A SunCam online continuing education course

The Citicorp Tower

Professional Ethics and Disaster Averted

by

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The first fundamental canon of engineering ethics from the National Society of Professional Engineers directs engineers to "hold paramount the health, safety, and welfare of the public." In engineering, keeping people safe from harm means doing sound engineering calculations and having a full understanding of the possible real-world scenarios that engineering designs will face. The third fundamental canon states that engineers shall "issue public statements only in an objective and truthful manner," and the fourth holds that the engineers shall, "act for each employer or client as faithful agents or trustees".[1] The case of the Citicorp building in New York City raises questions about what kinds of calculations can be expected of an engineer, what kinds of agencies or groups should oversee design calculations, and what kinds of public statements an engineer is responsible to make. In this case, action was taken by engineers who recognized a problem and were able to avoid a possible catastrophe, but statements made to the public did not reflect the true danger of the situation.

Design 'Curve Ball' and First Solution

The Citicorp Center[2] is a 59-story skyscraper in mid-town Manhattan completed in 1977. Skyscraper technology was well developed in the 1970s, with the structural forces and strains of the city giants well accounted for. Still, the Citicorp building was a world-class undertaking, being the 5th tallest skyscraper built at the time and still the 12th tallest in New York City. The lead structural engineer, William LeMessurier, was well known and of high reputation.

Many engineering projects are faced with constraints, and the Citicorp project faced a particularly interesting one from the beginning. Citicorp was unable to purchase all of the land for the square block where the foundation of the tower would be laid. A church that had long occupied one corner of the block refused to sell. Instead, St. Peter's Lutheran Church of Manhattan agreed to sell the 'air rights' above the church on the condition that Citicorp build them a new church and have their proposed skyscraper 'built around' it. This meant that the main supports for the Citicorp Center could not be placed at the four corners of the building as was the traditional and proven practice. Instead, the design called for the main supports for the building to be in the middle of the

[1] NSPE Code of Ethics.
[2] The Citicorp Center was officially named "601 Lexington Avenue" in 2010 (Landmark Planning Commission (LPC), p.2).

faces of the building, with cutout cantilevered corners nine stories high on adjacent corners making room for the entrenched church below on one side and public space on the other. At the time, New York City offered monetary incentives for creating privately owned public spaces and the project used the second cantilevered corner to take advantage of this.

Figure 1. - The cantilevered corners and mid-face supports of the Citicorp Center.

The design of the building called for diagonal V shaped braces connected around the tower in 8 story sections to distribute the load forces toward the mid-face main supports, creating a truss system that would secure the non-traditionally supported tower against the wind. This innovative system would allow for much lighter materials to be used. Indeed, the Citicorp Center weighed 40% less than a traditionally designed skyscraper.

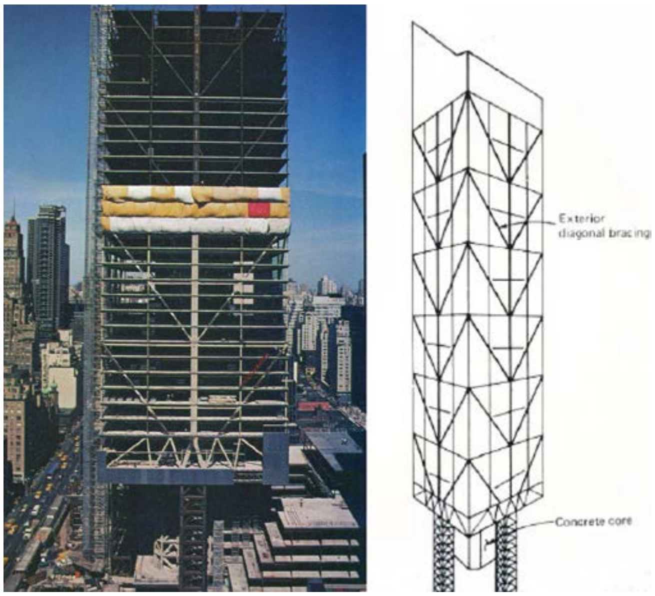

Figure 2. - The diagonal 'truss' bracing and mid-face supports.

