Wednesday, February 25

Swaying Skyscrapers: The Battle Against the Wind

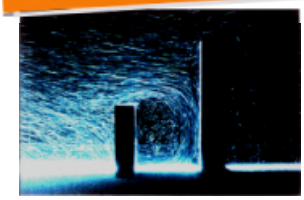
The Willis Tower (or Sears Tower) in Chicago is a 108-storey, 1,451-foot skyscraper. Its observation deck is one of the city's most popular tourist attractions.

Contributor:
Justin McGar

Published: 25 February 2015

However, Chicago's reputation as the 'Windy City' is a real issue. On some days, the tower moves so much that they have to close down the elevators because they get stuck as the shafts twist in a windy dance. The horizontal movement of skyscrapers caused by wind, especially as buildings continue to go higher, is a real challenge for engineers.

RELATED ARTICLES



Wind Tunnels

More Engineering

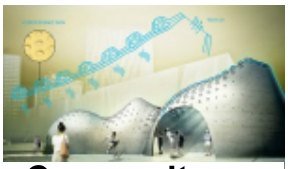
A New Paradigm for Addressing Severe Flooding

Given that the vast majority of the Australian population...

Political Risks to

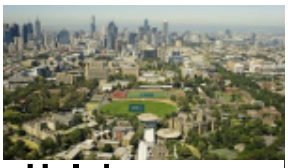
Wind Tunnels Can Help Ensure Pedestrian Comfort

Victorian Wind Farm Study Blasted as Biased



Composite Facade Cools Interiors Via Evaporation

A More Efficient Air-Con Solution for Tall Buildings



Helping Universities Solve Land Shortage Issues

The Earthquake Device that Solves Architectural Problems

For a given building height, shape and location, the amount of sway that a building undergoes is significantly influenced by the floor masses (structural density) and the rate at which the building oscillates.

The other big factors are the height of the building, the severity of the wind and the degree of shielding or exposure.

Another important factor is the effect of wakes from neighbouring buildings, especially if the interfering tower building has a similar shape and width to the subjection tower building. The extent of the wake interference depends on the level of the exposure of the site from the direction of the interfering tower building and the location of the interfering tower building relative to the subject building.

So what are they key technologies to reduce sway?

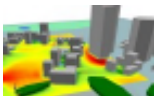
“If a building is predicted to exhibit excessive sway one approach can be to stiffen the building,” said Tony Rofail, director at Windtech Consultants. "This approach is most effective if the building is affected by the wake of an upstream building (usually located less than eight building widths away).”

“Excessive sway due to other phenomena such as the tower's own vortex shedding is most effectively

the Clean Energy Industry

The clean energy industry has been living in

Urban Comfort Technology Good for Business



When you are feeling cold, you want to warm...
MECHANICAL

Recently Published

Property

The Outlook for Green Bonds in Australia for 2015

Construction

Concrete Durability is Key to Sustainable

mitigated by means of auxiliary damping. Stiffening is often achieved by either widening the core or incorporating an outrigger system."

Auxiliary damping comes in a number of forms.

Chifley Tower in Sydney has a pendulum style tuned mass damper. The pendulum is tuned to sway at the same rate as the buildings natural frequency and dash pots or shock absorbers connect the 400-tonne mass to the floor slab at the top of the building.

Centrepoint Tower in Sydney has a combination of a tuned mass damper that also doubles up as a sloshing type tuned liquid damper. Eureka Tower in Melbourne has a tuned liquid column damper.

8 Chifley Square

The utilisation of auxiliary damping is, in most cases, a more cost-effective approach than stiffening when it is desired to control sway where it is

Building

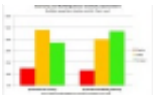
Construction

BIM: Fixing Australia's "Broken Circle"

Construction

Construction Clients Need to Step up to Get a Better Deal

Construction

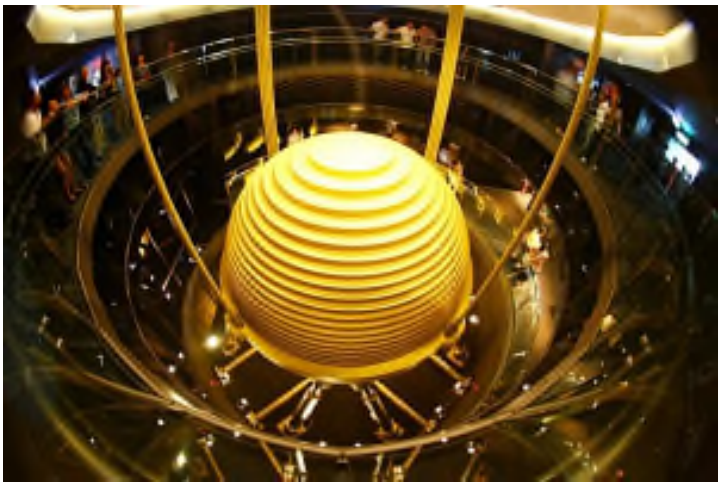


Queensland Builders Confident About Outlook

predicted that the sway will impact occupant comfort.

"It can actually cause motion sickness for some people if it exceeds certain levels," said Rofail. "This is because stiffening a building heightens the occupants' perception to the building's motion since the cycling rate of the building motion in that case would come closer to the natural frequency of our upper part of our bodies."

Tuned liquid or mass dampers are generally used to control serviceability displacements and for occupant comfort and are generally not recommended for the control of ultimate loads on a high-rise building unless there is a continual monitoring system to ensure that the dampers are always tuned to the natural frequency of the tower motion.



