Effect of low-rise building geometry on tornado-induced loads

140926 WANG Yong

Southeast University

September 16, 2015

Challenges to quantify tornado-induced loads:

- Lack of research facilities capable of determining tornado-induced loads (pressures, forces, etc.)

Challenges to quantify tornado-induced loads:

- Lack of research facilities capable of determining tornado-induced loads (pressures, forces, etc.)
- Absence of full-scale data

Challenges to quantify tornado-induced loads:

- Lack of research facilities capable of determining tornado-induced loads (pressures, forces, etc.)
- Absence of full-scale data
- Lack of interest in tornado-resistant design

How to overcome these challenge:

- Iowa State University (ISU) tornado simulator

How to overcome these challenge:

- Iowa State University (ISU) tornado simulator
- Full-scale data from several recent tornados

How to overcome these challenge:

- Iowa State University (ISU) tornado simulator
- Full-scale data from several recent tornados
- Pressures obtained form the ISU simulator are verified

Maximum horizontal wind speed

Fact 1: Around 90% of all tornados are rated F2 or less

Maximum horizontal wind speed

Fact 1: Around 90% of all tornados are rated F2 or less

Fact 2: Maximum velocity of F2 tornado is 74 m/s

Maximum horizontal wind speed

Fact 1: Around 90% of all tornados are rated F2 or less

Fact 2: Maximum velocity of F2 tornado is 74 m/s

Fact 3: Design wind speed ranges from 63 m/s to 80 m/s (ASCE 7-10, 2010)

Maximum horizontal wind speed

Fact 1: Around 90% of all tornados are rated F2 or less

Fact 2: Maximum velocity of F2 tornado is 74 m/s

Fact 3: Design wind speed ranges from 63 m/s to 80 m/s (ASCE 7-10, 2010)

Fact 4: Maximum horizonal velocity of the tornado generated by ISU Simulator is 11.7 m/s

Maximum horizontal wind speed

Fact 1: Around 90% of all tornados are rated F2 or less

Fact 2: Maximum velocity of F2 tornado is 74 m/s

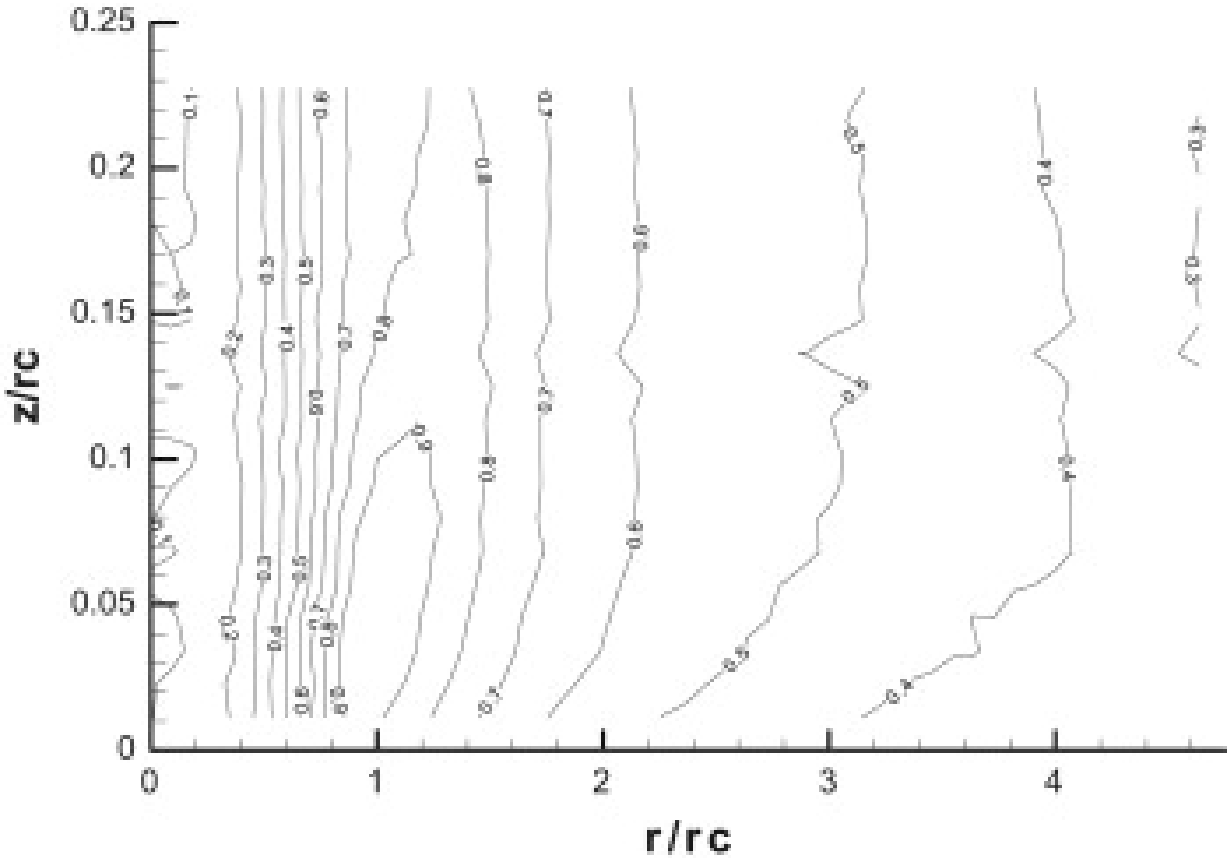
Fact 3: Design wind speed ranges from 63 m/s to 80 m/s (ASCE 7-10, 2010)

Fact 4: Maximum horizonal velocity of the tornado generated by ISU Simulator is 11.7 m/s

Choose target full-scale wind speed to be 74 m/s

Velocity scale $\lambda_v = 11.7/74 = 1/6.3$

Contour plot of normalized tangential velocity



Tornado vortex diameter

Definition

Radius of the core r_c: radius of the maximum wind near the ground

Tornado vortex diameter

Definition

Radius of the core r_c: radius of the maximum wind near the ground

Fact 1: r_c of F2 tornado is between 45 to 225 m

Tornado vortex diameter

Definition

Radius of the core r_c: radius of the maximum wind near the ground

Fact 1: r_c of F2 tornado is between 45 to 225 m

Fact 2: r_c of simulated tornado is 0.56 m

Tornado vortex diameter

Definition

Radius of the core r_c: radius of the maximum wind near the ground

Fact 1: r_c of F2 tornado is between 45 to 225 m

Fact 2: r_c of simulated tornado is 0.56 m

Choose r_c of target full-scale tornado to be 56 m

Length scale is 1 : 100

Swirl ratio: definition

Definition

Swirl ratio S:

$$S = \frac{\pi V_{\theta \max} r_c^2}{Q}$$

r_c: core radius

$V_{\theta \max}$: maximum tangential wind speed

Q: inflow rate of the vortex measured at $r = r_c$

How to choose swirl ratio

How to choose swirl ratio

Fact 1: Data from full-scale tornados indicates $S \geqslant 2.0$

How to choose swirl ratio

Fact 1: Data from full-scale tornados indicates $S \geqslant 2.0$

Fact 2: Best fit of full-scale data with numerical simulation when $S \geqslant 2.0$

How to choose swirl ratio

Fact 1: Data from full-scale tornados indicates $S \geqslant 2.0$

Fact 2: Best fit of full-scale data with numerical simulation when $S \geqslant 2.0$

Choose the swirl ratio S to be 2.6