Sampoong Superstore, Korea

Whether we like it or not, civil engineering, like other engineering professions, is becoming increasingly international. Many large U.S. construction and design firms compete throughout the world. In some countries, bribery and corruption are epidemic. However, the ASCE Code of Ethics and other professional standards do not have an international exception, and engineers licensed in the United States are bound by those standards, as well as by U.S. laws, no matter where they practice or where the project is located. Bribes are not a tax-deductible business expense. In some cases, U.S. firms have a difficult time competing successfully in construction markets where bribery is rampant.

This statement is not to imply that there is no corruption in the U.S. construction industry. Although it is not addressed in any reports, it is difficult to understand how a mismanaged project like 2000 Commonwealth Avenue (discussed in Chapter 5) could proceed without a bribe or two changing hands.

It is useful to study failures outside the United States, particularly those failures in which shoddy construction, bribery, or corruption may play a part. Earthquakes overseas often expose broad patterns of poor construction. An earthquake that would kill a few dozen people in California may kill hundreds or thousands in the developing world. Buildings sometimes collapse because of unauthorized construction of additional stories without permits. The principles of physics and engineering do not respect international borders.

Failures outside of the United States present some difficulties for researchers because the relevant documents and reports may be unobtainable or may not be available in English. News reports are generally sketchy with respect to technical matters and may oversimplify the case.

Another significant difference with U.S. practice is that engineers and contractors may be charged in criminal court. Some of the engineers involved with the Vaiont and Malpasset dam failures (in Chapters 7 and 8, respectively) were tried and convicted.

The collapse of the Sampoong Superstore in Seoul, South Korea, represents an example of a structural collapse attributed in large part to corruption. The late 1980s were an exciting time in Seoul and the rest of South Korea. In 1988, Seoul hosted the summer Olympic Games. The games gave South Korea an opportunity to show off its technological advances, and the nation took full advantage. I was stationed in South Korea as an Army officer during this period, and it was fascinating to watch the process unfold.

In Korea, large family-dominated firms called *chaebols* are responsible for much of the economy. Names that would be familiar in the U.S. include Hyundai, Samsung, and Daewoo. The *chaebols* often cross many industries, such as automotive, construction, retail, and shipbuilding. It would not be unusual for a *chaebol* to own a department store as well as the construction company that built it. Some of these *chaebols* are active in the international construction market.

Design and Construction

The Sampoong department store opened in December 1989. It was a nine-story building with four basement floors and five above grade. The building was laid out in two wings (north and south) connected by an atrium lobby. By the mid-1990s the store's sales amounted to more than half a million U.S. dollars a day (Wearne 2000, pp. 99–100).

Unfortunately, the store had been built on a landfill site that was poorly suited to such a large structure. Woosung Construction built the foundation and basement and then passed the project on to Sampoong's in-house contractors. Woosung had apparently resisted some proposed changes to the building plans, such as the addition of the fifth floor (Wearne 2000, p. 100).

Sampoong made significant changes to the structure. The most important was the conversion of the original use as an office block to that of a department store. Other changes included changing the upper floor from a roller-skating rink to a traditional Korean restaurant. Stricter standards had to be met for fire, air conditioning, and evacuation. Although the structure apparently met all building code requirements, the revised design was radically different from the original (Wearne 2000, p. 100).

Collapse

The building was put into service.

> For five and a half years business thrived. In June 1995 the store passed a regular safety inspection. But within days there were signs something was seriously wrong: cracks spidering up the walls in the restaurant area; water pouring through crevices in the ceiling. On June 29 structural engineers were called in to examine the building. They declared it unsafe. Company executives who met that afternoon decided otherwise. They ordered the cracks on the fifth floor to be filled and instructed employees to move merchandise to the basement storage area. (Wearne 2000, p. 100)

Some employees heard rumors of the structural damage and impending collapse but remained in their departments to work. At 6:00 P.M. on June 29, the center of the building collapsed, similar to a controlled implosion, in about 10 s. The five-story north wing, about 91 m (300 ft) long, fell into the basement, leaving only the façade standing (Wearne 2000, pp. 100–102).

