STRONG WINDSTORMS
CHAPTER 4.4

Windstorms are a common occurrence in New York City. Any variety of windstorms can occur with little warning, damaging property and infrastructure, disrupting transportation, downing trees and power lines, and causing serious injury. New York City's dense high-rise environment, older building stock, and open construction sites heighten its vulnerability to dangerous winds.

WHAT IS THE HAZARD?

Windstorms produce winds at speeds that typically exceed 34 miles per hour (mph), with winds blowing faster at higher elevations. A variety of windstorms can occur in New York City: straight-line storms that blow in one direction, thunderstorms, microbursts, and tornadoes. High-wind events are often associated with other storms, such as hurricanes or nor'easters, but may occur independently.

Windstorms may or may not be accompanied by precipitation. They vary in intensity, duration, and geographical extent. For example, they can range from short bursts of high-speed winds, as during a severe thunderstorm, to longer periods of stronger sustained winds. They typically have a few hours of lead time and can last for hours, or for up to several days if they result from a large-scale weather system.

TORNADOES

A tornado is a violently rotating column of air with winds ranging from 65 mph to more than 300 mph. These short-lived storms generally appear as funnel-shaped clouds extending toward the ground from the base of a thundercloud. Initially they are transparent — a danger because they cannot be easily seen. As they pick up debris and dust, they acquire their grayish coloration. That gray color can also be caused by a cloud, because water vapor condenses in the funnel due to its low pressure.

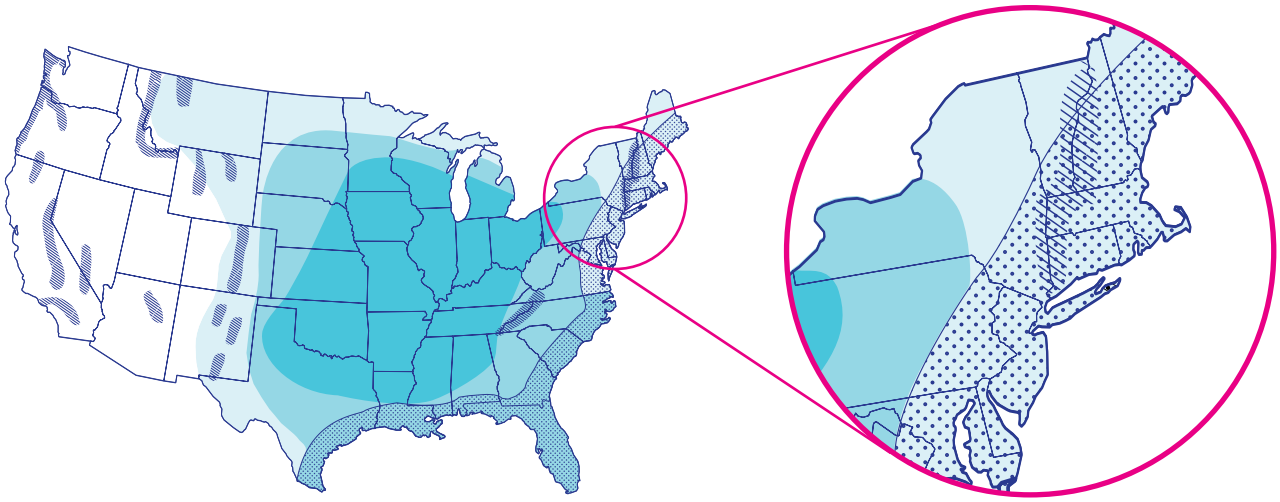
Most tornadoes advance west-to-east, but tornadoes can often move southwest to northeast, at an average speed of 30 mph. They are most frequent east of the Rocky Mountains during spring and summer, between 3 PM and 9 PM. They may accompany hurricanes.

Tornadoes are the most violent atmospheric phenomenon that occurs over land, and, over a small area, the most destructive. They are rarely predictable in advance and can uproot trees, demolish buildings, and turn harmless objects into deadly missiles in a matter of seconds. The path of destruction can exceed one mile in width and 50 miles in length. Each year an average of 1,200 tornadoes strike nationwide. Tornadoes cause on average 60 to 65 fatalities and 1,500 injuries per year.

