Aging Structures and the Risks They Present

Benjamin M. Cornelius, P.E., C.E., S.E., P.Eng[1]

[1]LERA Consulting Structural Engineers, RLLP. Email: benjamin.cornelius@lera.com

ABSTRACT

The 2021 collapse of the Champlain Towers South Condominium Tower in Surfside, Florida killed 98 people and stunned the engineering community over the apparent lack of advance warning of the disaster at what had been a fully-occupied oceanside address. In the investigations that followed, evidence revealed that warning signs did appear in the months and weeks prior to the collapse and raised questions over the standard of care for design professionals providing engineering services for aging buildings and infrastructure. In this paper, the author, a designer of rehabilitation and adaptive reuse projects and lead investigator for recent collapses involving aging structures, will discuss the condition assessment of aging structures, identification of unsafe conditions, and the duty to warn clients and the public when unsafe conditions are discovered. The author will discuss evidence from investigations of recent collapses to illustrate these topics.

INTRODUCTION

With the push for a greener construction industry and a desire to preserve and breathe new life into our existing building stock, the demand for continued use or reuse of aging structures is growing. Recent collapses of aging structures, however, highlight the risks that design professionals face when assessing the condition of and designing repairs or alterations to existing structures.

The 2021 collapse of Champlain Towers South, the 2023 collapse of the 57 Ann Street parking garage in New York City, and the 2023 collapse of an apartment building in Davenport, Iowa, all involved aging buildings that were being assessed, repaired, and/or altered in the weeks and months leading up to the collapses. The collapse of Champlain Towers South, alone, resulted in the loss of 98 lives, hundreds of millions of dollars of property damage, and legal claims over $1 billion. In media reports, the collapse was characterized as a sudden failure. Evidence that came to light during the ensuing investigation, however, indicated that a chain of events led to the failure, and warning signs in the days, weeks, and even months before the failure went unheeded.

Design professionals tasked with assessing and designing repairs or alterations for aging structures can and should take steps in their pursuit and execution of such work to protect the public and manage risks associated with unsafe conditions.

CONDITION ASSESSMENT OF AGING STRUCTURES

Clearly, design professionals who pursue work assessing the condition of, and designing repairs or alterations to, existing buildings should ensure they are qualified for each assignment they accept, having experience with similar structures and a thorough understanding of their unique characteristics and vulnerabilities to aging, the environment, and other forces. Additionally,

design professionals should take steps to manage the risks of concealed defects, damage, and deterioration to the public and to themselves and their employers.

Defining the Purpose and Scope of the Assessment

Before pursuing a project to assess an aging building, the design professional should understand the client's objectives for the project and develop an appropriate and clearly defined scope of work. Assessments of existing structures are performed for many reasons, including:

- To identify the nature, severity, and extent of defects, damage, and deterioration so that appropriate remedial measures may be designed and implemented and effective inspection and maintenance protocols developed;
- To ascertain the configuration and capacity of the structure to support continued occupancy, changes of occupancy, alterations, or additions; and
- To support a property appraisal or estimate of building maintenance costs in preparation for sale or insurance valuation.

The scope of the assessment should be tailored to include the efforts the design professional believes are necessary to gather the relevant information in accordance with building regulations and industry standards. Notwithstanding this, proposals should clearly communicate that assessments are not exhaustive examinations of existing structures and may not detect all defects, deterioration, damage, and other relevant conditions.

Establishing Limitations of Liability

Design professionals are responsible for performing their services to the applicable standard of care; however, limitations of liability consistent with insurance coverages and the relationship between risk and reward on each project—that is, the exposure to potential lawsuits versus the potential for profit on the project—can be appropriate. Insurance carriers or brokers can be a source of advice regarding appropriate limitation of liability terms for proposals and agreements. Where the client refuses to accept such a limitation of liability, or where time, budget, or other constraints do not allow for execution of the services the design professional believes are appropriate, the design professional should consider declining the assignment.

Using Qualified Firms and Individuals

Design professionals should include in their proposals appropriate allowances of time for inspection, analysis of observations, and development of remediation recommendations by appropriately qualified individuals. The design professional in responsible charge of the assessment should visit the site and observe the structure early in the project and should actively direct the work of the assessment team, so that the design professional's knowledge and experience are brought to bear in identifying defects, damage, and deterioration; prescribing appropriate remedial measures; and appropriately addressing unsafe conditions in a timely manner. The design professional's active involvement should continue into construction of recommended remedial measures and include appropriate levels of engagement of the construction team to increase the likelihood that concealed defects, damage, or deterioration revealed during construction are addressed appropriately.