As an additional feature, the design also called for an innovative 'sway damping' system to be housed at the top of the tower. This consisted of a heavy 'pendulum' sliding on a thin bed of oil that would counter the slight swaying of a building that tall and that light in the wind. This was added for comfort - it was not a structural necessity for the building. The device was housed under the angled top of the building. Reflecting the not atypical flow of constraints on engineering design, the angled top of the building itself was originally designed as a way to house 'tiered' residences, each having open floor space to the sky, another feature that was incentivized by the city. Alas, the permits for such residences were not granted. After that, the angled roof was thought of as a way to house solar panels during a time of surging interest in energy efficiency amid the gasoline crisis of the 1970s. These were seen as unfeasible. Given the photovoltaic technology of the time the amount of power generated would be trivial. Nevertheless, the distinctive angled apex of the tower was kept as a design feature that still distinguishes the building in the skyline of Manhattan to this day.

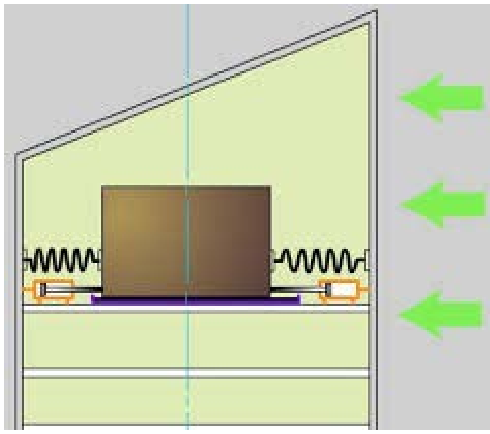

Figure 3. - The tuned mass damper and the signature angled top of the Citicorp Center.

The full design of the Citicorp Center, with its mid-face supports, angled top housing the tuned damper, and cantilevered corners accommodating the St. Peters church and creating public space, was approved by the New York City Building Commission in 1974. That year, amid general economic recession, it was one of only three new buildings approved for construction in New York. When completed in 1977, the building garnered much acclaim, with newspapers declaring it a "suave blockbuster" and "New York's most architecturally successful postwar sanctuary."[3] The Citicorp Center was an architectural and engineering triumph and proudly took its place among the esteemed skyscrapers of New York.

[3] LPC p. 2.

The Problem - Resisted at First

There was only one problem: there was a fatal flaw in the building that made it catastrophically unsafe. Considering how this information came to light and what was done about it raises ethical issues for the practicing engineer.

Since the building was a newly famous star in the world of architecture and engineering, it was studied and commented upon widely. One of those studying the building was an Architecture student at Princeton University, Diane Hartley. For her undergraduate thesis, she conducted an analysis of the building, especially the steel structures that distributed and guided the loads to the main mid-face building supports.[4] Comparing her own calculations to those she obtained from LeMessurier's firm, she found that the design as it stood did not properly account for the effect of the different kinds of winds that could impact the building. For a traditional tower, with supports at the corners, the main concern is winds that hit the building perpendicular to a side of it. Winds that hit at an angle to the building, the so called 'quartering winds', are much less of a factor. If the supports are switched to mid-face, however, as it was with the Citicorp Center, the quartering winds, now impacting the building at location where the supports are not located, plays a much larger role. Hartley found that the calculations used in the design of the Citicorp Center did not account for the real role played by the quartering winds. The proper calculations showed that the building was actually much less safe than it was purported to be. According to the new calculations, the wind loads increased by 40% and thus for some of the connections on steel V supports the forces would quadratically increase by 160%. At the time, the building code put forth by the New York City Buildings Commission did not require calculations regarding these quartering winds, since traditionally the perpendicular winds were the controlling factor in building designs. Therefore, this aspect of the building design was not reviewed by regulators. The student communicated her concerns, and her new calculations, to LeMessier's firm, but was reassured that although this miscalculation made the building 'less-safe', it was still not 'un-safe'. Safety factors had been built into the design such that even with this mistake, the tower and the people who used it and lived near it were not in danger. There were, however, mitigating factors that would push the building into the danger zone.

[4]Hartley, Diane, "Implications of a major urban office complex: The scientific, social, and symbolic meanings of Citicorp Center, New York City." Princeton, NJ: Princeton Univ. 1978.