BEAUFORT WIND SCALE TABLE
Source: NOAA

FORCE	WIND SPEED (MPH)	NAME	DAMAGE
0	< 1	Calm	Calm, smoke rises vertically
1	1 – 3	Light Air	Smoke drift indicates wind direction, still wind vanes
2	4-7	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	8-12	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	13 - 18	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	19 - 24	Fresh Breeze	Small trees in leaf begin to sway
6	25–31	Strong breeze	Large branches in motion; whistling in telephone wires; umbrellas used with difficulty
7	32–38	Near gale	Whole trees in motion; resistance felt while walking against the wind
8	39–46	Gale	Twigs break off trees; wind impedes walking
9	47–54	Strong gale	Slight structural damage to chimneys and slate roofs
10	55–63	Storm	Seldom felt inland; trees uprooted; considerable structural damage
11	64–72	Violent storm	Very rarely experienced; widespread structural damage; roofing peels off buildings; windows broken; mobile homes overturned
12	72-83	Hurricane	Widespread structural damage; roofs torn off homes; weak buildings and mobile homes destroyed; large trees uprooted

U.S. WIND ZONES
Source: FEMA



ZONE 1 (130 MPH)
ZONE 2 (160 MPH)
ZONE 3 (200 MPH)
ZONE 4 (250 MPH)
SPECIAL WIND REGION
HURRICANE PRONE REGION

WHAT IS THE RISK?

WINDSTORMS

Gale-force windstorms are common here and a highly probable hazard in the future. From 1996 to 2013, at least 31 documented windstorms with gusts above 40 mph occurred in the city. During this same period, 14 major windstorms with gusts ranging from 50 to 80 mph occurred. For example, on February 12, 2009, wind gusts reached up to 50 to 60 mph, killing a construction worker in Staten Island, injuring several people in Brooklyn.

Windstorm speeds can range from 34 mph to more than 75 mph. One of the earliest scales for measuring wind speeds and associated damage is the Beaufort Wind Scale, developed in 1805 and still in use.

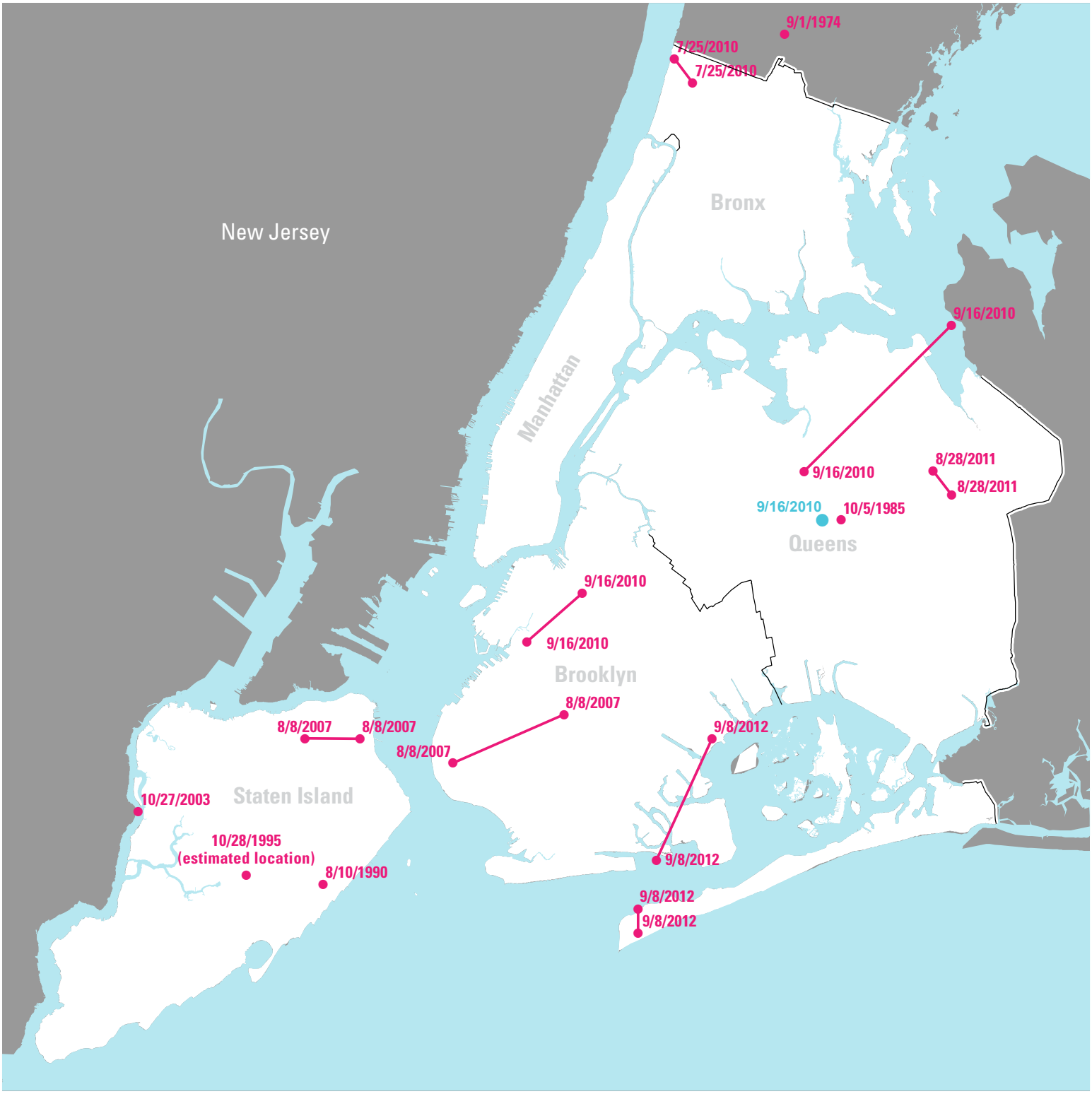
New York City is located in a hurricane prone area and exposed to hurricane winds that can potentially reach much higher speeds than windstorms as shown in the Wind Zones in the United States map put out by FEMA. The NYC Building Code requires that city buildings be designed to resist high winds and hurricanes. The difference between these two events is that windstorms occur more frequently than hurricanes. The result is that buildings are designed at a much higher level due to concerns of high hurricane winds.

