2015 Wall of Wind (WOW) Challenge
Informational Workshop

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Introduction

What is Wind Engineering?

Civil Engineering

- Geotechnical Engineering
- Environmental Engineering
- Structural Engineering
- Coastal Engineering
- Transportation Engineering

Wind Engineering

- Wind engineers study the effects of wind on the natural and built environments
Wind engineering is best described as the rational treatment of interaction between wind in the atmospheric boundary layer and man and his works on the surface of Earth.

Synthesis of knowledge from
- fluid mechanics
- meteorology
- structural mechanics
- physiology

Aerodynamics is of central importance but most applications are non-aeronautical in nature.
Atmospheric Boundary Layer (ABL)

Mean wind speed profile:
• Shape of profile is created by friction between moving air and the earth’s surface
• Two mathematical expressions are commonly used to describe the mean wind speed profile over various terrain (Holmes, 2001):

1. The “Logarithmic Law”
\[ U(z) = \frac{u_*}{k} \log_{e} \left[ \frac{z - z_0}{z_0} \right] \]

where:
- \( U \): mean wind speed
- \( z \): height above ground
- \( u_* \): "friction velocity" = (surface shear stress/density of air)^(0.5)
- \( k \): von Karman’s constant (≈ 0.4)
- \( z_0 \): roughness length (obtained from a table)
- \( z - z_p \): “zero plane displacement” (≈ % of rooftop height)

2. The “Power Law”
\[ U(z) = U_{10} \left( \frac{z}{z_{10}} \right)^{n} \]

where:
- \( U \): mean wind speed
- \( z \): height above ground
- \( U_{10} \): mean wind speed at \( z = 10 \) m
- \( n \): exponent (obtained from a table)

(Note: FIU Florida International University)
Atmospheric Boundary Layer (ABL)

Turbulence:
- The “gustiness” of the wind
- Turbulence intensity is mathematically equivalent to the standard deviation of a given wind speed time history
- Like the mean wind speed profiles, turbulence profiles vary for different types of terrain

Example of a typical wind speed record.

Turbulence describes the relationship between fluctuations in the wind speed with respect to the mean wind speed over a given time period.

Image Source: (http://miamiweatheralert.com/history.htm)
Basic Bluff Body Aerodynamics

- Generally speaking, the way that wind flows around an object is dependent upon the object’s shape.
- Bluff bodies may be defined as objects that do not have a streamlined shape.
- Most buildings can generally be classified as bluff bodies located in ABL flows.

(Image source: http://suberic.net/~avon/mxphysics/Ame%20and%20Debbie/web%20page.htm)

Aerodynamic (streamlined) object
Bluff Bodies
Basic Bluff Body Aerodynamics

- The flow around bluff bodies is typically defined by flow separation, reattaching shear layers, and vortex formation.
Wind can be a friend...

...or an enemy
Wind can also make people uncomfortable or even be dangerous to them.
Wind breaks can be porous or solid. The length of the sheltered region behind the wind break depends on the porosity.
Wind Breaks

• Wind breaks are often made up of vegetation. Having a hedgerow or line of trees can be effective.

• Solid or porous screens are also used. In some cases glass screens are used so the view is not blocked by the screen.

• Screens can be very important for some businesses such as an ocean side restaurant.

• The length of the region protected by the screen depends on its design, including its porosity.
• Porous plate:

\[ c_{D,\text{porous}} = C_D \cdot K_p \]

\[ K_p = \text{porosity factor}, \]

\[ K_p \approx 1 - (1 - \delta)^2. \]

\( \delta = \text{solidity} = \text{solid area/total area} \)

\( K_p: \text{not sensitive to shape of openings} \)

(plate could be a truss with linear members)

\( \text{Fits cases where ratio of height to breadth ranges from approx. } 0.2 \text{ to } 5 \)
Wind Flows Around Buildings
Wind Flows Around Buildings
Criteria for Level of Comfort and Safety

Safety: Winds with peak 3 sec gusts greater than 25 m/s should not occur more than 0.1% of the time.