The first was a decision made years before at the outset of construction. The design had called for the labor intensive and expensive method of using full penetration welds to connect the various steel angle truss supports to the main columns. The secure strength of welding built in a safety factor that more than accounted for the real effect of the quartering winds. As frequently happens in engineering, however, the cost of this technique was questioned. Would a less secure, but still safe, method that saved the customer money not be more appropriate? In this spirit the contractor, Bethlehem Steel, requested at the outset of construction that bolts be used to connect the building supports instead of the more expensive welds. It offered the customer, Citicorp, a $250,000 price reduction if this change could be made.[5] This request, with its associated price reduction, was approved by all parties involved, including the Building Commission. In and of itself, the decision to switch to bolts from welds did not compromise the safety of the building, but combined with the actual effects of the quartering winds, as well as yet another miscalculation, Manhattans newest architectural star and skyline gem was a disaster waiting to happen.

With the decision to use bolts instead of welds, it was up to LeMessier's firm to give the contractor the specifications for doing the job. The second miscalculation involved the number of bolts specified by the firm to be used at each connection. The building code governing such specifications distinguishes between 'columns' that support a building and 'trusses' that stabilize but do not support. In considering the forces on a building, the winds that are pushing the building sideways must be accounted for, but these are mitigated, to a certain extent, by the forces of the 'dead weight' of the building pressing down on itself. According to the code, when calculating the stresses and strains on columns, engineers could subtract three quarters of the 'dead load' force from the building. For trusses, however, engineers were allowed to subtract the entire dead weight force of the building. In the Citicorp Center design, the diagonal braces around the building served, essentially, as both columns and trusses. Yet in calculations, the firm treated them as 'mere' trusses, subtracting the entire dead weight of the building from the wind forces that they must withstand.[6] This led to a specification that called for half the number of bolts per connection than was actually properly safe.

The tuned mass damper at the top of the building, installed to counterbalance a swaying structure, could not be counted on as a mitigating factor that might reduce the danger since it required electricity to operate. Since the kinds of winds that might topple

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[5]Vardaro, Michael, "LeMessier Stands Tall," AIATrust.com.
[6]Vardaro, ibid.

the building usually occurred in storms that also would likely lead to power outages, the damper could not be counted on as a safety device.

It was when LeMessier put all of these developments together, the miscalculation of the quartering winds, the decision to switch from welds to bolts, the miscalculation of the number of bolts required, and the likely failure of the tuned damper in a storm, that he came to understand that there was a potentially significant problem. What he thought was a building that was designed to withstand anything short of a 200 year storm, in fact could in fact be compromised by a 16 year storm.[7] To make matters worse, the east coast hurricane season was approaching, and the forecasters were calling for just such a storm to possibly occur in a matter of weeks!

The Approach to Solution

The engineer, customer, and regulators now faced ethical decisions about how to proceed. Somebody had to say something, or thousands of people would be put at risk of great harm, while all the while thinking that they were perfectly safe. But what could be done? For the actions that he pursued next, LeMessurier has been widely praised. He blew the whistle on himself even though he could have been sued by Citicorp for producing an unsafe design, even if it abided by the regulations of the time, if the quartering winds calculations were seen as not an unusual consideration for the building. Yet, questions can still be asked about the process that unfolded, especially with regard to statements made to the public as the lead engineer on the project.

The first step LeMessurier took was to go to his insurance carrier who recommended bringing in an outside engineer to confirm the issues and then contacting the chair of Citicorp to explain the situation. The outside engineer indeed confirmed that the problems were real and while a meeting could not be directly set up with the chair of Citicorp himself, LeMessurier and the head of the architecture firm, Hugh Stubbins, did meet with Citicorp Executive Vice President John Reed. Mr. Reed had an engineering background and had been an interested supporter during the design and construction of the building. LeMessurier laid out the problem, including his understanding of the predictions for upcoming storms, and his suggestion for a fix. To secure the building, LeMessier proposed welding two-inch-thick six-foot-long steel plates on top of some 200

[7]Morgenstern, Joseph, “The Fifty-Nine Story Crisis,” *The New Yorker*, May 29, 1995.

of the bolted connections. Fortuitously, these connections were located between floors of the building and were relatively accessible. LeMessier also proposed installing backup generators for the tuned mass dampers (and arranging for 24-hour maintenance service) as well as developing an evacuation plan for the area surrounding the tower in cooperation with the Red Cross. Finally, LeMessier advocated the installation of strain gauges on the connections as they stood to monitor in real time whether they were headed into unsafe territory. He proposed working on the new welded plates at night in order to keep the building open during the day. Mr. Reed saw the gravity of the situation and immediately arranged a meeting with the chair of Citigroup, Walter Wriston, who had the authority to agree to the plan. Mr. Wriston did so without hesitation also agreeing to LeMessier's plan to fix the problem. All the parties involved agreed to share the expenses of the new project, each paying several million dollars to get it done.