Areas with large concentrations of high-rise buildings are subject to higher wind loads because of the "urban canyon effect." This occurs in areas where narrow streets cut through dense blocks of tall buildings such as Midtown Manhattan, the Financial District in Lower Manhattan, and Downtown Brooklyn.

TORNADOES

A common misconception is that tornadoes do not occur in dense urban areas like New York. But over the past 40 years, 12 tornadoes have hit our city. At least one has occurred in each of the five boroughs.

The standard measurement for rating the strength of a tornado used to be the Fujita Scale (F-Scale). The National Weather Service previously used this scale and an analysis of damage done by a tornado to estimate wind speed. In 2007, the National Weather Service transitioned from the F-Scale to the Enhanced Fujita Scale (EF-Scale).



HISTORICAL TORNADOES (1950 - 2014)

SOURCE: NOAA NATIONAL CLIMATIC DATA CENTER

*8/31/1995 NEW YORK COUNTY (MANHATTAN) TORNADO IS NOT DISPLAYED ON THE MAP. NO ACCURATE COORDINATES ARE AVAILABLE FOR THIS EVENT.

WIND EVENT TYPE

TORNADO

THUNDERSTORM WIND (MACROBURST)

TORNADO TRACK

The EF-Scale is more complex and enables surveyors to assess tornado strength with greater precision. It is now the standard for determining tornado strength. But the EF-scale references to the old F-scale are needed for historical purposes.

Reported tornadoes have increased over the years. Seven tornadoes have been reported in New York City from 2007-2014, in comparison to only six over the previous 33 years. (The first reported tornado was in 1974.) This increase in reported occurrences may be due to the greater precision of the Enhanced Fujita Scale.

One of the strongest tornadoes, rated an EF2, hit Brooklyn in 2007, damaging 16 homes, tearing the roof off a car dealership, and destroying trees. This was a presidentially declared disaster in which FEMA provided more than $5.1 million in Individual and Household Program funding to property owners. On September 16, 2010, an EF0 tornado in Brooklyn caused significant tree damage and an estimated $8.5 million in total damages. The same day an EF1 tornado in Queens killed one person and severely damaged residential buildings, causing an estimated $17.2 million in damages. In addition, some tornadoes have occurred during major coastal storms, include Tropical Storm Irene, which had two confirmed tornadoes: one EF0 in Cunningham Park and one on Long Island.

