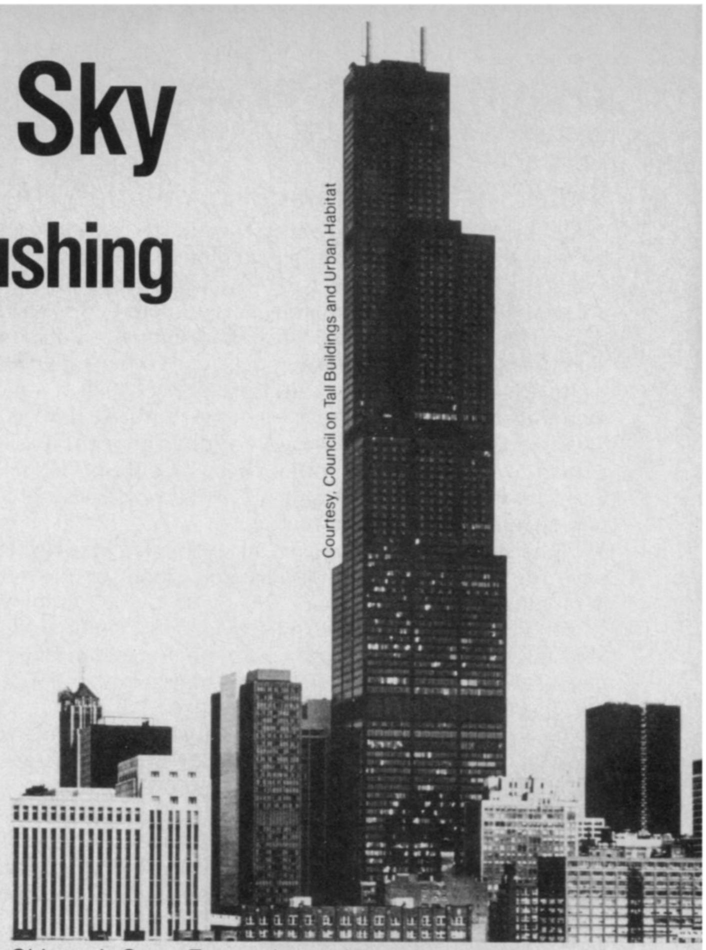
Reaching for the Sky

New technologies are pushing skyscrapers ever higher

By IVARS PETERSON


Courtesy, Council on Tall Buildings and Urban Habitat

Chicago's Sears Tower, the world's tallest building.

The skyline of a city like Chicago or New York has the look of "extravagant pins in a cushion," one commentator said many years ago. Such sky-scraping needles, stretching ever higher, now dominate many cityscapes.

Today, even the word "extravagant" seems a little mild when applied to some of the visions that real estate developers, architects and engineers are playing with. Within reach, they say, are soaring concrete towers that tickle mile-high clouds or gigantic steel frames from which a city's walkways, roads and buildings hang.

"The technology is here," says Joseph P. Colaco of CBM Engineers, Inc., in Houston. "There is no reason why we can't build very high concrete buildings." Or, other builders say, why we can't put up huge steel structures.

A mile-high skyscraper would be almost four times taller than Chicago's 110-story Sears Tower, completed in 1974 and currently the world's tallest building. Two taller skyscrapers now on the drawing boards – one in New York and one in Phoenix – would rise nearly 1,700 feet. But this would be only 200 feet more than the Sears Tower. The step to a superskyscraper is still a long one.

Nevertheless, new building techniques, novel materials and the ubiquitous computer are pointing the way. These factors and others affecting the future of tall buildings were the subject of the Second Century of the Skyscraper conference held earlier this year in Chicago. The meeting was organized by the Council on Tall Buildings and Urban Habitat, located at Lehigh University in Bethlehem, Pa., to celebrate 100 years of skyscraper design and construction.

A superskyscraper doesn't have to look very different from today's tall buildings, says Colaco. Like the Sears Tower, it could be constructed as a bundle of "tubes" – concrete shells with rectangular or triangular cross sections – that terminate at various heights. Only one such module would actually go the full height.

At cloud level, this structure would have to resist steady winds of 90 miles per hour or more. Otherwise, such a tall building would creak and squeak as it shifted in the wind. Chandeliers and draperies would swing; water in toilet bowls would slosh about. Inhabitants could even get seasick. The use of lightweight materials would make the problem even worse.

