

# Sleuthing the Mundane and the Catastrophic

**FORENSIC ARCHITECTS AND ENGINEERS EMPLOY INVESTIGATIVE TECHNIQUES, NOT TO POINT FINGERS, BUT TO FIND THE ROOT CAUSE AND RECOMMEND SOLUTIONS FOR PROBLEMS THAT PLAGUE BUILDINGS**

By Joann Gonchar, AIA

For the general public, mention of “forensics” most likely brings to mind television shows like the current *CSI: Crime Scene Investigation* or *Quincy, M.E.*, popular in the late 1970s and early '80s. For design and construction professionals, however, the word is associated with tragic collapses, such as the 1981 walkway failure at the Kansas City Hyatt Regency, or this summer's ceiling module collapse in a tunnel that is part of Boston's Big Dig.

It is no wonder that the term is associated with litigation. The Hyatt collapse, for example, which killed 114 people and injured another 185, is one of the most litigated building failures in history. At one time, the claims under review totaled more than \$3 billion, according to Kenneth Carper, professor at Washington State University's School of Architecture and Construction Management.

However, despite the protracted litigation surrounding some high-profile failures, architects and engineers who specialize in investigative work say they typically focus on less catastrophic building performance issues, like water penetration or poor indoor air quality, and that disputes are often resolved without lawsuits. Carper estimates that less than 5 percent of building failures end up in court.

In fact, many practitioners avoid the use of the term “forensic” simply because the dictionary definition “of or used in law courts” is not an accurate description of their primary goals—to find the source of the problem and propose a solution. “We call it ‘root cause investigation,’” says Robert Vecchio, principal of New York City-based Lucius Pitkin, Inc. (LPI), a firm that performs failure and material evaluation services. “We don't want to be considered hired guns,” he adds.

For the owner of a mid-1960s Midtown Manhattan office build-



A surveyor, suspended by a two-rope system similar to that used by climbers, evaluates and documents facade conditions of a historic building.

ing, litigation was “never really a topic of conversation” when a 30-by-30-foot section of louvered curtain wall fell from the upper floors of the 35-story tower in February 2003, says Gary Mancini, principal of Thornton Tomasetti, the New York City-based engineering and architectural consultants called in to investigate.

The curtain wall section fell during an intense snowstorm in the early morning hours of a public holiday and no one was hurt. The streets, which would have typically been coming to life at that hour, were deserted. And the team's first task, as it would be after any failure, was to make certain that occupants and pedestrians were not subsequently put at risk. The investigative team's top priority “is to make sure the situation doesn't get worse,” says Mancini. The police had cordoned off the street below, and Thornton Tomasetti, working with New York City-based contractor Structure Tone, used cables and netting to secure the failed area of the facade and the surrounding curtain wall.

Next, the investigators took a closer look at the remaining components at and near the area of collapse. They were particularly concerned about a concrete masonry block wall behind the section of failed curtain wall enclosing an elevator machine room. Typically, these types of walls are not reinforced and not tied to the building structure, explains Mancini. “It was never intended to be exposed to wind loads,” he

## CONTINUING EDUCATION



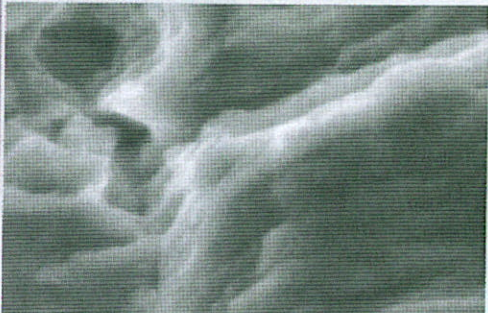
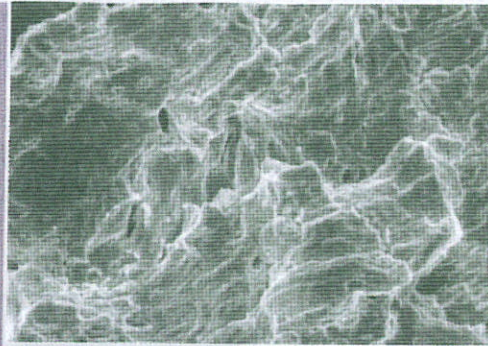
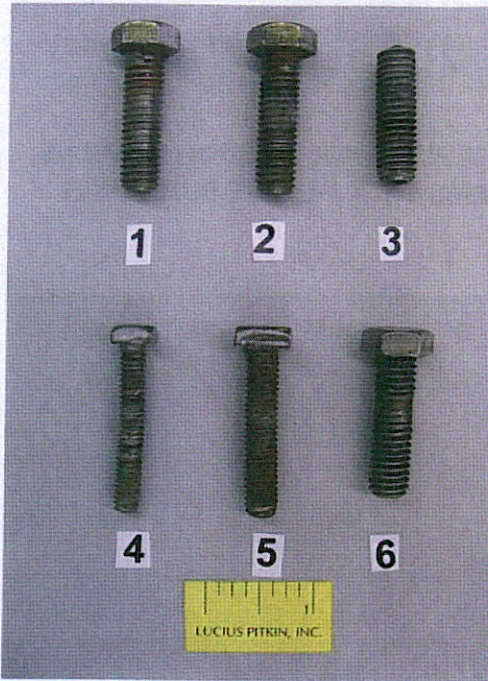
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## LEARNING OBJECTIVES