Climate change is projected to bring warmer weather and moister air. This could create conditions that generate severe weather. But these same conditions have been shown to reduce the wind shear necessary for tornadoes to get a full lift. At this point it is unclear how the long-term effects of climate change will impact the strength and frequency of tornadoes. What is clear is that windstorms and tornadoes will continue to be a risk.

VULNERABILITY

Tornadoes and other windstorms can cause many kinds of damage, of greatly varying severity. Besides the impacts on people and buildings, these storms can disrupt transportation, and down trees, phone lines, and power lines, causing outages and in some instances fires. In turn, power outages trigger their own cascade of effects. Heavy branches torn from trees and falling trees can damage cars and houses. Storms can damage the natural environment, by destroying historic trees and degrading the beauty of our parks and open spaces.

COMMON TYPES OF WINDSTORMS

Straight-line: These storms, the most common, blow in one direction at speeds varying from low to very high. They're associated with intense low atmospheric pressure. They can last for up to a day.

Thunderstorm: These storms can produce high wind speeds, heavy rain, hail, or sometimes a tornado.

Microburst: Associated with a thunderstorm, this is a powerful downdraft that can cause severe, localized damage.

Tornado: A violent, rotating column of air with wind speeds ranging from 65 to 300 mph.

Hurricanes/nor'easters: These storms are featured in the Major Coastal Storms section of this chapter.

People at risk

In extreme cases, tornadoes and windstorms can cause injuries and fatalities. Flying debris can injure or kill people. So can falling trees and heavy branches. Since 1996, at least 12 people have been killed by downed trees in New York City during severe weather events:

- February 25, 1996 – 1 fatality during a high-wind event
- October 19, 1996 – 3 fatalities during a high-wind event
- March 6, 1997 – 4 fatalities during a high-wind event
- December 23, 2004 – 1 fatality during a high-wind event
- September 16, 2010 – 1 fatality during a tornado
- October 29, 2012 – 2 fatalities caused by downed trees during Hurricane Sandy

TAKE COVER!

Windstorms allow six to eight hours of lead time. By contrast, tornadoes are rarely predictable, and in most instances, people will have only about a 30-minute warning.

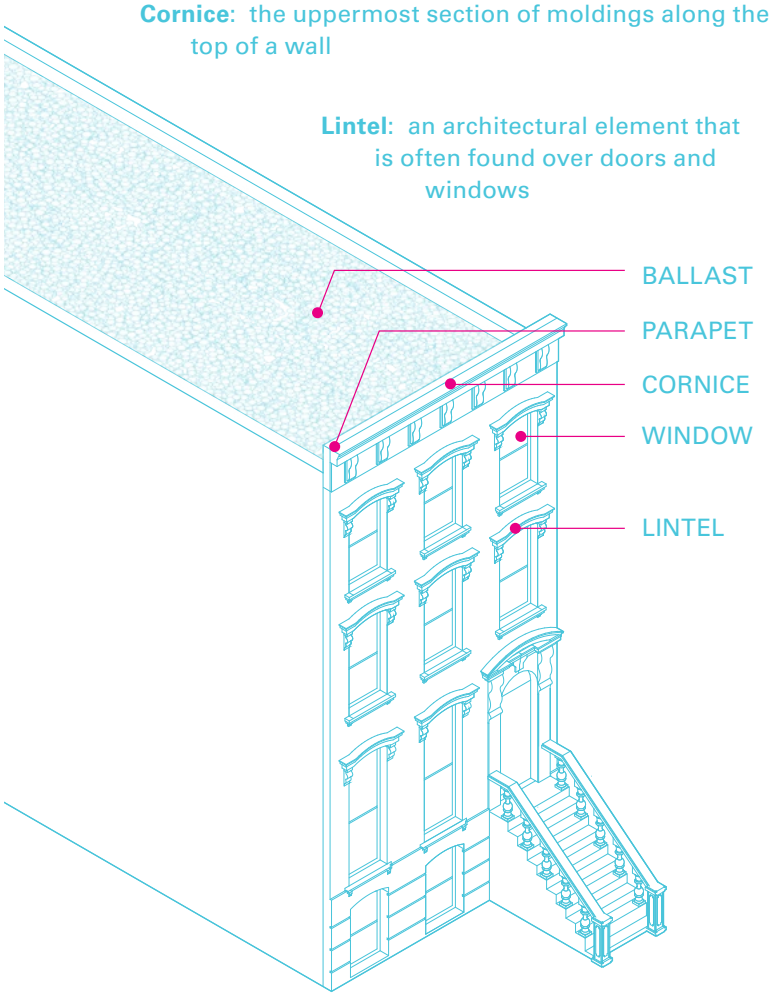
In a building that cannot withstand high winds well, occupants' best strategy is to take cover in the most secure area of the building.