One solution is to build gigantic diagonal braces into the walls and floors to provide the necessary stiffness. In some of today's tallest buildings, structural braces are clearly visible, and architects turn them into an important element in a building's appearance.

Engineers are also exploring other methods for reducing skyscraper sway. New York's World Trade Center towers have special spongelike pads sandwiched into their structures to absorb vibrations. The Citicorp building in New York has an 800,000-pound weight sliding about on an upper floor to counter wind effects and dampen building movements.

One new approach is to build the equivalent of muscles and a nervous system into a structure. Arrays of implanted sensors would detect movements and deformations, while systems of "actuators" would respond by changing the structure's shape or stiffness. Composite materials, such as graphite or glass fibers embedded in an epoxy matrix, would have to be used to provide the necessary strength and flexibility. A simpler version of this idea requires the use of motors to pull on or relax metal "tendons" stretched out within structures.

Mechanical engineer Richard E. Klein of the University of Illinois at Urbana-Champaign suggests the use of cables attached to a building's framework and anchored to the ground. Each cable would be fitted with a control mechanism similar to a fishing reel. When the cable was slack, the device would reel in the line. When the cable was taut, the mechanism would brake, allowing the cable to stretch and absorb vibrational energy.

Another simple way to reduce sway would be to link two or more buildings by cables equipped with control mechanisms. As the buildings shook, the cable controls would react accordingly, pulling in slack lines while letting taut cables stretch. Klein sees no reason why whole areas of closely packed high-rises couldn't be connected in this manner.

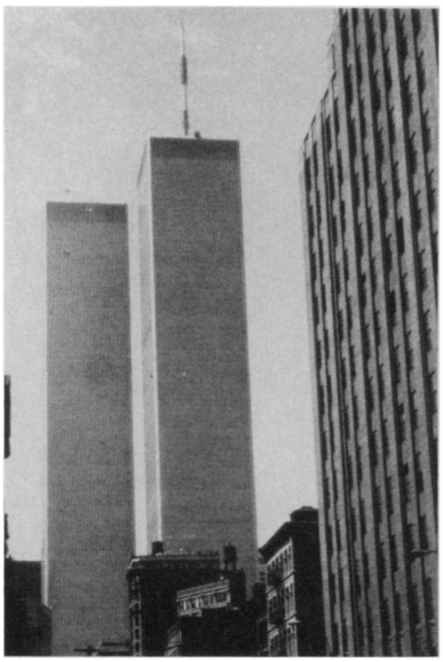
Early skyscrapers, such as the Empire State Building in New York, swayed little because their structures incorporated massive steel beams and diagonal braces. But these buildings contained about twice as much steel per square foot as would be used in a typical modern tower. The use of lighter materials helps reduce construction costs and allows buildings to rise even higher.

The recent development of high-strength concrete is opening a new path to the heights. Compared with steel, concrete is less costly, and its greater mass and rigidity lead to stiffer buildings. Ordinary reinforced concrete can support loads of 4,000 to 6,000 pounds per square inch (psi). High-strength concretes contain chemical additives such as polymers in addition to the sand or gravel, water and Portland cement normally used.

The world's tallest all-concrete building, Chicago's 859-foot Water Tower Place, could easily be surpassed with the use of these new steel-reinforced concretes. Concrete with a strength of 14,000 psi would be enough for a building to reach a 1-mile height, says Colaco. Such a structure would shrink about 11 feet as the concrete sets, he notes, but that is much less than the shrinkage and creep that ordinary concrete suffers.

Danish scientists are already studying dense concretes with a strength of 30,000 psi. However, so far these materials are somewhat brittle and sensitive to fire, and explode when heated or put under great stress. Nevertheless, some engineers predict that 20,000-psi concrete will be commercially available by the year 2000.

A new building technique, called composite construction, involves the use of steel columns surrounded by reinforced concrete. With such concrete blankets, steel columns can be lighter than usual. This method combines the short erection time of structural steel with the low cost of reinforced concrete.



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The twin towers of the World Trade Center in New York City have a rigid outer frame made up of closely spaced steel columns.

Photo: Tom Cramer/Courtesy. Council on Tall Buildings and Urban Habitat

At 859 feet, Water Tower Place in Chicago is the world's tallest all-concrete building. Its construction required special, high-strength concrete.

