

BUILDINGS

Tuned Liquid Damper Tops Chicago Hotel

SKYSCRAPER DESIGNERS can limit wind-induced motion in a number of ways, for example, by changing a tower's shape or stiffening its structural system. The designers of the Elysian Hotel and Private Residences, a mixed-use building currently under construction in downtown Chicago, are counteracting such motion by means of four enormous tanks of water.

The 685 ft (209 m) tall, 638,000 sq ft (59,270 m²) Elysian is a slender building that narrows as it rises. Its lowest 26 floors, which contain the hotel space, typically are 97 by 126 ft (30 by 38 m) in plan. Above the hotel, the second-largest segment of the building, which comprises 30 stories of condominiums, typically measures just 86 by 112 ft (26 by 34 m) in plan.

Because of the building's slim profile, its principal designers—architect Lucien Lagrange Architects and structural engineer Halvorson and Partners, PC, both of Chicago—understood early on that wind-induced vibration and other dynamic effects would govern the structural design. Wind tunnel tests on scale models at the University of Western Ontario's Boundary Layer Wind Tunnel Laboratory confirmed that in a 10-year storm the building would experience a peak acceleration in excess of 0.020g. The project team deemed such accelerations too high to ensure the comfort of occupants in a residential building, says Nick Isyumov, Ph.D., a consulting director of the laboratory.

To reduce the potential accelerations, the building's designers studied the possibility of stiffening the structure by increasing the size of various structural members. They concluded that such strat-

egies would not only be expensive but would also lead to unacceptable reductions in column-free interior space, says Tim Laken, S.E., P.E., the project manager for Halvorson and Partners. Ultimately, the team settled on an unusual but increasingly common device for controlling building motion: a tuned liquid damper.

A tuned liquid damper is an uncomplicated device, in essence being "a tub of water," notes Isyumov. The dimensions of the tub and the depth of the water inside it are carefully calculated so that the water sloshes back and forth at a frequency close to the natural frequency of the building. When strong winds cause the building to vibrate, the motion of the water interferes with the motion of

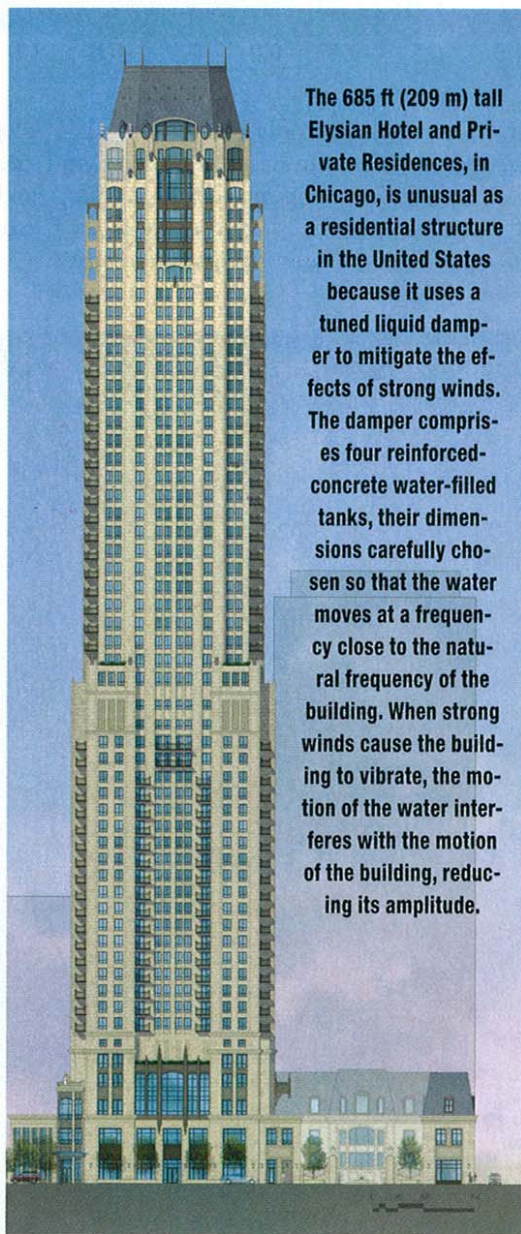
the building, reducing its amplitude. In this way, tuned liquid dampers are much like tuned mass dampers, but they are simpler and therefore usually less costly to install and maintain, Isyumov says.

The Elysian's tuned liquid damper actually consists of not one but four reinforced-concrete tanks, each located near the top of the building and measuring 21 ft (6.4 m) long, 18.5 ft (5.6 m) wide, and 6 ft (1.8 m) deep. During a wind event, the tanks will work in unison, functioning as a single mass, explains Isyumov. Inside each tank, baffles made up of horizontal steel tubes will regulate the flow of the sloshing water, keeping its movement under control.

The project team has already established the tanks' dimensions on the basis of the building's expected periods of vibration, Isyumov says. For the damper to function properly, however, it must be tuned to an extremely high degree of precision. Such parameters as the depth of the water and the space between the interior steel tubes must be based not on calculated values but on measurements of the building's actual behavior. For this reason, the Boundary Layer Wind Tunnel Laboratory will monitor the completed building for several months and then make any necessary final adjustments to the damper.