"There are active control systems," noted Rofail. "But they depend on power which may not be available during an ultimate event. Some semi-active dampers can operate on a relatively low

dampers can operate on a relatively low battery power and may be viable for this purpose."

"On the other hand Viscoelastic dampers may be used to control both serviceability and ultimate loads as they operate over a broad frequency spectrum. They also have an added benefit in the control of seismic loads in earthquake prone regions."

Rofail argues that the most cost effective way to control of wind induced building sway is to have the wind engineering consultant involved in the concept design. This, he says, is particularly important for buildings more than 200 metres in height where small adjustments to the building form can reduce the building sway by 50 per cent or even more.

Working with a wind engineer early in the process has been integral to the success of Abode318, a residential tower on Russell Street in Melbourne's CBD. With a height to depth ratio of 9:1 it could almost be classified as super skinny or pencil thin skyscraper (this is usually defined at a ratio of 11:1)

To achieve the requirements for 58 storeys on such a small site, optimising the building's stability solution was critical. Wind tunnel testing and Finite Element Analysis were therefore conducted early in the project.

This early analysis highlighted the challenges associated with wind acceleration and revealed an overall building natural frequency on the borderline for occupancy comfort.

Abode318

"We incorporated provision for a tuned mass damper to be located at the top of the building, while at the same time optimising all of the building's primary elements and lateral mechanisms, including car park ramps, lift cores and shear walls, in a computer model," explained Meinhardt senior structural engineer Vincent Amato.

"When the structure was 80 per cent complete the actual building frequency was measured using a 'drop test.' One of the building cranes safely swung a weight above the structure and the building response was measured."

This test revealed the dynamic response of the building to be acceptable without the need of the costly tuned mass damper, which could have cost the client $100,000 to $150,000.

$100,000 to $150,000.

Other than reducing sway, there are a number of other benefits that wind engineering bring to the structural design of tall buildings.

“Wind Engineering also assists in rationalising construction costs by identifying the areas in the structure that need strengthening and at the same time avoiding significant over-specification of member sizes,” said Rofail.

“Wind engineering techniques have advanced quite considerably over the past couple of decades to the point where it is possible to investigate the aerodynamic efficiency of various design options for a tall building in a very short time. In the event that after the wind tunnel study is completed, the structural system changes for the same general envelope the current techniques enable us to update the entire analysis and report within a day or so.”

So hypothetically could a tall building blow over?

Fortunately, Rofail says that he has not come across any tall building that has actually blown over but he raises the story of the 59-storey Citicorp Center in

New York (now called 601 Lexington Avenue), built in 1977.

Here, the structural engineer realised

Here, the structural engineer realised that he had overlooked the effect of wind approaching from the diagonal directions after it was built.

This issue was particularly important for this building because of the way the skyscraper connected to the ground.

601 Lexington Avenue

Results from subsequent wind tunnel testing by Dr Alan Davenport revealed that the tower could potentially blow over in a storm the size of which could be expected to occur once every 16 years. In this case, the risk was averted by modifying the connections throughout the building.

Is there a limit to the height that we can go before technology to combat wind doesn't work well enough that it would become too uncomfortable for occupants?

Rofail says that for the very tall buildings, the extent of wind induced motion is roughly related to the cube of the height. For example, the forces that

the height. For example, the forces that produce sway in a building that is 500 metres in height would by approximately eight times those of a building with the same plan dimensions but only 250 metres in height. For this reason the concept design of the 828-metre Burj Khalifa Tower in Dubai was largely driven by the aerodynamics and no auxiliary damping was required as a result.

"The simple answer is when there is a will there is a way," said Rofail.

Published on 25 February 2015

CONTRIBUTED BY:

Justin McGar

Justin has been writing for the construction and property sectors for more than 15 years.

At Sourceable his particular focus is on "what makes buildings work?" From structural materials to the latest energy efficiency technologies, from future trends to the latest research, he shares new ...

SHARE

COMMENTS

Your Name (required)

Your E-Mail (will not be published) (required)

1200 characters available

Post Comment

ARCHITECTURE

BUSINESS
COMMERCIAL
GREEN ARCHITECTURE
HOTEL
HEALTHCARE
LANDSCAPING
PUBLIC
RESIDENTIAL
RETAIL
STADIUM
TECHNOLOGY
URBAN PLANNING

DESIGN

BUSINESS
EDUCATION
GREEN INTERIOR DESIGN
HEALTHCARE
HOTEL
INDUSTRIAL
MUSEUM
OFFICE SPACE
PUBLIC
RESIDENTIAL
RETAIL
TECHNOLOGY

CONSTRUCTION

BUSINESS
COMMERCIAL
COMPLIANCE
EQUIPMENT
ESTIMATING
GREEN
PREFABRICATION
PROCUREMENT
RESIDENTIAL
ROADS
SAFETY
TECHNOLOGY
TRANSPORTATION

ENGINEERING

BUILDINGS
BUSINESS
CIVIL
ELECTRICAL
ENERGY
ENVIRONMENTAL
MECHANICAL
MINING
STRUCTURAL
TECHNOLOGY
TRANSPORTATION

PROPERTY

BUSINESS
GREEN
INVESTING
REAL ESTATE

SECURITY
STRATA
ZONING

ADVERTISE RSS TERMS & CONDITIONS SUBSCRIBE