Understanding the Existing Structure

A design professional undertaking a condition assessment or design of repairs or alterations to an aging structure should discuss with the client the need to understand the configuration and condition of the existing structure, and the efforts necessary to do so. Topics should include, among others:

- the availability of original construction drawings, alteration drawings, maintenance and repair logs, prior condition assessments and surveys, building department violations, and other relevant documentation of the structure;
- the need for probing and testing to ascertain or verify information about the existing structure;
- the potential need for structural analysis of components that are found to be compromised; and
- the potential need to predict the probable service life of components in identifying appropriate remedial measures and future inspection and maintenance protocols.

Again, where time, budget, or other constraints do not allow for the proper execution of the services the design professional believes are necessary to develop an appropriate understanding of the configuration and condition of the existing structure, the design professional should consider declining the assignment.

IDENTIFYING AND ADDRESSING UNSAFE CONDITIONS

Condition assessments and remediations of aging structures are often accomplished without the discovery of unsafe conditions; however, it is important for design professionals and their assessment team colleagues to be alert to the potential for unsafe conditions and prepared to respond appropriately should they arise.

Types of Unsafe Conditions

The New York City Building Code defines an "*unsafe condition*" as "*any structure, temporary construction installation, material, operation, or equipment found to be defective or unsafe, and posing a risk to the public or property*."[1] Unsafe conditions take various forms. For purposes of this paper, the author has focused on unsafe conditions that relate to an aging structure itself.

Unsafe conditions include defects, damage, or deterioration of structural components that have taken place prior to or during the assessment or during construction and that present imminent danger to building occupants, the public, and/or property. Unsafe conditions can also include work that is performed on a building structure without the required building department work permits. Such conditions may be observed by the design professional during pre-proposal walk-throughs, official assessment inspections, or other site visits.

Identifying Unsafe Conditions

Among the most important measures in identifying and properly addressing unsafe conditions are:

- awareness of and adherence to building regulations;

[1] 2022 New York City Building Code, Section 3301.5, *Unsafe Conditions*

- awareness of the kinds of issues that characteristically affect the types of structures being assessed, repaired, or altered;
- vigilance by property owners and their consultants and contractors in being alert to deterioration, damage, or other conditions that suggest a structure is not performing as intended and may be progressing toward failure;
- appropriate verification of assumptions regarding the configuration or condition of components that are critical to the structural stability of the building or a portion thereof;
- appropriate investigation of apparent damage that could be of a structural nature through a more detailed assessment and/or careful probing of the structures;
- where appropriate, performance and consideration of structural analyses in judging whether observed defects, damage, or deterioration pose a threat;
- open lines of communication between contractors, the design professional in responsible charge of the assessment, repair, or alteration design, and field personnel; and
- preparedness on the part of design professionals to take appropriate steps to protect the public, building occupants, and property when confronted with unsafe conditions.

It is important to note that whenever probes to verify conditions or investigate damage are to be performed, the design professional should consider whether shoring will be necessary to safely execute the probing.

Duty to Warn the Public, Building Occupants, and Clients

An engineer's paramount responsibility is to "*protect and advance the health, safety, and welfare of the public through the practice of Civil Engineering.*"[2] An engineer must use knowledge, experience, and judgment in deciding whether a condition is unsafe. When an engineer becomes aware of an unsafe condition, he or she has a duty to take steps to protect the public. Some of the steps a design professional might take when confronted with an unsafe or potentially unsafe condition include:

- Reporting the condition to the property owner and/or manager;
- Reporting the condition to the building authority;
- Recommending the stoppage of construction or other work that may be contributing to an unsafe condition;
- Recommending temporary shoring and/or bracing;
- Recommending evacuation of the building or structure;
- Recommending evacuation of surrounding areas that may be affected by the potential failure; or
- Some combination of the steps above.

It is important for design professionals to be aware of, understand, and adhere to regulations in the jurisdictions of their projects that may govern how design professionals respond to unsafe conditions.

[2] *Code of Ethics*, the American Society of Civil Engineers, October 26, 2020, https://www.asce.org/career-growth/ethics/code-of-ethics

CASE STUDY: THE COLLAPSE OF CHAMPLAIN TOWERS SOUTH

The Champlain Towers South Condominium ("CTS") was a 13-story, 136-unit, condominium at 8777 Collins Avenue in Surfside, Florida. It consisted of one rectangular basement parking level covering most of the site and an L-shaped condominium tower. On the deck over the basement parking level was the condominium lobby, an outdoor parking area, and an outdoor swimming pool and lounge area.

