Lessons from the Coalinga Earthquake

by Dennis Meredith

By the standards of seismologists, this earthquake rated only a "moderate," but to most of the 7,200 residents of Coalinga, California, last spring's disaster was a terrifyingly violent episode. At 4:43 on the afternoon of May 2, 1983, this small San Joaquin Valley town was wrenched by the strong shaking from a magnitude 6.5 earthquake. Just 10 seconds later the town had sustained some $33 million in damage that varied in severity from a few minor cracks in some buildings, through foundation failure in others, to total collapse in still others. Some 45 people were injured, a few seriously, but — almost miraculously — no one was killed.

No major earthquake is without its aftermath, most of which is an unhappy reminder of the tragedy. There are, for example, the continuing aftershocks, the care of the injured and homeless (the Red Cross served over 53,000 meals in the three weeks after the quake), and the rebuilding of houses and businesses. The one long-term consolation is that seismologists, earthquake engineers, and planners extract as much knowledge as possible from each seismic calamity in the hope of making the consequences of the next one less tragic. Thus, after any sizable earthquake dozens of experts arrive with instruments, cameras, and note pads, ready to gather relevant data. Paul Jennings, Caltech professor of civil engineering and applied mechanics, is one of the more than 50 such experts examining the Coalinga earthquake for the lessons it offers.

The work of Caltech engineers and seismologists began within a few hours of the main shock, when Assistant Professor John Hall, engineer Raul Relles, and several Caltech graduate students arrived in the area to install strong-motion instruments to capture records of aftershocks. (One distinguishing feature of this earthquake is that there were more aftershocks in the magnitude 5 to 6 range than are normally expected.) In addition, students from Caltech's Seismological Laboratory went to the area, primarily to look for evidence of fault movement near Coalinga and on the nearby San Andreas fault. On May 3, the day after the quake, Jennings arrived with another student group to survey the damage to structures. Interestingly, in some places it took a really practiced eye to spot it.

"Until we got into downtown Coalinga, which is the older part of town," says Jennings, "it was not obvious that there had been any earthquake damage at all. We could see some very minor damage to the freeway bridges — some spalling (chipping) and cracking — but only an experienced observer could tell that it wasn't just normal wear and tear. When we came to the first stopping point on the way into the city, where the patrolmen were issuing passes, on one side of the street was the Cambridge Motel open for business, and on the other side was the office of the county sheriff. There was no damage to either place. It wasn't until we reached the older part of the town that we could really see the damage, and it confirmed what engineers have known for a long time — that modern construction practices really make a difference."

Jennings feels that the Coalinga earthquake was a clear test case of the resistance of older commercial and residential construction versus newer commercial and residential buildings. It's obvious to him that modern construction practices, codes, and engineering combined in varying degrees to make the newer buildings perform much better. Old commercial buildings, which were primarily of unreinforced masonry, suffered heavy damage or were totally demolished, and modern commercial buildings emerged practically unscathed.

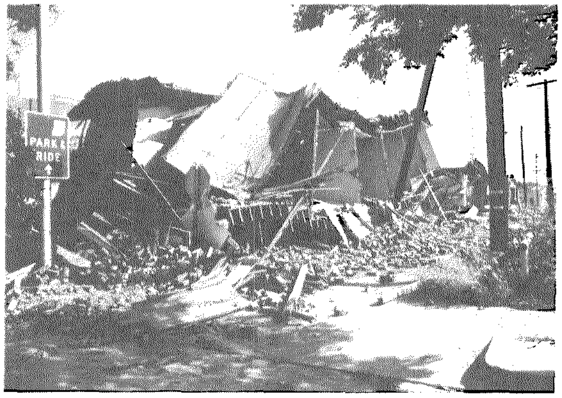
An equally strong contrast was evident in the behavior of older residential housing, particularly old wooden housing built before 1933, versus modern housing. Before 1933, a common method of constructing a wood frame house was to build the floor level of the house two or three feet off the ground with a front porch and steps leading up to the floor. The perimeter of the box-like house rested on a mud sill of concrete, and the floor was supported with 14- to 18-inch-long four-by-four studs, each of which rested on a small concrete pad. Typically, such a house has a skirt of clapboard or siding around the outside. In the 1933 Long Beach earthquake and in virtually every large earthquake since, houses like those — if they