Table 3: Example of Simple Criteria, Based on 20% Probability of Exceedance

<table>
<thead>
<tr>
<th>Activity</th>
<th>Comfortable Ranges for $\bar{U}$ and $U_{GEM}$, m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncomfortable for any activity</td>
<td>&gt; 5.4</td>
</tr>
<tr>
<td>Walking</td>
<td>0 - 5.4</td>
</tr>
<tr>
<td>Standing</td>
<td>0 - 3.9</td>
</tr>
<tr>
<td>Sitting</td>
<td>0 - 2.6</td>
</tr>
</tbody>
</table>

Note: 1 m/s = 2.24 mph
Wind environment around buildings

• The wind environment around the bases of buildings and on terraces and balconies is also important.
• If it is too windy, people will not use the outdoor spaces.
• In some instances people have been blown over by the accelerated winds near tall buildings
• The economic viability of some businesses can be seriously affected by having too windy of an environment (e.g. outdoor restaurants, hotels, local shopping areas)
Wind can make outdoor leisure areas unusable.

Model of Rio Hotel & Casino, Las Vegas

RWDI

FIU | Florida International University
Wind conditions are often studied with a wind tunnel model to develop a wind mitigation solution.
Another example of using a wind tunnel to determine a wind mitigation solution.

Wyndham Inner Harbor East Hotel, Baltimore
So how do we design a wind break to be effective?

• We build a scale model
• We test it in the Wall of Wind using little blocks to represent people
• The blocks will blow over when the wind becomes too strong
The objective for the 2015 WOW Challenge is to design a wind screening device that will provide the best wind shelter for a Miami Beach hotel property. Imagine a six-story hotel situated along the beach, and between the hotel and the beach is a leisure area that hotel management wants to be well sheltered from strong sea breezes from the Atlantic Ocean. Theoretically, this leisure area could include a pool and or restaurant seating area. The below figure illustrates the Challenge scaled down by about a factor of 25.
2015 WOW Challenge

- Each team will design a wind screen and each entry will be tested in FIU’s Wall of Wind research facility.
- The test will consist of gradually increasing the wind speed until small blocks (provided by FIU and spread around the leisure area) start to fall over due to the wind speed they experience.
- Teams are tasked with developing a wind screen that will provide the best shelter for the leisure area, which will be measured by how many of the small blocks fall over as the wind speed is increased. Teams must develop and construct their chosen wind screen in compliance with the requirements and restrictions that follow.
Scale Building Model Requirements and Restrictions

• Each team will place their wind screening device on a ¾ inch plywood board (provided by FIU) 8 inches wide by 8 ft. long. Two plywood boards of these dimensions will be supplied by FIU, one for experimentation, and the other, which will be painted FIU Gold, for the live competition on May 20th. Other components of the scale model hotel property will be created by FIU.

• Each team will bring their plywood board with wind screening device to FIU on May 20th for the live testing.

• The wind screen can be no more than 9 inches high and multiple screens (e.g. one behind the other or overlapping) are permitted just so long as they remain within the 1 ft. by 8 ft. area shown in Figure 1. The screens can be straight or curved, porous or solid.

• There must be a 4 inch wide passageway within 1 ft. of the center of the screen(s) which allows hotel guests to have access to the beach (4 inches at 1:25 model scale represents an 8 ft. 4 in. wide passageway at full scale).
Scale Building Model Requirements and Restrictions

- Wind speeds will be measured by FIU and Teams will be able to watch the tests from the WOW Operations & Control Center.
- The number of small blocks that are blown over will be counted by FIU.
- Each Team will be supplied with $50 cash. Teams are permitted to spend more than the provided $50, but any additional cost incurred shall be at the expense of the team.
- Any type of non-hazardous material shall be allowed and considered acceptable for designing the screens, given that the solution complies with the construction guidelines described in sections 2.1-2.3. Some common examples of acceptable materials include (but are not limited to) wood, foam, bug screen, plastic, metal, white glue, super glue, and epoxy.
Physical Test Requirements and Restrictions

- During the competition, each team’s screen model will be placed in the Wall of Wind test section and tested by gradually increasing wind speeds.
- Only one wind screen model will be accepted from each team for wind testing.
- All models will be tested for one wind direction at 90 degrees to the line of the screen.
- Safety is paramount during competition and testing. The WOW’s technical team will be responsible for attaching the wind screen models in the test section of the Wall of Wind.
- NO ONE is allowed in the WOW test area during testing.
Physical Test Requirements and Restrictions

• Prior to wind testing, Judges will inspect the screen models to verify that the design is in compliance with the requirements and restrictions listed in Section 2; the Judges reserve the right to disqualify from competition any wind screen model that is found to be in violation of the rules and regulations of the competition.

• **The score** for each team for the blow-over tests will be calculated as follows: The speeds at which the first 5 blocks fall over will be recorded. The average of these 5 speeds will be calculated and will serve as the score for the physical test with the Wall of Wind.
Thank you

Questions??