Design and Construction Defects Resulted in Reduced Structural Strength

CTS was designed and built in the late 1970s and early 1980s. In our forensic investigation of the collapse, we identified several key design and construction defects in the CTS Project that left it with a margin of structural safety that was substantially less than required by the applicable building code, as well as an elevated vulnerability to progressive collapse, right from the beginning of its service life. The design defects included deficiencies in the strength of the structural slab over the parking area, and the omission of waterproofing to protect the structural slab from the harmful effects of pool and sea water, among others. The construction defects included improper positioning or omission of reinforcing steel bars in the structural slab over the parking area, tower columns, and other components.[3]

Ineffective Maintenance Further Eroded Structural Strength

Ineffective maintenance and repair during CTS's 40-year lifespan further reduced the margin of safety and, we believe, ultimately triggered the collapse.

There were signs of severe, long-term water infiltration through the pool deck slab, as well as cracking and spalling of the slab, and corrosion of reinforcing steel bars embedded in the slab. Based on our investigation, we concluded that chlorinated pool water, ocean spray, and other chloride-laden moisture repeatedly saturated the inadequately waterproofed pool deck slab, causing corrosion of reinforcing steel.

Through the corrosion process, refined reinforcing steel is converted to corrosion product, or rust. The corrosion product is not as dense as the refined steel it replaces, resulting in a volumetric expansion of the corroding rebar. This expansion induces internal stresses in the concrete that eventually cause cracking of concrete. In certain instances, cracks that form in the slab can propagate and join, causing areas of the concrete to separate from the body of the slab. This condition is referred to as "delamination."

Delamination that occurs in a slab around a supporting column is particularly dangerous, as it can contribute to a phenomenon known as "punching shear" in which the slab loses strength and fails around the column, resulting in the column literally "punching" through the slab. A punching shear failure can lead to the collapse of a large area of slab, and such failures often occur with little warning. For these reasons, it is important to pay careful attention to any signs of water infiltration around columns.

---

[3] Cornelius, B.M., and Simpson, J.E., *The Collapse of Champlain Towers South, Review of A Forensic Engineering Investigation*. Proceedings of the American Society of Civil Engineering's 10th Forensic Engineering Congress: *Forensic Engineering 2024: Finding Answers to the What, Why, Who, and How of Preventing Failures*, 2024, pp. 487 – 498.

In photographs taken in the months and weeks prior to the collapse, there was evidence of severe, long-term water infiltration through the pool deck slab around the supporting columns, as well as staining that indicated corrosion of reinforcing steel bars, and debris on the garage floor that was likely dislodged concrete from the pool deck slab.

The Association Retained an Engineer to Assess CTS

In 2018, 3 years prior to the collapse, the CTS Condominium Association retained a licensed engineer (the "Recertification Engineer") to perform the 40-year recertification of the building's structural and life safety systems mandated under Florida State Law, among other things. In reports summarizing his observations, he reported that the pool deck waterproofing was past its useful life, allowing ongoing water infiltration through the structural slab, and warned that structural damage at the pool deck would "*expand exponentially*" if the waterproofing were not replaced:

> "*the waterproofing below the Pool Deck & Entrance Drive as well as all of the planter waterproofing is beyond its useful life and therefore must all be completely removed and replaced. The failed waterproofing is causing major structural damage to the concrete structural slab below these areas. Failure to replace the waterproofing in the near future will cause the extent of the concrete deterioration to expand exponentially*."[4]

The Recertification Engineer also concluded that past efforts to repair the pool deck slab had been "*ineffective*," and he recommended that "*entrance/Pool deck concrete slabs that are showing distress be removed and replaced in their entirety*." Despite these recommendations, the repairs were not completed.

Warning Signs

About 7 months prior to the collapse, photographs were taken of columns in the garage that supported the pool deck. The photos show that substantial amounts of water were coming through the slab around the tops of certain columns in the area where the collapse likely originated. The photographs show the build-up of heavy mineral deposits on the underside of the slab and the surfaces of the columns, which is an indication that the infiltration was a long-term problem. Brown staining, likely resulting from rebar corrosion in the area of the water infiltration, was also visible in the photographs, as was debris, likely concrete, on the garage floor that appeared to have dislodged from the slab due to cracking.