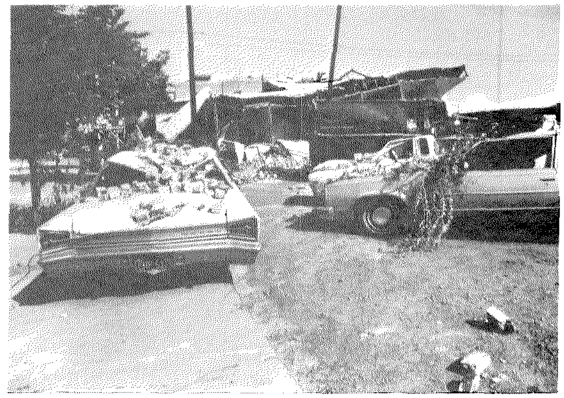
The two pre-1933 residences at the left show the effects of a magnitude 6.5 earthquake — one losing much of its front wall and the other shifting off its foundation.

Damage to freeway bridges was fairly minor. An example of spalling is shown at the left and of cracking, above.

The older part of Coalinga suffered major damage. Just 10 seconds of shaking created this kind of havoc in the downtown area.

The advice to "Park and Ride" may have been good for some people, but the shakeup was hard on buildings and cars left in the area.





haven't had any additional bracing — have fallen off their foundations. This happened in the Coalinga earthquake too. The damage isn't necessarily hazardous to life or limb, but it's terribly expensive to repair.

"What wasn't tested in Coalinga," says Jennings, "was the structural integrity of the intermediate-height concrete buildings built in the 1950s and 1960s, before there were codes for ductile concrete. Nor were tall skyscrapers and various types of industrial and large commercial structures tested, because there weren't any in the area. There was, for example, no building in Coalinga like the Imperial County Services Building, which was damaged so severely in the Imperial County earthquake in 1979 that it had to be taken down. If there had been a building of that size and construction in Coalinga, it wouldn't have done well either, because the shaking was comparable in the two earthquakes."

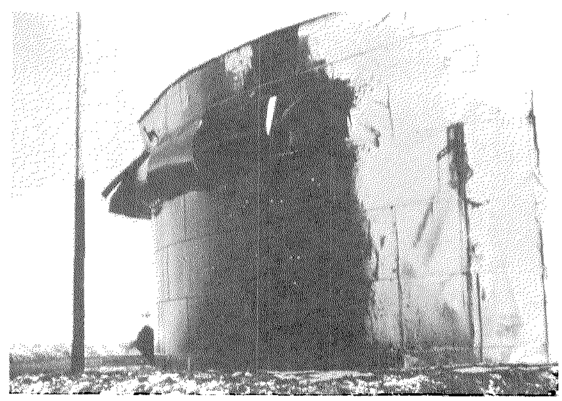
But could the effects of the Coalinga earthquake be taken as a milder, smaller version of the effects of a truly large earthquake on Los Angeles?

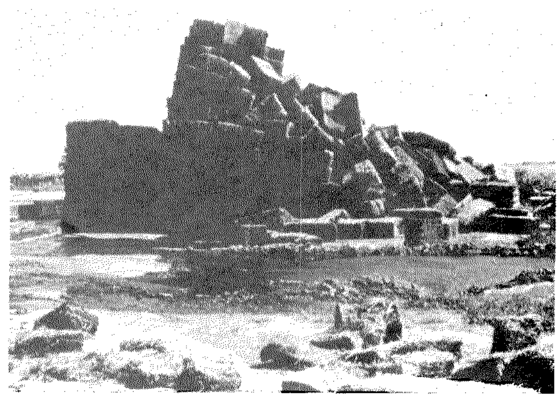
"Not really," says Jennings. "I don't expect the picture of damage in a large earthquake in L.A. to be so black and white. I'm definitely convinced that, as a class, new buildings are much better than old buildings. I'm also sure that we're moving strongly in the right direction in our construction practices. But there are tens of thousands of buildings in the Los Angeles metropolitan area, and even some of the newer ones were built when the understanding of earthquake-resistant design wasn't what it is now. We also have to realize that it's impossible to prevent construction and design errors completely. So we have to expect that both the old buildings and some of the newer buildings are going to have trouble.

