/8/78, p. 22).

Thiel says that FEMA is expected to be in operation by April, although no administrator has yet been nominated. At present, research sponsored by the act is being carried out by the National Science Foundation and the U.S. Geological Survey, with $6 million appropriated for the current fiscal year for fundamental research, $31.5 million for work on prediction, induced seismicity studies (stimulating small quakes in hopes of avoiding big ones) and hazards assessment. Earthquake engineering research receives $16.6 million and social sciences studies aimed at utilizing the results of other research have $0.8 million.

The biggest concern facing researchers now, Thiel says, is that "the problem is just a lot tougher than we hoped five years ago." Earthquake prediction theories have not proved as useful as first expected and the social consequences of prediction appear more serious than anticipated. A commonly heard rumor in earthquake research circles maintains that the successfully forecast quake near Oaxaca, Mexico (SN: 12/9/78, p. 404) did more damage by scaring away tourists than was done by the quake itself in damaging buildings. But Thiel remains optimistic: "I believe when we learn how to deal with the negative aspects of prediction, as well as its positive aspects, we can save many lives."

Unfortunately, funds for utilization of research results have been hamstrung because of a scandal involving one of the social scientists doing the work. The administration had originally asked for more than $6 million for research utilization, and leaders in various branches of earthquake research have expressed dismay that the Congress should have used an isolated incident to cut those funds to less than $1 million. Growled one knowledgeable observer, "We damn well better know what to do with those predictions."

The prospects for reducing the hazards of earthquakes thus come down to this: Predictions of time, place and magnitude will take longer to perfect than believed only a few years ago, but forecasts of eventual earthquakes in some areas are clear enough that many lives could be saved if steps were taken now to reduce the risks. Among those risks, the most serious are that some soils have been found to be especially dangerous during a quake. Buildings should therefore be constructed elsewhere when possible. And among various building designs, some have been shown clearly more earthquake resistant than others.

In the one major U.S. city almost destroyed by a quake, these lessons are taken quite seriously. The skyscrapers now common in downtown San Francisco display a wide variety of earthquake resistant designs, including pyramidal shape and diagonal steel supports. To prevent a recurrence of uncontrollable fire, the city has constructed cisterns under streets, a separate high-pressure water line, new reservoirs and a system for bringing water from fire boats to a blaze downtown.

Elsewhere, the pace of utilizing the lessons of research is much more leisurely. If history is any guide, only another major earthquake will stimulate full mobilization of what is already known about earthquakes to save lives and property. □