Approximately 6 months prior to the collapse, the Recertification Engineer performed a structural analysis of the western portion of the pool deck slab. The results indicated that, as designed, areas of slab were overstressed by up to 42 percent.[5] In our investigation, we did not find evidence of whether the Recertification Engineer also performed an analysis of the eastern portion of the pool deck slab, where the collapse is thought to have originated. Had such an analysis been performed, the results may have alerted the engineer to higher overstresses of

---

[4] Morabito, F., *Champlain Towers South Condominium: Structural Field Survey Report*. October 8, 2018. Town of Surfside Public Records.

[5] Cornelius, B.M., and Simpson, J.E., *The Collapse of Champlain Towers South, Review of A Forensic Engineering Investigation*. Proceedings of the American Society of Civil Engineering's 10th Forensic Engineering Congress: *Forensic Engineering 2024: Finding Answers to the What, Why, Who, and How of Preventing Failures*, 2024, pp. 487 – 498.

approximately 80 percent in the area of the pool deck slab where we concluded the collapse originated.

Approximately three weeks prior to the collapse, photographs were taken of concrete planter walls sitting on the pool deck in the area where we concluded the collapse originated. These photos show new wide cracks, that were not observed in prior photos of the same walls. The visible width and the orientation of the cracks indicated that the pool deck slab had begun to deflect, likely as a result of an initial punching shear failure at a nearby column. It is likely that following the initial punching shear failure, the slab initially had barely enough strength to span around the failure and remain standing, but increased stresses were taking a toll and the slab was progressing toward collapse.

The analytical results indicating severe design defects in the western portion of the slab, the photographs showing severe water infiltration through the slab around supporting columns, and the photographs showing severe progressive deflection of the slab, were a warning of impending collapse. Despite this warning, we found no indication that these conditions were identified as unsafe, that emergency shoring was recommended, or that building occupants were warned to evacuate.

At approximately 1:14 a.m. on June 24, 2021, the pool deck slab collapsed.[6] In our investigation, we concluded that when the pool deck collapsed, it dislodged a portion of concrete from one or more of the tower columns—which were particularly vulnerable to such damage due to construction defects we observed in our post-collapse examination of tower column fragments. The damaged tower columns were no longer strong enough to carry the loads imposed on them, and at approximately 1:22 a.m., they succumbed to the damage and the eastern portion of the condominium tower collapsed.[7]

Despite substantial efforts to investigate the cause of the collapse, there was more work to be done when the parties to the litigation announced a settlement.[8] The observations and findings presented in this paper should be considered preliminary and subject to change should new information be made available.

Lessons to be Learned

The collapse of CTS was a tragic occurrence that claimed the lives of 98 people and injured many more. In our investigation, we concluded that the collapse was caused by a combination of serious design and construction defects that compromised the pool slab and tower columns and the deterioration of the pool slab due to ineffective waterproofing and maintenance. Warning signs of an impending collapse were not recognized or went unheeded. Lessons that can be learned from the collapse include, among others:

- Visible defects, deterioration, and damage should be carefully documented, especially deterioration that affects components of the structure that are critical to the stability of a structure or portion thereof;

[6] *Video, images and interviews deepen questions about role of pool deck in condo collapse*, Jon Swaine, Brittany Shammas, Joyce Sohyun Lee, Atthar Mirza, Emma Brown and Amy Brittain, The Washington Post, June 30, 2021
[7] *Video, images and interviews deepen questions about role of pool deck in condo collapse*, Jon Swaine, Brittany Shammas, Joyce Sohyun Lee, Atthar Mirza, Emma Brown and Amy Brittain, The Washington Post, June 30, 2021
[8] Hanzman, M.A., *In Re: Champlain Towers South Collapse Litigation: Final Order and Judgement*. Case No. 2021-015089-CA-01. June 24, 2022. CTS Receivership.

- Engineers who assess structures should be cognizant of such critical components when inspecting structures and analyzing the observations and other data gathered;
- Experienced and qualified assessment team members should visit the site to see the conditions firsthand and should actively manage the assessment work so that they are informed of observed conditions and analytical results and can apply their knowledge and experience in identifying what safety issues the observations and results may reveal; and
- Design professionals and other qualified individuals should carefully consider the available information, make an informed decision as to whether an unsafe condition exists, and identify appropriate measures for protecting building occupants and the public.