Ballast: designed to anchor roofing materials to the structure by sheer weight. Materials commonly used include pea gravel or stones

Parapet: a low protective wall around the edge of a roof or balcony

Cornice: the uppermost section of moldings along the top of a wall

Lintel: an architectural element that is often found over doors and windows



Buildings at risk

New York City's dense urban environment, concentration of high-rise buildings, older building stock, and construction sites amplify risk.

Although the 1938 Building Code addressed wind loads for skyscrapers and multi-family buildings, the requirements were not as stringent as current building codes. Approximately two-thirds of all buildings in our city were built before this code was adopted. In particular, the glass and metal envelopes of some commercial high-rise buildings constructed under this code could be vulnerable to high wind events. The Urban Green Council say approximately 60 of these buildings still stand in our city today.

The 1968 Building Code incorporated new requirements to make buildings better able to withstand high winds. Thus, some buildings that pre-date the 1968 Building Code are particularly vulnerable because engineers were not required to consider wind loads as a factor in designing buildings under 100 feet high, and wind load calculations were less precise. And although buildings constructed after the 1968 code (and some before) are designed to withstand windstorms, there is no clear engineering method to design for tornadoes.

Flying debris can damage structures. And because wind pressures are higher at greater heights, some older tall buildings with aging exteriors are more easily damaged: they can withstand strong winds, but cladding that is not securely attached and components such as glass windows and parapets, cornices, lintels, and roof coverings pose potentially fatal threats to pedestrians on sidewalks below.

On historic buildings, parapets can crack or collapse when exposed to wind, rain, snow, and heat for a long time. In particular, poorly maintained masonry parapets and cornices on six-story structures may be vulnerable to wind events. In addition, street facades on a typical brownstone are also vulnerable, because they are often poorly attached to the party walls and are vulnerable to collapse during a high wind event.

Some buildings built in the 1960s that feature cavity wall construction (two masonry walls separated

ENHANCED FUJITA SCALE
Source: NOAA

F-Scale	3 -sec. gust speed (mph)	EF-Scale	3 -sec. gust speed (mph)	Typical Damage
F0	45-78	EF0	65-85	**Light damage**. Some damage to chimneys. Branches broken off trees. Shallow-rooted trees pushed over, signboards damaged.
F1	79-117	EF1	86-109	**Moderate damage**. Peels surface off roofs. Mobile homes pushed off foundations or overturned. Moving autos blown off roads.
F2	118-161	EF2	110-137	**Considerable damage**. Roofs torn off frame houses. Mobile homes demolished. Boxcars overturned. Large trees snapped or uprooted. Light-object missiles generated. Cars lifted off ground.
F3	162-209	EF3	138-167	**Severe damage**. Roofs and some walls from off well-constructed houses. Trains overturned. Most trees in forest uprooted. Heavy cars lifted off the ground and thrown.
F4	210-261	EF4	168-199	**Devastating damage**. Well-constructed houses leveled. Structures with weak foundations blown away some distance. Cars thrown and large missiles generated.
F5	262-317	EF5	200-234	**Incredible damage**. Strong frame houses leveled off foundations and swept away. Automobile-sized missiles fly through the air in excess of 100 meters (109 yards). Trees debarked. Incredible phenomena will occur.

by a cavity of 2 to 4 ½ inches) may be vulnerable, too, because this construction type was still in the early stages of development and the need to anchor walls to back-up blocks was not fully understood.

Some older buildings use loose stone, aggregate, or gravel as roof covering. Small fragments of such materials can become dangerous projectiles during a high wind event, injuring people and damaging surrounding buildings.