Architects and engineers are beginning to use computers extensively not only as drawing boards but also for scheduling construction, selecting appropriate materials and finding paths through the maze of codes and regulations that surround major construction projects. In addition, computer and telecommunications systems are being installed in new, "smart" skyscrapers to control everything from elevators to heating and air conditioning systems, while providing enough flexibility to meet the changing needs of tenants.

"The future of the skyscraper," says engineer Gordon C. Rigg of Rankine & Hill Pty. Ltd. in Melbourne, Australia, "is very much tied in with that of the smart building."

"We'll be seeing more and more automatic control," says Joseph H. Newman of Tishman Research Corp., in New York. This includes devices that sense the presence of people and automatically regulate light and temperature levels. Other sensors would monitor air quality and diagnose building ills such as leaks and cracks.

However, attempts to introduce such controls have not come without glitches. Many office workers are uncomfortable with an elevator's parental voice or the "unseen hands" that adjust window shades or turn off lights as people leave a room. In one office building, employees found that the only way to darken a room in order to show slides was to sit perfectly still for 12 minutes at a time. Otherwise, a motion detector would turn the lights on. The eventual solution was to unscrew the light bulbs.

In a superskyscraper, elevators and horizontal transportation systems would also pose special difficulties. In a mile-high building, people would have to get used to waiting 10 minutes or more for an elevator, just as they would wait for a bus or a train. The elevator system, which may include double- or quadruple-deck cars, would have local and express lines. Sky lobbies at higher floors, equivalent to major train stations, would be needed to facilitate transfers among sets of elevators.

Elevator technology itself is advancing. In a building as tall as the Sears Tower, the wire "ropes" that support elevator cars stretch 10 feet or more over a period of years. Shutting down the elevators periodically to shorten the cables is an expensive chore. When new elevators were recently installed at the Sears Tower, the problem was solved by putting the hoist machinery on a platform that could be gradually jacked up to compensate for cable stretching.

Technical innovations and a better understanding of resonance, which can set an elevator car and its cables into wild swings when the wind is right, have also led to smoother and quieter rides.

But the human body sets its own limits. Elevators shouldn't be allowed to travel faster than 2,000 feet per minute, says elevator expert William S. Lewis of Jaros, Baum & Bolles in New York. Otherwise, the human ear can't adjust comfortably to the continuous pressure change, particularly on a downward trip. Moreover, a 100-story trip is about as far as an express elevator should go, he recommends. These factors must be considered in the design of elevator systems for superskyscrapers.

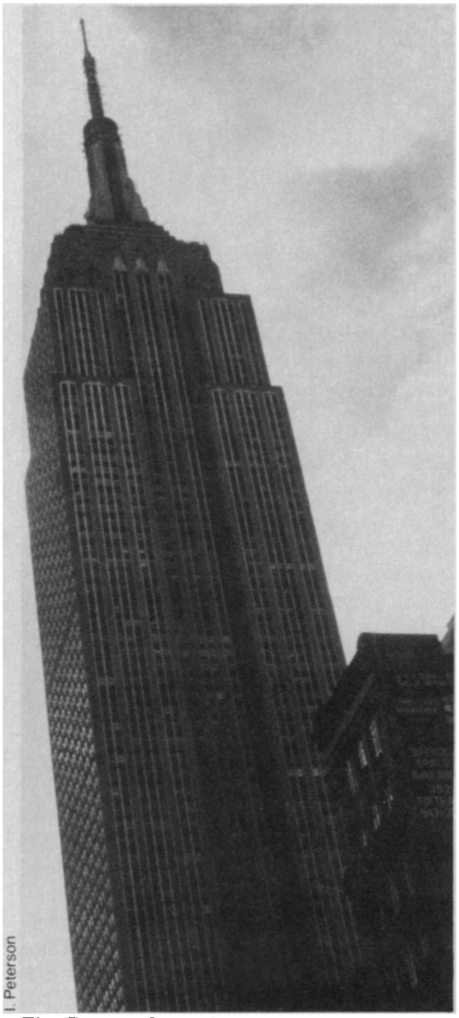
Despite the sleek appearance of most of today's glass, steel, stone and concrete towers, all is not well within. Perhaps 90 to 95 percent of all buildings constructed, says engineering consultant Israel A. Naman of I.A. Naman & Associates, Inc., in Houston, never operate as they were intended to. Inadequate or poorly maintained air conditioning and heating systems are often the central problems.