"Also, Los Angeles has larger, more complicated structures. These buildings use their materials at closer to their capacity than the typical one- or two-story residential or commercial building, which has a lot of resistance to shaking that's independent of the calculations made in the design. In the bigger structures, on the other hand, the materials are used more efficiently, so their properties are being pushed nearer the limits. The structural engineers are still meeting all building codes in these buildings, but because of the volume, cost, and size of the structures, some don't have the built-in margin of safety that most one-story commercial structures have."

The Coalinga earthquake also offered valuable lessons about how well utilities can withstand earthquakes, providing added understanding of what needs to be done to protect

Storage tanks are a familiar sight in and around Coalinga. The chief damage was buckling and seepage of the contents, as in the oil tank at the right. At the far right, a toppled stack of baled hay sits in a lake of molasses that leaked from a cattle food tank.





electrical distribution, telephone, and water systems. By and large these came through very well. Their performance added to engineers' knowledge of what kinds of problems to expect and what kinds of solutions seem to work best.

"The lessons aren't clear yet," says Jennings, "but I think the Coalinga earthquake is going to provide very good case studies for the people who are interested in the mitigation and disaster relief processes. The situation in Coalinga was unlike that in the San Fernando earthquake of 1971, in which a part of a major urban community was damaged, but the rest was not. In Coalinga, there were no surrounding communities, and so it should be simpler to understand how various agencies interacted with one another. There were fewer actors involved in the roles, making them easier to understand. In my opinion, the public officials in Coalinga responded well. I was particularly aware, visiting the day after the earthquake, that the people in charge of trying to control the influx of persons into the affected area were doing a very good job. They were a sensible, well-organized group."

The Coalinga earthquake, and other such damaging tremors around the world, are being actively studied by earthquake engineers. But serious gaps still remain in the data they must use to design earthquake-resistant buildings.

"First," says Jennings, "we've not yet recorded the strong shaking close to the fault in a truly great earthquake, one of magnitude 8-plus. Second, we don't really know very much about the near-field motions for earthquakes of magnitude 7 and above. We think that the motions saturate; that is, that a magnitude 8 isn't going to give much stronger shaking than a magnitude 7 near the fault, although it will last longer. And, finally, for a variety of buildings we don't have measurements of shaking strong enough to cause serious damage or failure. Those kinds of readings are necessary to find out the real shaking capacity of the buildings. Such information has to be complemented by full-scale testing of buildings plus laboratory work, of course, but we still need records of buildings shaken so strongly by earthquakes that they are really tested to their limits."

So Coalinga was not an "ideal" earthquake from the engineers' point of view. Nevertheless, warns Jennings, its lessons must not be lost on California. "Every city in the state should look at Coalinga and say, 'There but for the grace of God go I.' All the major cities in California have older buildings like those in Coalinga, and if they experience an earthquake like Coalinga, they can expect to suffer similar damage.

"Most cities have some time to do something about their major hazards — their old, unreinforced buildings. And they also have time to help homeowners strengthen the old pre-1933 wooden houses. Such efforts would only cost a few hundred dollars per house, less if the homeowner does it himself. It might only take some nails and one-by-sixes, and in some cases bolts drilled into concrete."

Earthquake engineers know that there will always be damage from earthquakes, because it will seldom make sense to make all buildings totally earthquake resistant. But the buildings *can* be made safe for their occupants in an earthquake, and there remain inexpensive measures that can yield large paybacks in reduced damage. This is the really important take-home lesson from Coalinga's experience. □

Some structures, of course, didn't fall down completely, though the long-term integrity of the two above is doubtful. The benefits of modern construction are demonstrated below by Coalinga's Elks Club, complete with undamaged statuary.