Although tuned liquid dampers are relatively rare in residential towers in the United States, the damper is not the only distinguishing feature of the project, observes Laken. One of the architect's major goals was to provide column-free interior space. Thus lateral loads are resisted only by four reinforced-concrete perimeter columns and an 18 in. (460 mm) thick shear wall, also of reinforced concrete, that surrounds the building's core. The enormous columns, which measure 6 by 10.5 ft (1.8 by 3.2 m) at their base, are connected to the core by outrigger shear walls. At the upper levels of the building, even the outrigger walls are eliminated to create opportunities for spacious, customizable floor plans.

Because the floor plates are



The 685 ft (209 m) tall Elysian Hotel and Private Residences, in Chicago, is unusual as a residential structure in the United States because it uses a tuned liquid damper to mitigate the effects of strong winds. The damper comprises four reinforced-concrete water-filled tanks, their dimensions carefully chosen so that the water moves at a frequency close to the natural frequency of the building. When strong winds cause the building to vibrate, the motion of the water interferes with the motion of the building, reducing its amplitude.

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smaller at higher levels of the tower, loads must be transferred at several levels where the floor plate changes in size. One particularly significant transfer occurs roughly halfway up the building, between the hotel and condominium spaces, Laken explains. Here the loads are transferred via a reinforced-concrete slab 6 ft (1.8 m) deep—so deep, in fact, that the contractor had to place the concrete in two stages. The contractor, James McHugh Construction Company, of Chicago, first placed a 2 ft (0.6 m) deep layer, then post-tensioned it in order to support a second, 4 ft (1.2 m) deep layer that was placed on top. Vertical shear reinforcement ensured that the two parts of the slab would act compositely.

Halvorson and Partners originally designed the tower's foundations as caissons bearing on bedrock, but a value engineering exercise showed that caissons bearing on a layer of hardpan clay would be much more economical, Laken says.

Further analysis, however, revealed that installing the hardpan caissons was feasible but would result in some 2 in. (50 mm) of settlement, roughly twice the amount desired. That finding raised concerns that differential settlement would occur at the interface between the 61-story tower and two 4-story steel buildings that were to be attached to the tower's east and west sides.

In the end, the contractor installed hardpan caissons having shafts 2.5 to 7 ft (0.8 to 2.1 m) in diameter and belled bases 4 to 20 ft (1.2 to 6.1 m) in diameter. Furthermore, the design team and the contractor took special precautions against differential settlement. During construction, the tower was structurally isolated from its smaller neighbors so that each structure could settle at its own pace. Workers monitored the settlement until it was within acceptable limits, then proceeded to place the concrete that would link the three structures.

Construction of the tower began in 2006 and is expected to be complete next year. The hotel portion is scheduled to open late this summer. —JEFF L. BROWN

BUSINESS

Engineering Salaries Continue to Rise Despite Recession

A SALARY SURVEY released in June by ASCE in conjunction with the National Society of Professional Engineers (NSPE) and the American Society of Mechanical Engineers (ASME) reveals that, despite the precarious state of the nation's economy, the salaries of engineers continue to reflect a positive trend that began in 2005. Entitled *Salary Survey 2009: The Engineering Income and Salary Survey Standard Report*, the survey finds that for the period between April 1, 2008, and April 1, 2009, the median base salary of engineers was \$87,500, 9.4 percent higher than the figure in the 2008 survey and 24.5 percent higher than in the 2004 survey. The median annual income, which includes salaries, fees, cash bonuses, commissions, and profits, is \$92,245 in the 2009 report, 8.5 percent higher than in the 2008 survey

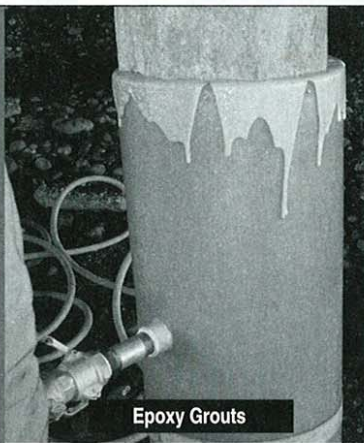
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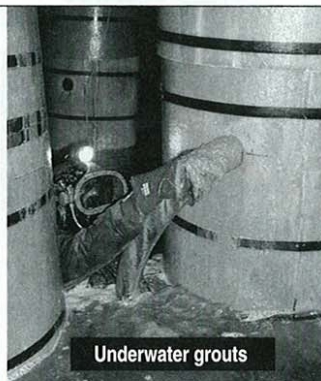
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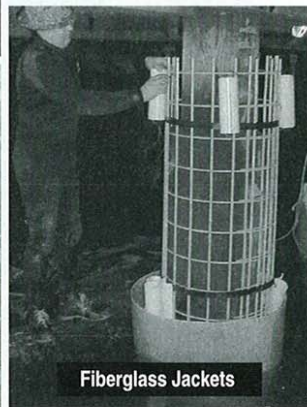
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