"It's astonishing what a poor job our architects, engineers and contractors are doing in designing and installing air conditioning systems," says Naman. "These are the kinds of things that have to be done better."

A higher level of automation and computer control and some newly developing technologies may help, Naman says. One is the development of electrothermal refrigerators in which electrical energy directly provides local cooling. This type of cooling device is now used experimentally in the space program. Such machines, if compact models suitable for homes or office buildings could be produced, would eliminate the need for bulky, centralized heating and cooling units.

Says Rigg, "We must make sure that what we design is maintainable into the future." This includes considering seemingly insignificant factors like the texture and shape of a building's exterior. It isn't a simple matter to clean the complex and ornate stone, glass, aluminum or concrete facades of some modern skyscrapers, Rigg says. This is a problem that is already worrying government officials in Australia.

For more than a century, skyscrapers have represented the state of the art in construction. Many innovations first developed for these tall structures later become standard for all buildings. Included in this list are changes in



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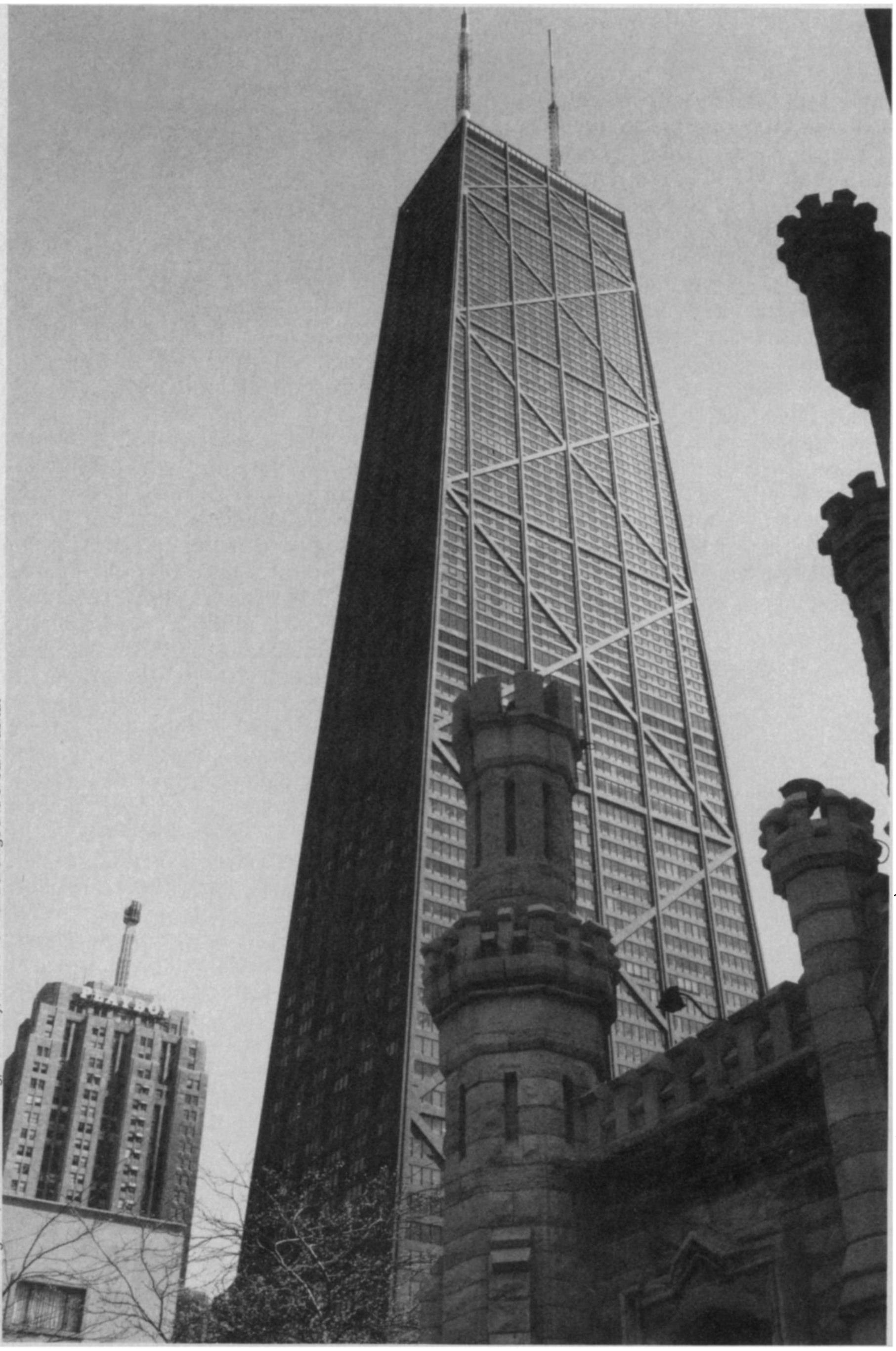