Next, LeMessier approached the Buildings Commission and explained to them the problem, again explaining what he knew about the forecast for hurricane season and the likelihood of the next strong winds that would put the building in the danger zone as well as the now agreed upon solution. There was no time to waste and the commission agreed to let LeMessier proceed with his plan.

Informing the Public - In an Objective and Truthful Manner?

Now the building residents and those in the surrounding area needed to be informed, but how to do this? Here, the engineer's actions call for further ethical consideration. Publicly telling everyone that the building was unsafe and a storm was coming that could topple it would have caused panic. As LeMessier himself said after the repairs were safely completed, "You don't want to cause terror in a community to people that don't need to be terrorized"(Vardaro). Accordingly, LeMessier made public statements that had a questionable relationship to the reality at hand. The Engineering News Record reported that, "LeMessurier maintains that the...tower has well over the structural support it requires to withstand anticipated wind loads and that the purpose of the extra bracing is simply to supplement it." (Vardaro). When pressed on whether the new bracing was necessary or optional, LeMessier hedged, noting that, "I advised the bank, and they listened to me…As the bank put it, 'we'd like to have belts and suspenders'."(Vardaro) Citicorp itself issued a bland but definitive announcement stating that, "a review of the Citicorp Center's designation specifications was recently made . . . [it]

caused the engineers to recommend that certain of the connections in Citicorp Center's wind bracing system be strengthened through additional welding . . . there is no danger."[8] It happened that just at this time there was a newspaper strike in New York City, so the public announcements went unchallenged for the most part. The fact that mistakes had been made that made the building unsafe, and that correcting those mistakes was the reason for the new work being done, went largely under the radar. The work proceeded quickly, largely in the background, and in only four months after the first notification of possible problems by the Princeton student, the building was secured, by all current calculations, against a 700 year storm without the aid of the tuned mass damper[9]. It stands thusly to this day, an iconic member of the Manhattan skyline and one of the safest skyscrapers in all of New York City.

While avoiding panic is plausibly in the public interest, fully disclosing the reasons for the repairs would certainly also have publicized the engineering mistakes made. This would have reflected poorly on all parties involved, especially the engineer responsible for the design of the building. It was in all of their interests to 'clean up the mess' as quickly and quietly as possible, and in this case it worked. This approach, however, raises an important consideration. Fully disclosing the series of events and miscalculations that led to an unsafe building being being erected could have been useful information for future projects. By burying the information, all parties involved, and especially the lead engineer, kept information out of records and discussions that might have helped keep future engineering projects from being unsafe.

[8] LCP p. 9.
[9] Vardaro, Michael and Hegarty, Timothy, "The Citicorp Center Project: LeMessurier Stands Tall," victoriainsurances.com, p. 8.

Conclusion

The case of the Citicorp Center is widely held up as an engineering ethics success - unexpected mistakes were found, the lead engineer blew the whistle on himself, and all the relevant parties agreed to do the right thing, including paying additional millions of dollars to fix the problem. But ethical questions arise. Is the effect of the quartering winds not a basic and fundamental calculation that the engineer should have been accountable for, even if it was not legally required? Did the false public statements made by the engineer serve the greater good of public safety or put the public at greater risk from future projects that were not made aware of the problems with the Citicorp Center? Did the engineer balance his obligation to be a faithful agent for his client with his obligation for public safety properly - even though there is no separate canon or code from the NSPE that determines how such balancing should be handled? As is usual in ethics, these questions may or may not have definitive answers, but and understanding of the relevant canons of ethics as put forth by the NSPE is the cornerstone for an engineer working to understand how to proceed in such circumstances. The questions associated with this course serve to elucidate the basis for ethical analysis of the decision-making in the Citicorp Center case.

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