CONNECTIONS

The EERI Oral History Series

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Robert Reitherman
Interviewer

to accurately provide the reinforced concrete material where it is called for—to fit the bars in but provide minimum spacing and cover, and to place the concrete. A line on a drawing that represents a reinforcing bar is easy for the computer to draw, but it may be difficult to construct. And a design is only as good as the way it is constructed.

In the lab at MIT, when I was a graduate student conducting experiments on beams and walls, I would order a precise mix of concrete to get 4,000 psi concrete. The concrete company would deliver 5,000-pound concrete. I would explain I needed 4,000-pound concrete, because that was what the specimens were designed for, what the intent of the test was, and they would say, "What are you complaining about? We are giving you more strength." That happens in actual building construction, and getting materials that are stronger than you assumed can negatively affect the behavior. It can change the location of plastic regions. It can reduce ductility that the engineer or the building code assumed.

The provision of construction materials that are overly strong as compared to the design assumptions is a current problem, as well as an old one. In Argentina from 1950 to 1953, when I was designing structures with our firm Weder-Bertero, there was a shortage of steel. A company began to produce twisted reinforcing steel bars. A bar was twisted enough to strain-harden it. The company was quite proud of their product—it had a higher yield point. But they had used up some of the original physical ductility that I wanted to rely on in my structures.

Soil-Structure/Adjacent Structure Interaction

Bertero: There is another adjacency problem in urban areas, beside the problem of pounding, which is lateral impact of adjacent buildings, or one building collapsing onto another. We do a soil-structure interaction analysis of one building to be built, as if it is in the middle of a huge, empty field. But right next door on all sides there are other large buildings experiencing soil-structure interaction. An engineer analyzing one of those buildings would also look at it by itself. That would neglect the probable effects that the response of the nearby building can have on the building being designed. The motion of the adjacent building will interact with the soil and thereby affect the ground motion input to the building under design. And the seismologist and/or geotechnical engineer today will give you the same ground motion as input to each of the buildings in an urban area without considering the soil-structure interaction from each of the other buildings that will modify that input motion.

Reitherman: Something like the way one boat that is set into a rocking motion affects the water around it and can rock the boat that is moored next to it?

Bertero: Yes, the ground motion is different because of adjacency. The rocking of a big building's foundation imparts its own motions into the soil, in addition to what the earthquake delivered in the first place.

Reitherman: How would you take urban-scale soil-structure interaction into account, especially if you don't know what might be built next door in the future? In wind design, there are wind exposure categories, where surface roughness category B applies to a site where the wind is reduced by numerous adjacent buildings and trees, C to a lesser extent, and D where the surroundings are flat. Would you zone urban areas in some fashion like that to take into account the seismic soil-structure effect of surrounding development?

Bertero: This is a very complex problem whose solution would require the cooperation and collaboration of experts in several areas of seismic engineering, such as a seismologist, geotechnical engineer, structural engineer, urban planner. Something has to be done to change present practice, which is based on just specifying the design earthquake ground motions based on records obtained in the free field. That neglects the effects of the soil-structure interaction that can occur in blocks of a city that are crowded with buildings that have completely different mechanical characteristics and foundations at different depths. For example, let us consider the case of a two- or three-story building with its foundation at practically ground level, and that it is surrounded by tall buildings with multi-level parking basements. The question is, what should be the earthquake ground motion used in the design of these buildings? Should it be based on free-field recordings, as is usually assumed? I do not think so. It is necessary to consider the effects of the soil-structure interaction, not only of each of the individual buildings, but the effects that such interaction can produce among all the surrounding buildings. It is my understanding that Professor Jonathan Stewart at UCLA and Professor Jon Bray at U.C. Berkeley have started to investigate the effect of such interaction.

Reitherman: Could you give an example of a bad combination of adjacency soil-structure interaction, as distinct from a case where building response might be lessened by the interaction?

Bertero: For one building on its own, we usually consider soil-structure interaction to be beneficial. Radiation damping, like other damping, reduces the response of the structure. But let us now consider the case mentioned before of tall buildings with multi-level basements surrounding the two- or three-story building. Where does the energy radiate from the perimeter walls and foundation? It radiates away from the foundation and walls of that building, and toward the foundation and underlying soil of its neighbors. The tall buildings, with long periods, can hurt the short buildings. We should have learned more about this problem and applied lessons learned from the 1985 Mexico City earthquake.

Design for Aftershocks

Bertero: Let me tell you another lesson about ground motion that we should have learned from the large 1960 Chile and 1985 Mexico earthquakes. I think Allin Cornell is starting to look at this problem, but the codes, and most of the experts studying strong motion seismology, and the practicing engineers, do not consider the fact that the building that undergoes significant earthquake shaking is likely to undergo significant aftershock shaking. The 1985 Mexico City earthquake was not actually a single event. Even before you