Photo: Bill Engdahl, Hedrichs Blessing/Courtesy, Council on Tall Buildings and Urban Habitat

The Empire State Building's heavy masonry and stiff internal steel framework help it resist the force of the wind. The John Hancock Center in Chicago relies on clearly visible diagonal braces for the same purpose.

The Trump Organization

The centerpiece of the proposed Television City project in New York is a 150-story, 1,670-foot tower that would make it the world's tallest building.

the types of glass to provide greater insulation, the growing use of wind tunnel tests to determine wind resistance and the effects of buildings on wind patterns, and the increasingly widespread use of adhesives in place of nuts and bolts and other fasteners. "People imitate the glamor buildings of the world," says architect Michael Flynn of I. M. Pei & Partners, New York.

Technology now available points to ever higher buildings. "We have been building up a vocabulary to construct towers more economically and more adventurously," says architect Bruce Graham of Skidmore, Owings & Merrill in Chicago.

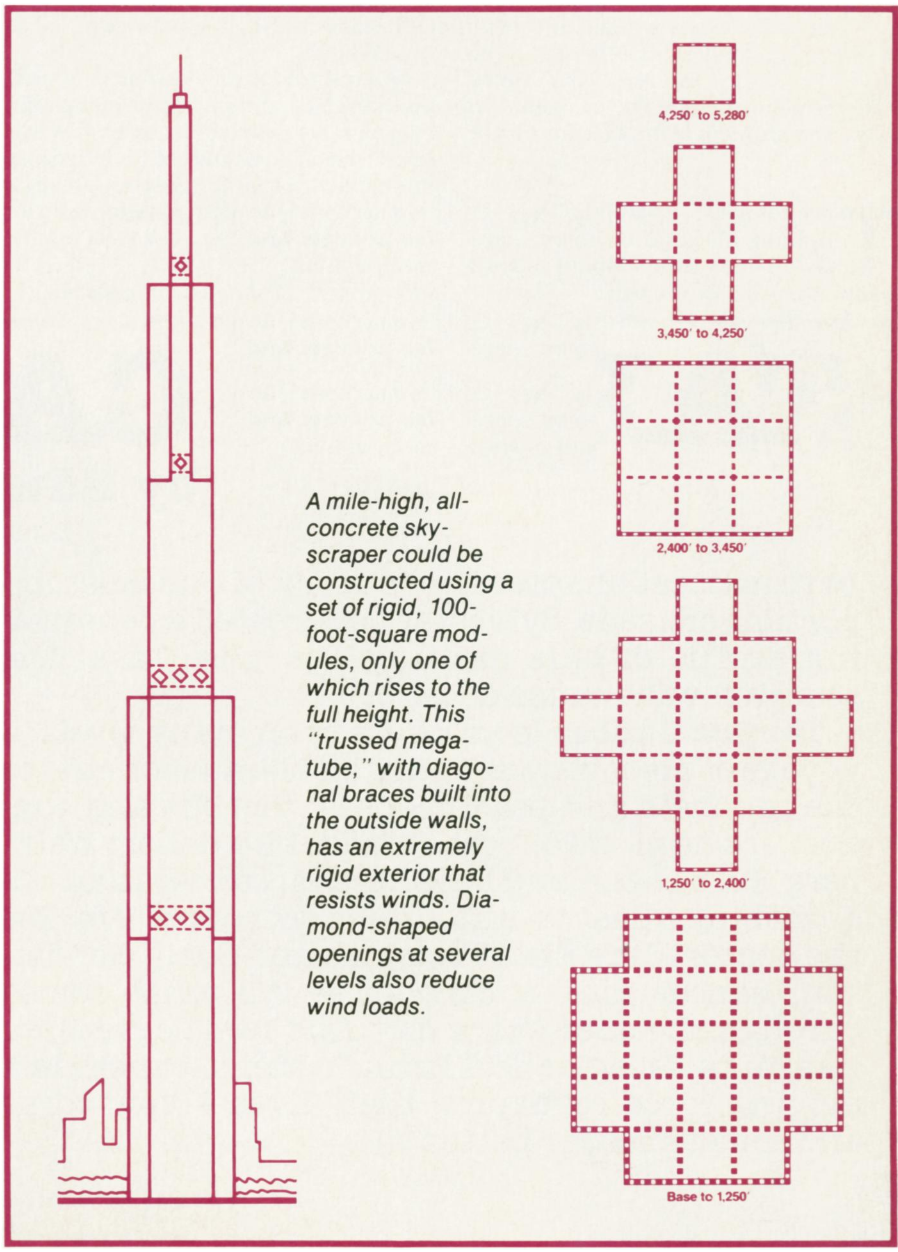
"Today, we are at another turning point in skyscraper construction," says developer John Norris of Olympia & York in Toronto. "The sky is literally the limit."