Customers were concentrated in the basement and in the fifth-floor restaurant. The customers and employees had no time to run. Some survivors were found in the wreckage, and one was brought out 17 days after the collapse. The overall death toll was 498 (Wearne 2000, pp. 100–107).

Investigations and Conclusions

The technical causes of the collapse seemed straightforward. "The investigating committee noted design errors, many construction faults, poor construction quality control, reduction in the cross-section of the columns supporting the fifth floor and roof and change in use of the fifth floor . . ." (Gardner et al. 2002, p. 523).

> Two Korean professors, Lan Chung of Dan Kook University in Seoul, and Oan Chul Choi of Soongsil University, investigated. Their findings were summarized by Wearne (2000, pp. 107–111):
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> - The store was a flat slab structure, without cross beams supporting the slab. This made the structure inherently less redundant. This design explained why the building had collapsed so quickly and completely.
> - Quality of the concrete was not the cause. Samples tested for compressive strength did not show extraordinary weakness.
> - The foundations and basement built by Woosung Construction had survived the collapse, and the foundation rested on rock. Therefore, foundation problems could be ruled out as the cause of the collapse.
> - When the building design had been converted from an office block, it had been necessary to cut holes for escalators in each floor slab and remove some supporting columns.
> - The change of use also required installation of fire shutters. Large chunks of the concrete columns had been cut away to fit the fire shutters.
> - The fifth-floor conversion to a restaurant had added considerable weight. In a traditional Korean restaurant, diners sit on the floor, which must be heated. The floor and embedded heating system was 0.9 m (3 ft) thick and made of concrete. Refrigerators also increased the dead load.

- Because the floor plan of the restaurant was not compatible with that of the lower floors, the placement of the support columns was irregular. Columns did not line up from floor to floor. Therefore, the slab between the fourth and fifth floors, not columns, transferred loads.
- The building's large, heavy water-cooling blocks for air conditioning had been installed on the roof, rather than on the ground. In summer, when the collapse occurred, they were full of water and weighed a lot. They had been placed on the roof to avoid noise complaints from neighbors.
- Rather than adding columns, the builders increased the thickness of the roof slab to accommodate the water-cooling system.
- The roof system had about a quarter of the capacity required to support the water-cooling system.
- The building owners had recently moved the water-cooling blocks from the back of the building to the front. Instead of lifting them with a crane, workers slid them across the roof, causing considerable structural damage. Cracks up to 25 mm (1 in.) wide were observed where the blocks had been moved.
- On the lower four floors, columns specified to be 890 mm (35 in.) thick were only 610 mm (24 in.) thick and had only 8 reinforcing bars rather than the 16 specified.
- Slab dead loads had been miscalculated, based on 100-mm (4-in.) thick slabs when some slabs were three or four times thicker.
- Some reinforcement had not been installed, and connections between slabs and walls were poor.
- To maximize sales space, the spans between the columns had been increased to almost 11 m (36 ft), which was much too large.

> Professor Chung and his colleagues blamed the Sampoong department store collapse unequivocally on "human ignorance, negligence, and greed." The prime cause, they said, was the "illegal alteration of the architectural design and usage of the building." They cited the negligence of supervision of the planning authorities and the refusal to act on any of the indications of structural problems by the management as crucial contributing factors to the disaster. Cracks and leaks had been appearing in the building for more than five years. . . . (Wearne 2000, p. 111)

The concrete used was only 18 MPa (2,600 lb/in.^{2}) rather than the specified 21 MPa (3,000 lb/in.^{2}). Actual concrete strength from samples taken after the collapse ranged from 18.4 to 19.3 MPa (2,700–2,800 lb/in.^{2})

(Gardner et al. 2002, pp. 523–524). The originally specified value is rather low for structural concrete, and the further reduction in strength would reduce the slab punching shear capacity.