After reading this article, you should be able to:

1. Discuss causes of building failures.
2. Describe methods of investigating building failures.
3. Describe methods of investigating water problems in buildings.

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After a portion of louvered curtain wall fell from the upper floors of a Midtown Manhattan office tower (right), investigators braced a concrete masonry wall (above far right) and stabilized other surrounding construction. Debris was

cataloged (above) and tested. Magnification of the surface of a fractured bolt revealed a pattern of failure consistent with fatigue (two images, above middle). But this bolt was not ultimately considered to have played a role in the collapse.



says. Although it showed no signs of impending failure, engineers devised shoring from steel angles and channels that the contractor had on hand. In addition, the outside face of these walls was covered with plywood.

After completion of the stabilization process, the team was free to focus its attention on the rest of the building envelope. It began examining representative sections of the facade and the connections between the curtain wall and the building structure wherever these were not hidden by interior finishes, finding many locations where bolts tying the mullions to the building's structure at spandrel beams were missing. Wear on brackets and plates indicated that fasteners had been originally installed but had backed out over time. The building was a relatively early curtain-wall tower, and the facade system did not use fasteners with locking devices, explains Mancini. "It was not until the '70s or '80s that these curtain-wall systems were refined."

At the owner's urging, the inspection quickly expanded to examination of all of the nearly 2,000 connections between the facade and the tower's structure. In the case of curtain walls, "there is no textbook [formula] for determining how much investigation is enough," says Eric Hammarberg, Thornton Tomasetti vice president.

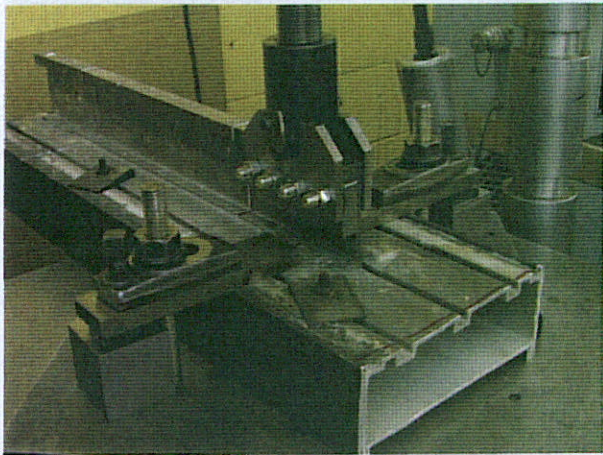
Over the course of the next six or seven months, during weekends and after normal working hours, the Thornton Tomasetti team and the contractor examined every mullion bracket and spandrel beam clip. These connections, hidden on both the exterior and interior, were accessed through the convection units within offices using a device called a borescope that links an objective lens to an eyepiece with a flexible tube.

The investigators found that the locations with missing bolts were concentrated primarily at the corners and at the upper floors, the areas of the building subject to higher wind loads. When locations with missing fasteners were found, the contractor replaced them on the spot with new stainless-steel bolts and nylon threaded nuts.