Structural vulnerability is also related to building construction type and age. Wood-frame structures are more susceptible to high winds; steel and concrete are more resistant. In New York City, 50 percent of all buildings are wood-frame structures. Staten Island has the highest percentage, where 92 percent of its structures are made of wood, increasing that borough's vulnerability to windstorms and tornadoes.

Even if a building remains structurally sound, broken glass from windows can cause injuries inside and outside the building and badly damage building contents. Failures of windows and doors can greatly increase storm damage. Wind entering the building changes the pressure differential between the building's interior and exterior, causing more windows to break.

If wind-driven rain and water reach the interior, materials can be damaged or ruined. Wet materials can promote the growth of mold, and even materials that do not appear damaged can harbor enough moisture to contribute to mold growth later on.

Construction sites are especially vulnerable to high winds because they are so exposed to the elements. Tools, construction materials, cranes, scaffolding, derricks, concrete formwork, sidewalk bridges, and other items may loosen in high winds. Partially completed buildings are also vulnerable if their components have not yet been fully connected, or if structural features intended to withstand strong winds have not yet been completed.

HOW DO WE MANAGE RISK?

Many strategies can be employed to protect people, property, infrastructure, and the environment from the impacts of strong windstorms. What follows is a sampling and a few examples of their application in New York City. Because our city's immense and dense building stock constitutes such a significant risk exposure, we begin with measures to strengthen buildings.

REGULATORY CONTROLS TO STRENGTHEN BUILDINGS

Our Construction Codes specify design standards for winds probable in the dense, high-rise environment of New York City. New buildings and older buildings undergoing major renovations must meet those standards.

New buildings

Design strategies:

- Ensuring that structural components are connected in such a way as to form a reliable load path for wind forces.
- Incorporating lateral bracing to resist movement caused by windstorms.
- Installing dampers to increase comfort for building occupants by counteracting the movement of the building.

Structural engineers use highly refined methods to analyze how a building responds to wind loads and the response of structures. Most of the wind loads on high rises in NYC are evaluated using wind tunnels (small-scale models of the built environment and of wind conditions). The structures are designed with highly sophisticated computer programs that assure not only building resistance but also the comfort of occupants during high wind events.

Retrofitting existing buildings

Older buildings can be retrofitted to withstand high wind loads. Measures include these:

- Strengthening the connections of a building's structural components, by anchoring wooden buildings to their foundations and anchoring the roof frame to load-bearing walls.
- Replacing unreinforced brick masonry parapets with reinforced masonry parapets securely anchored to the rest of the building.
- Replacing roof covering with larger pavers to meet code standards, to reduce the risk of their being blown off.
- Installing impact-resistant windows.
- Installing window shutters.
- Reinforcing and securing rooftop equipment, such as heating, ventilation, and air conditioning units.

MAINTENANCE AND REPAIRS

Protecting our existing building stock requires inspection, maintenance, and repair of structural weaknesses.

For buildings that predate the 1968 building code, maintenance is particularly important to lowering the risk from high winds. Measures include these:

- Keeping roofs tight and in good condition.
- Regularly inspecting wood for rot.
- Securing cornices.
- Repointing mortar regularly and fixing cracks.
- Replacing glass that is not rated for New York winds. (The standard is 30 pounds per square foot for buildings under 100 feet high).

The Department of Buildings Façade Safety Inspection Program requires owners of buildings taller than six stories to have exterior walls and appurtenances inspected once every five years and to file a technical report with the Department. This program helps identify the need for repairs and reduces risk.