Whether buildings actually do get taller depends not so much on technology as on social and economic factors. Are people really interested in living and working in huge structures? Can giant projects be financed? Do building codes and national, state and local regulations get in the way?

Leo Finzi of the Technical University of Milan in Italy suggests that one possible future course involves the gradual disappearance of solitary high-rises. Instead, planners will be designing "tall cities," he says.

The idea would be to construct a giant steel framework — a three-dimensional grid — covering an area perhaps the size of a small city. This jumbo framework would then be the reference skeleton from which houses, shops, offices, walkways and roads could be built.

By linking many buildings together, such megastructures would solve some of the wind resistance problems, says



A mile-high, all-concrete skyscraper could be constructed using a set of rigid, 100-foot-square modules, only one of which rises to the full height. This "trussed mega-tube," with diagonal braces built into the outside walls, has an extremely rigid exterior that resists winds. Diamond-shaped openings at several levels also reduce wind loads.

Colaco/Courtesy, CIVIL ENGINEERING

Finzi, and by providing pathways from building to building at many different levels, they would relieve the ground-level congestion often associated with a collection of separate skyscrapers, each occupying its own narrow block of land. "The cost of tallness would be largely reduced," he says.

Finzi admits that it would take radical changes to get present cities to accept this kind of development. "But for new settlements, that should not be a great difficulty," he says.

Some real estate developers are already proposing projects that are practically cities within cities. In New York, Donald J. Trump's plans for his Television City project include several towers, one of which would be taller than the Sears Tower. This complex, set on a 100-acre site, would house 20,000 people, provide 1.7 million square feet of shopping area, office space for tenants like television networks and about 40 acres of parks and public areas.

"Such a building is plausible technologically," says Paul Goldberger, architecture critic for the New York Times. "The structure is not the problem," he says. The problem is the race for height.

Technological capability may be running ahead of common sense, Goldberger says. "Would [such a building] provide a civilized place to work and live?" he asks. The quest for height seems to have many of the symptoms of a technological addiction.

Hence, the word "egonomics" enters the picture. "Technology alone will not fuel the construction of new tall buildings," says developer Gerald D. Hines of Gerald D. Hines Interests in Houston. "But we should never underestimate the power of romance." Few business decisions are ever made purely on logical grounds. The lure of a skyscraper as a statement or an image — a sculpture in steel, stone and glass — can't be taken lightly.

There's something intoxicating about height. Carl W. Condit, an architecture historian now retired from Northwestern University in Evanston, Ill., tells this story:

In 1870, engineer George B. Post completed work on the Equitable Life Assurance Building in New York. Some historians consider this 130-foot, 7½-story building to be the first true skyscraper (SN: 4/5/86, p. 218). It was twice as tall as its neighbors.

As a reward for redesigning the building's structure and saving the company a considerable amount of money, Post was offered an office on the top floor because this carried with it the greatest prestige. Post accepted the offer gratefully, and for the privilege and the view paid double the usual rent.

Ever since, it's been ever upward. □