The effective slab depth for negative moment areas had been reduced from the specified 410 mm to 360 mm (16 to 14 in.) because the reinforcement was improperly placed. Also, the change in use had increased the dead load on the fifth floor by 35%. The lightweight concrete topping used on the roof had more than twice the dead load assumed in the design. Dead load of drop panels was also neglected (Gardner et al. 2002, pp. 523–525).

Punching shear of concrete slabs is discussed in Chapter 5. The factors that reduced the punching shear capacity of this structure included (Gardner et al. 2002, pp. 524–525):

- the reduction in concrete strength,
- the reduction in effective slab thickness,
- the reduction in column diameter, and
- omission of a drop panel at the top area of column line 4 and E, reducing slab thickness from 450 to 300 mm (18 to 12 in.).

Also, moment transfer to columns was only checked for the exterior columns, not the interior columns. The South Korean structural concrete building code requirements were identical to the U.S. ACI (1983) 318 code. The ACI 318 code now requires carrying some positive moment steel through the columns, which might have minimized the extent of the collapse (Gardner et al. 2002, pp. 525–529).

The final report was delivered by the Seoul District Prosecutors Office, entitled *The Final White Book of Finding Out the Real Truth of the Collapse of the Sampoong Department Store*. The public was outraged. In particular, the news that the senior executives had fled the building without warning others was disturbing. The report on the collapse, as well as earlier structural and construction failures, suggested a widespread pattern of corruption in the country's construction business. A government survey of high-rise structures found 14% were unsafe and needed to be rebuilt, 84% required repairs, and only 2% met standards. Joon Lee, the chairman of Sampoong, and his son Han-Sang Lee, were convicted and sent to prison for 10½- and 7-year terms, respectively. Twelve local building officials were found guilty of taking bribes of as much as $17,000 (U.S. equivalent) for approving changes and providing a provisional use certificate (Wearne 2000, pp. 111–112).

The cause of the Sampoong collapse, then, was not a technical issue as much as outright fraud. The Korean construction industry, protected by government regulation from outside competition, had become complacent. Bribes were used to get around the usual government checks and balances that serve to protect public safety.

It is difficult for a firm that insists on maintaining ethical standards to operate in such an environment. It is worth noting that Woosung Construction lost the project after balking at making the requested changes.

Essential Reading

This case study is discussed by Wearne (2000, pp. 99–113) in Chapter 5, entitled "Crooked Construction: Sampoong Superstore." A technical paper on the collapse entitled "Lessons from the Sampoong Department Store Collapse" (Gardner et al. 2002) was published in the *Cement & Concrete Composites* journal.

Misuse of the Professional Engineer License

Although there are other paths to licensure, the most common way to earn a professional engineer (P.E.) license today is to graduate from an Accreditation Board for Engineering and Technology (ABET) accredited engineering program, pass the Fundamentals of Engineering (FE) examination, practice engineering for four years under the supervision of a licensed P.E., and then pass the principles and practice examination.

There are more than 50 licensing jurisdictions in the U.S. states and territories, and as a general rule a separate license must be acquired for each jurisdiction. Licensing requirements may be different in the various jurisdictions but generally follow a national model law. Each jurisdiction has its own licensing board that enforces requirements and may suspend or revoke licenses. Land surveying has a separate LS or PS (Professional Surveyor) license, and in some jurisdictions structural engineering also has a separate examination and license. In the states where I hold licenses—Alabama, Ohio, and Virginia—there is no separate licensure for structural engineers.

Depending on jurisdiction, a P.E. may be referred to as a registered engineer, a licensed engineer, or a professional engineer. Within the jurisdiction, only a person with a P.E. in that jurisdiction may offer or perform engineering services. Professional engineers are also bound by the jurisdiction's code of ethics, which are usually similar to the ASCE Code of Ethics.

Beyond the licensing boards, engineering is a largely self-regulating profession. Engineers are supposed to restrict their practice to areas in