Research

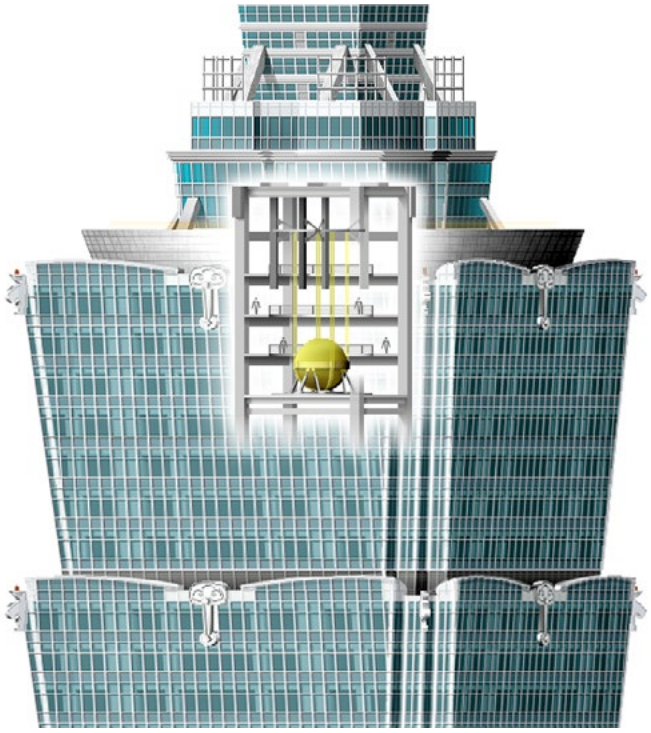
What is learned from research can help inform future revisions to our Construction Codes. Subjects for investigation include how high winds impact different building types; how windstorms impact partially completed buildings and construction sites; and how building age, construction, materials, and height affect vulnerability to structural damage.

Local Law 81 of 2013 requires the Mayor's Office of Long-Term Planning and Sustainability in consultation with the Department of Buildings to complete a report that analyzes the impact of heavy winds on certain at-risk buildings. The analysis will identify the types of existing buildings that are vulnerable to falling debris, based age, construction type, construction materials, height, and occupancy. In addition, the study will focus on buildings that are raised and buildings that are under construction in the city.

ENVIRONMENTAL CONTROLS

As stressed above, trees are exceptionally vulnerable during high winds and can themselves become a hazard. Tree pruning and tree maintenance strategies can help lower that risk.

Con Edison's vegetation maintenance program trims branches and removes damaged or unhealthy trees and vegetation near power lines along right of ways, to create minimum distances between power lines and surrounding trees. Every three years Con Edison returns to trim back growth, to reestablish the minimum clearance.



MASS DAMPER IN TAIPEI 101

MASS DAMPERS

Mass dampers are sometimes used in tall buildings to limit wind vibrations, which increase the comfort of building occupants during a high wind event. Dampers can be made of different masses such as water or steel plates.

"Tuned mass dampers" move in a way that counteracts the movement of the building caused by heavy winds.

The Citicorp Building, completed in 1977 in midtown Manhattan, was one of the first buildings in the world to feature a tuned mass damper. Taipei 101, a high-rise in Taipei, the capital of Taiwan, contains a 728-ton tuned mass damper on the upper levels of the building in full view of the building's occupants.

TORNADO DAMAGE

The Department of Parks' Central Forestry Division oversees block pruning and commitment-pruning programs. Every seven or eight years on each city block, contractors prune all street trees. Commitment pruning deals with emergency situations such as tree limbs obscuring traffic signals. The Division also prunes trees in parks.

PROMOTING PREPAREDNESS

Because windstorms and tornadoes can arrive suddenly, the public needs to know beforehand how to respond to a warning of a severe storm. Communication strategies include:

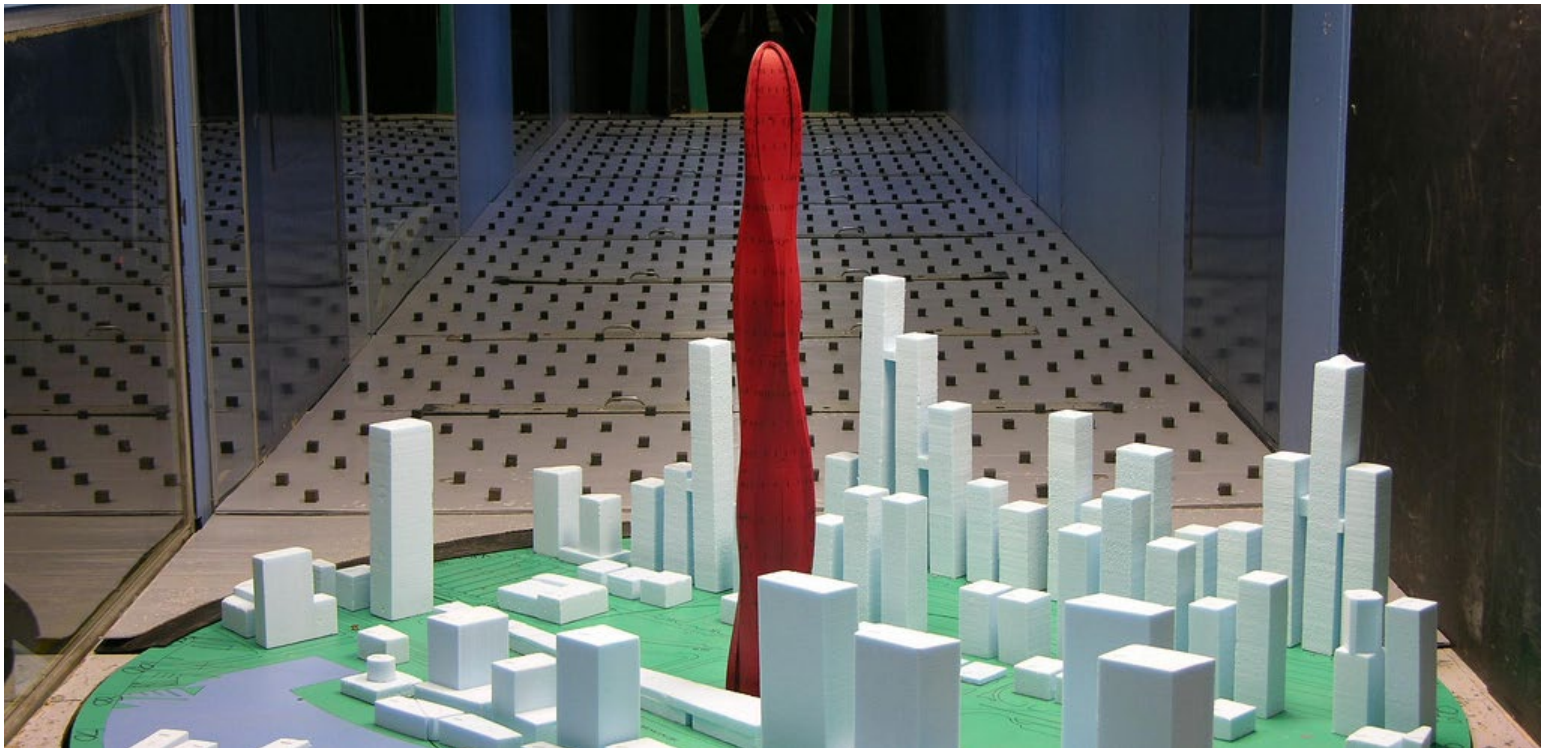
- Sending emergency alerts that a high wind event is forecast, using text messaging, email, local radio and TV stations, and social media.
- Targeting vulnerable and special needs populations.
- Ensuring that communication is multi-lingual.

Notify NYC is the City's official source of information about emergency situations and is used prior and during strong windstorm events. NYC Emergency Management sends these notifications and alerts swiftly to more than a quarter million subscribers.

Another important communication strategy is to send weather advisory notifications to property owners, contractors, and developers, and alerting them to preventive actions they can quickly take like removing loose construction materials and securing loose items.

The Department of Buildings offers an emergency warning system that building owners can sign up for. It also issues Inclement Weather Advisories to property owners, builders, and contractors, advising them to take precautionary steps to prepare for high winds. The Department's *Extreme Weather Guide* provides more-detailed instructions for securing buildings and sites prior to a windstorm. Violation notices are issued as enforcement actions when construction sites are not safely secured.

Longer-term education efforts can help the public learn how to prepare for and respond to strong windstorms. Messaging stresses points like these:



WIND TUNNEL

- People in buildings not built to modern standards should know beforehand the safest place to take cover inside the building.
- Furniture on balconies and other loose items should immediately be secured.
- Building owners and residents should have emergency action plans that define procedures to be implemented in the event of a building-related incident or emergency.

NYC Emergency Management's *Ready New York Household Preparedness Guide* provides information on how households can prepare for severe weather events like strong windstorms.

The *Ready New York Reduce Your Risk Guide* explains to New Yorkers, and in particular to homeowners, how to reduce risks posed by tornadoes and other strong windstorms. Measures include performing routine building maintenance, inspecting buildings for structural weaknesses, and making needed repairs.