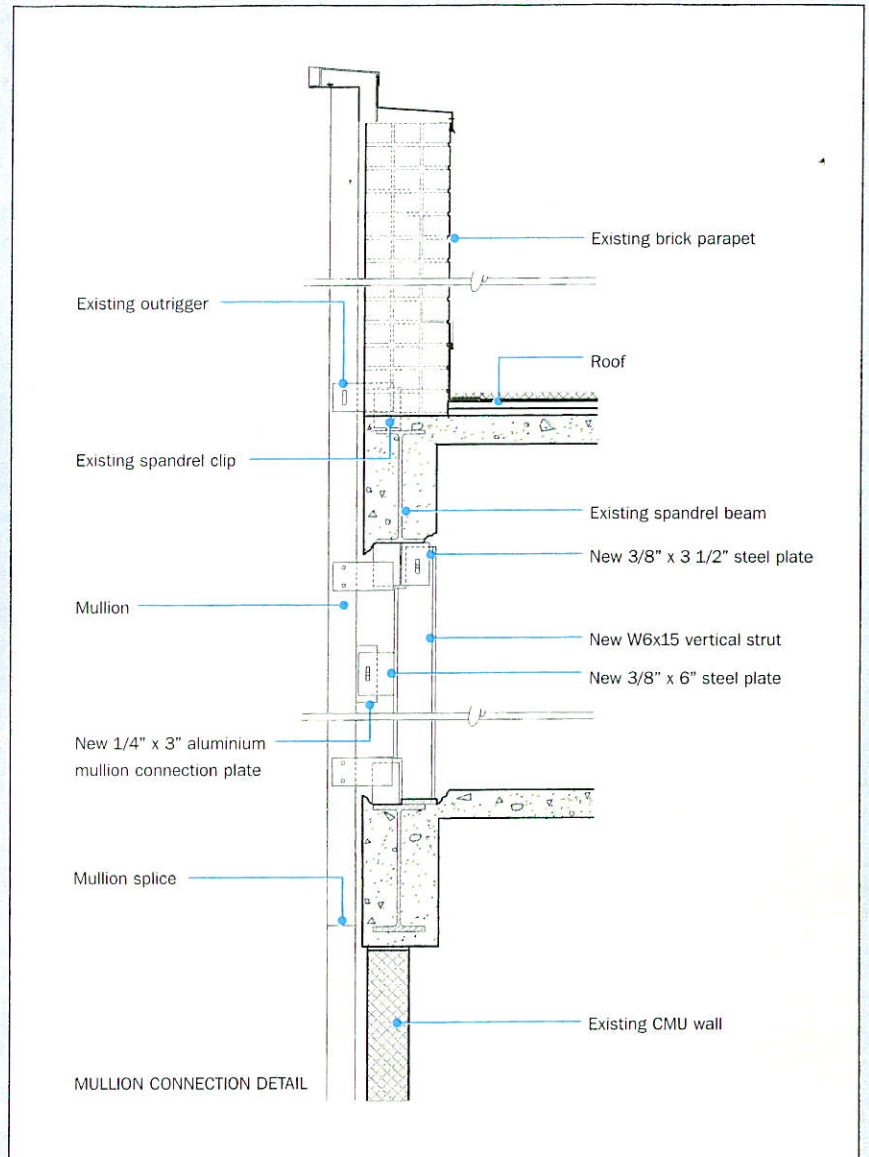
Concurrent with the examination of the mullion-spandrel connections, Thornton Tomasetti was also trying to determine what made the louvered section that fell during the February snowstorm particularly vulnerable. Using methods not so different from those employed by plane-crash investigators, the team cataloged the recovered debris and reconstructed the facade in a vacant retail space on the building's ground floor.

Some debris was sent for metallurgical testing and microscopic examination to Vecchio's firm, LPI. It tested the loading capacity of the

LPI tested a portion of recovered mullion (below) from the Midtown Manhattan office building's failed section of curtain wall to determine the load-carrying capacity of the weld holding the clip to the mullion. However, no deficiencies were found.



The specified repair for the failed area of curtain wall (right) included construction of the previously omitted connections between the mullions and the building's structure.



welds attaching the connection plates to the mullions, but no deficiencies were found. LPI also examined other recovered components, including the bolts used to secure the curtain wall to the building's structural frame. The majority of recovered bolts showed evidence of damage from wind loading. "The bolts had moved back and forth [within the clips and connection plates] to the point of rubbing off the threads," says Mancini.

One bolt with a missing head was recovered. Its surface, magnified 7,500 times, revealed a pattern of parallel bands—an indication of failure due to fatigue, explains Vecchio. But the Thornton Tomasetti team

## FOR CURTAIN WALLS, THERE IS NO TEXTBOOK FORMULA FOR DETERMINING HOW MUCH INVESTIGATION IS ENOUGH.

could not link the bolt directly to the failed area and theorized that it may even have been a stray bolt broken during construction.

The final conclusion of the investigative team was that the louvered section of curtain wall had failed because spandrel clips had been omitted at three different locations. "The outrigger plate had been installed on the mullion, but there was no evidence it had ever been

attached to clips on the spandrel side," says Mancini.

The reason for the absence of these connections is still unclear. It may have been a result of a field change, or due to the elevation of the spandrel beam, which was higher in relation to the surrounding structure on this floor than on others. Because of the floor's unusual configuration, there may have been a misalignment of the tie between curtain wall and building structure, according to Thornton Tomasetti. Although the reason for the omission is a mystery, the repair was straightforward. This work, completed in late 2003, involved replacing the failed section of curtain wall and constructing the omitted connections.

### Water woes

More mundane than falling facades, but still vexing to building owners and occupants, is the common problem of water infiltration. The owner of an early-20th-century warehouse discovered that his heavy-timber and masonry-bearing-wall structure had this problem in the summer of 2001, just a year after its gut renovation and conversion to a corporate headquarters was completed, according to Dean Vlahos, AIA, a principal and head of forensics practice at Santa Monica, California-based WWCOT.

The owner, who asked that neither he nor the location of his