

# Skyscrapers



**ASSIGN  
BUSTER**

Picture in your mind the skyline of downtown Toronto. There's the CN Tower, of course, and the 72-floor First Canadian Place, the city's tallest skyscraper. Cascading from there are the assorted banks and hotels and insurance towers. Now, use your imagination to construct some new buildings, these ones reaching three, four and five times higher than the others. Top it all off with a skyscraper one mile high (three times as high as the CN Tower). Sound fanciful? It did 30 years ago when Frank Lloyd Wright proposed the first mile-high building. But not today. We are now said to be entering the age of the superskyscraper, with tall buildings poised to take a giant new leap into the sky. Skyscrapers approaching the mile mark may still be awhile off, but there are proposals now for megastructures soaring 900 m — twice as high as the world's tallest building, the 110-story Sears Tower in Chicago. Suppose that you were asked to erect such a building. How would you do it? What are the obstacles you'd face? What materials would you use? And where would you put it? Building a superskyscraper, the first thing you would need is a considerable slice of real estate. Tall buildings require a large base to support their load and keep them stable. In general, the height of a building should be six times its base, so, for a skyscraper 900-m tall, you'd need a base of 150 square m. That much space is hard to come by in, say, downtown Toronto, forcing you to look for an undeveloped area, perhaps the Don Valley ravine, next to the Science Centre. Bear in mind though that the Don Valley is overlain by loose sand and silt, and tall buildings must stand on firm ground, or else risk the fate of edifices like the Empress Hotel in Victoria. This grand dowager, completed in 1908, long before the science of soil mechanics, has since found herself slowly sinking into the soft clay. Soil analysis is especially critical in facing the threat of earthquakes. The

Japanese have learned many times the hard way what happens when an earth tremor shakes a high-rise constructed on soft, wet sand. The quake's enormous energy severs the loose connections between the individual grains, turning the ground into quicksand in just seconds and swallowing up the building. . Engineers have actually built machines that condense loose ground. One machine pounds the earth with huge hammers. Another plunges a large vibrating probe into the ground, like a blender in a milk shake, stirring up the sand so that its structure collapses and the individual grains fall closer together. Anchoring a skyscraper in the Don Valley would best be solved by driving long steel piles down through the sand and silt into the underlying hard clay till. Or, if the clay till lies too far underground, inserting more piles into the sand. The friction between sand and so much steel would then be sufficient to hold the concrete foundation above in place. The next obstacle in erecting a superskyscraper, and perhaps the biggest one, is wind. Tall buildings actually sway in the breeze, in much the same way that a diving board bends under the weight of a diver. Building an edifice that doesn't topple over in the wind is easy enough. The real challenge is keeping the structure so stiff that it doesn't swing too far, cracking partitions, shattering windows and making the upper occupants seasick. As a rule, the top of skyscraper should never drift more than 1/400 of its height at a wind velocity of 150 km/h. Older buildings, like the Empire State Building, were built so that their core withstood all bending stresses. But structural engineers have since found that by shifting the bracing and support to the perimeter of a building, it can better resist high winds. The most advanced buildings are constructed like a hollow tube, with thin, outer columns spaced tightly together and welded to broad horizontal beams.

Toronto's First Canadian Place and New York's World Trade Center towers are all giant, framed tubes. A superskyscraper would undoubtedly need extra rigidity, which you could add by bracing its framework with giant diagonal beams. You'll see this at Chicago's John Hancock Center where the architect has incorporated diagonal braces right into the look of the building, exposing five huge X's on each side to public view. Alternatively, you might design your building like a broadcasting tower, and tie it to the ground with heavy, sloping guy wires extending from the four corners of the roof to the ground. A control mechanism at the end of each cable would act like a fishing reel, drawing in the cable whenever the sway of the building caused it to slacken. Tall buildings also encounter the problem of vortex shedding, a phenomenon that occurs as the wind swirls around the front corners of the building, forming a series of eddies or vortices. At certain wind speeds, these vortices vibrate the building, threatening to shake it apart. In New York City's Citicorp Center, engineers have tackled vortex shedding with a 400-tonne concrete block that slides around in a special room on one of the upper stories. Connected to a large spring and a shock absorber, and riding on a thin slick of oil, the big block responds to oscillations of the building by moving in the opposite direction. Other ways to disrupt vortex shedding include making several large portals in the upper part of the tower, through which the wind passes freely. In New York City's World Trade Center, vibrations are dampened with special spongelike pads sandwiched in its structure. The price tag on a superskyscraper is going to be enormous, but one way to cut costs is with high-strength concretes. Ordinary concrete is much cheaper than steel, but lacks steel's rigidity, and could not withstand the huge burdens in a superskyscraper. But recent experiments with chemical

