Tutorial 1.2. Wind Profile Generation Along the Height of a Structure

Description: The design wind speed computed from example 1.1 is at the reference location. The variation of the wind load along the height of the structure is explained in this tutorial. The wind profile depends on the terrain at which it is located. Norm-based formulas are introduced. A distinction should be made between (10 min) mean and (3 s) gust wind profiles. Some exercises are proposed.

Students are advised to complete the exercises.

Project: Structural Wind Engineering WS19-20 Chair of Structural Analysis @ TUM - R. Wüchner, M. Péntek

Author: kodakkal.anoop@tum.de, mate.pentek@tum.de

Created on: 30.11.2015

Last update: 27.09.2019

Contents:

Wind profile - the variation of (a certain) wind speed (component) along the height of the structure - for the building in Terrain category I and IV

In [1]:

```
# import
import matplotlib.pyplot as plt
import numpy as np
from ipywidgets import interactive
```

Gust wind speed computed from the previous example for the location of the Jeddah Airport considering a return period of 50 years is 40.12 m/s. The mean wind speed is computed as

In [2]:

```
gust_windspeed = 40.12
# 1.4 is the approximate factor to convert from gust to mean wind speed
mean_windspeed = gust_windspeed/1.4
```

According to EN 1991-1-4: Eurocode: Actions on structures - Part 1-4: General actions - Wind actions

1. (1.6.1) fundamental basic wind velocity $v_{b,0}$: the 10 minute mean wind velocity with an annual risk of being exceeded of 0.02, irrespective of wind direction, at a height of 10 m above flat open country terrain and accounting for altitude effects (if required)
2. (1.6.2) basic wind velocity v_b: the fundamental basic wind velocity modified to account for the direction of the wind being considered and the season (if required)
3. (1.6.3) mean wind velocity v_m: the basic wind velocity modified to account for the effect of terrain roughness and orography

Note that the various coefficients are provided in the national annexes. Sometimes these are all 1.0 leading to identical values for the above distinct quantitites.

Two terrain categories are assumed in this exercise.

1. The building is located at the seaside: **Terrain category I**
2. The building is located at an urban area with height of adjacent building up to 15m: **Terrain category IV**

Let us calculate the design wind and pressure values for **200 m tall building** having a uniform **square cross section of 30 m * 30 m.**

In [3]:

```
height_total = 200
storey_height = 4 # height of each floor
air_density = 1.2 # airdensity in kg/m3
height = np.arange(0, height_total, storey_height)
```

Let us compute for terrain category I

According to DIN EN 1991-1-4/NA the wind profile for terrain category I is
$$ u_{mean}(z) = 1,18 . v_b . (z/10)^{0,12}$$

$$ u_{gust}(z) = 1,61 . v_b . (z/10)^{0,095}$$

The gust wind pressure along the height can be determined as
$$ q_{gust}(z) = 1/2 . \rho_{air} . u_{gust}^2(z)$$

In [4]:

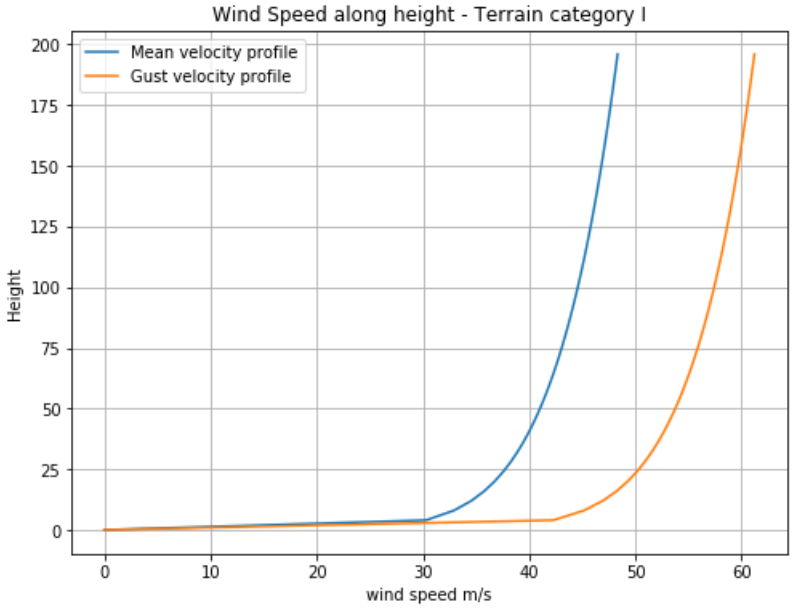
```
a_mean_1  = 1.18
alpha_mean_1 = 0.12
a_gust_1 = 1.61
alpha_gust_1 = 0.095

umean_1 = a_mean_1 * mean_windspeed * (height/10)** alpha_mean_1
ugust_1 = a_gust_1 * mean_windspeed * (height/10)** alpha_gust_1
qgust_1 = 0.5 * air_density * ugust_1**2
```

Let us plot

In [5]:

```
plt.figure(num=1, figsize=(8, 6))
plt.plot(umean_1, height, label = 'Mean velocity profile')
plt.plot(ugust_1, height, label = 'Gust velocity profile')
plt.ylabel('Height')
plt.xlabel('wind speed m/s')
plt.title('Wind Speed along height - Terrain category I')
plt.legend()
plt.grid(True)
```



Let us compute for other terrain category

According to EN 1991-1-4 the wind profile for terrain category IV is
$$ u_{mean}(z) = 0,56 . v_b . (z/10)^{0,3}$$

$$ u_{gust}(z) = 1,05 . v_b . (z/10)^{0,2}$$

In [6]:

```
def plot_windspeed(mean_windspeed, Terrain_category):

    a_mean  = {'I':1.18,'II':1.0,'III':0.77,'IV':0.56 }
    alpha_mean = {'I':0.12,'II':0.16,'III':0.22,'IV':0.3 }
    a_gust = {'I':1.61,'II':1.45,'III':1.27,'IV':1.05 }
    alpha_gust = {'I':0.095,'II':0.12,'III':0.155,'IV':0.2 }

    umean = a_mean[Terrain_category] * mean_windspeed * (height/10)**alpha_mean[Terrain_category]
    ugust = a_gust[Terrain_category] * mean_windspeed * (height/10)**alpha_gust[Terrain_category]
    fig = plt.figure(num=2, figsize=(8, 6))
    ax = plt.axes()
    ax.plot(umean, height, label = 'Mean velocity profile')
    ax.plot(ugust, height, label = 'Gust velocity profile')
    ax.set_ylabel('Height')
    ax.set_xlabel('Wind speed m/s')
    ax.set_xlim([0,120])
    ax.set_title('Wind Speed along height - Terrain category  ' + Terrain_category)
    ax.legend()
    ax.grid(True)
    plt.show()
```

Let us plot

Try different terrain category and mean wind speed values and observe the changes in the wind speed along height

In [7]:

```
mean_plot=interactive(plot_windspeed,mean_windspeed = (0.0,100.0), Terrain_category = ['I','II','III','IV'])
mean_plot
```

Exercise: Wind profile generation for Jeddah Airport

For the given data of Jeddah airport compute the mean and guest wind speed profiles for two terrrain categories. Make necessary changes in block 2. Evaluate and plot the gust wind pressure $q_{gust}(z)$ using the formulas in the slides provided.

Check Point: Discussion

Discuss amoung groups the observations regarding the generation of wind profiles.