additives, called superplasticizers, have whipped up double and triple-strength concretes that could make superskyscrapers an economic reality. Once you've built your superskyscraper, there still remains the job of servicing it — providing water, electricity, fire protection, ventilation and cooling. Servicing also means controlling stack effect. If you've ever been up in a skyscraper and heard the wind moaning and whistling by the elevator — that's stack effect. In any tall building, the difference in temperature and air pressure between the outside and inside the structure pushes air up the stairwells and elevators, like smoke up a chimney. Strong, cold drafts blowing up the building create heating problems and make it difficult to open doors into stairwells. To control stack effect, buildings must be as airtight as possible, with ventilation ducts extending only part way up the building, and revolving doors at ground level. The one invention that, above all, has enabled buildings to climb higher is the elevator. As skyscraper populations have grown, elevator manufacturers have handled larger loads with double-decker cars — one car piggybacking another, with each one stopping at alternative floors. Another innovation is the sky lobby system, in which passengers take one car to a floor part way up the building, and then transfer the next flight up to another car in the same elevator shaft for the rest of the journey. Elevators will probably never move any faster than they do today, since the human ear can only endure a descent speed of 600 m per minute. So, an elevator ride in a superskyscraper might be comparable to a subway trip, with several transfer points and extended waits between cars. Which brings designers to the inevitable question: Will office staffs and tenants stand for such long rides? Indeed, will they tolerate all the other shortcomings of skyscrapers — the feelings of entrapment inside them, the

dark, windy canyons between them, and the congested traffic below — made worse by higher heights. Developers now claim they've worked most design bugs out of the new megastructures. Whether or not people will actually want to occupy them should prove if the sky is really the limit. Don Valley — loose deposits of sand and silt overlying deep deposits of clay. Soft deposits. — or is sand cover on top of clay. terms: loose sand, loose silt, soft clay. Increase surface area of piles. Perhaps the most critical servicing job is protecting the building's occupants from fire and smoke. Today's skyscrapers are equipped with ultra-sophisticated fire-control systems: automatic sprinklers help douse the fire while exhaust fans suck out the smoke from burning areas, preventing it from escaping into other floors and stairwells. Feeding the sprinkler systems are huge water storage tanks that sit on the top floor or roof. These are the same tanks that Paul Newman blew up to douse the rampaging fire in "The Towering Inferno". Exploding tanks undoubtedly made for exciting climax, but they could never contain that much water to put out a skyscraper fire. Built in the early Seventies by I. M. Pei, one of America's foremost architects, the "John Hancock" towers majestically over the Back Bay area of Boston. Over time, it developed the bad habit of letting its windows fall out on windy days. This problem grew so serious, that police had to cordon off the leeward side of the skyscraper to keep unsuspecting pedestrians from getting beamed by falling glass. In fact, the situation became so dangerous that doormen were escorting workers in and out of the building during the daily invasion and exodus, keeping a wet finger to the wind and an eye peeled for falling glass. And what was the foundation of this perplexing and disturbing window-popping habit? As it turned out, the foundation was to blame; it and what is known as Bernoulli's Principle,

( which states that the pressure of a gas falls as its velocity increases.) What happens is this: a light wind comes along and has to get around a large slab of building. It pushes against the front of the tower, and then speeds up to get to the edges of the building so it can keep up with the rest of the wind, (this is why the areas around tall buildings and groups of tall buildings become very windy). The back side of the skyscraper, because of all the fast air on its sides, develops an area of low pressure, as predicted by Bernoulli's Principle, and because the air pressure inside the wall is suddenly higher than that outside, there is the potential for windows blowing out This is obviously what was happening to Mr. Pei's building; but why was it happening with such frequency? After all, this building was becoming a lethal weapon! The search for the solution would have to start from the ground up, and the design team began with the history of the site... As is the case with many cities built beside a body of water, Boston's downtown area expanded rapidly during the last century, and its bay was filled in to provide more building space. Because this land was built on more or less right away, it didn't have the chance to compact and provide as much support as land that had been settling for thousands of years. The design of the " John Hancock" took into consideration the condition of the soil on which it was built, and the engineers did their best to allow for settling. What they couldn't accurately predict was how the building would settle, so they planned for a uniform settling of the building. Instead, they found that the building had settled unevenly! The result of this settling caused an unequal surface tension on the curtain wall, which, as all curtain walls are, had been designed only to serve as an envelope for the building, and to support no weight other than its own. This meant that it was nearing its maximum strength limit even

without any wind blowing on it. The suction of the low pressure area on the leeward side of the building caused the wall to billow out and pop windows like buttons. The mechanical engineers, realizing that the negative air pressure was too much for the wall, decided to fight that negative pressure with negative air pressure of their own. Using the fact that all skyscrapers are completely sealed, the perimeter air supply system of the whole building was monitored with regards to the exterior air pressure, and then air was supplied or removed to balance the tension on the curtain wall. Quite literally, they would make the building suck in its billowing stomach to keep from popping buttons. Simple, huh? This tale ends with a moral and with a warning: the moral of the story is to look up when you're around tall buildings on very windy days ; the warning (for local folks) is that all the land south of Front Street is infill!