Università degli Studi della Campania *Luigi Vanvitelli*

Dipartimento di Ingegneria

Northeastern University Civil and Environmental Engineering

June 2022

Introduction to Wind Science and Engineering

INSTRUCTOR: Luca Caracoglia, Associate Professor, Northeastern University, Boston, 02115 MA, USA, email: lucac@coe.neu.edu.

DURATION: 16 hours total with tutorials

AUDIENCE: Doctoral students in Civil, Mechanical, Environmental Engineering

FORMAT: In person lectures with video-streaming option.

LOCATION: Dipartimento di Ingegneria, Via Roma 9, 81031, Aversa, Caserta

REGISTRATION: To get the link for the Team Platform and other information please send an e-mail to albertomaria.avossa@unicampania.it

SYNOPSIS

A wide range of engineering applications require simulation and estimation of loads and excitations that are random in nature as they are often associated with hazards such as earthquakes, winds, waves, etc.

In the first module, the course will introduce the audience (doctoral students) to the discipline of wind science and engineering that provides students and practitioners with a broad instruction that enables the solution of problems related to the effects of windstorms on the built environment. At the same time, the audience will provide information on wind's beneficial effects (wind power). This module will also partially examine modeling of wind fields and atmospheric turbulence.

In the second module, the course will review theory and methods for random data (and vibration) analysis and probability for scientists and engineers; furthermore, the module will discuss aerodynamic loads, analysis methods applicable to structural systems under random wind loads. Examples will be primarily related to the field of wind hazard engineering, which is the primary research field of the instructor.

In the last module, the course will describe examples of fluid-structure interaction problems, and will introduce the audience to the field of qualitative risk analysis and "resilience" due to wind hazards.

Various design applications of probability principles will be considered (tall buildings, long-span bridges, etc.). The course will provide lectures and a practical tutorial.

COURSE TOPICS

Module 1: Fundamentals of wind science

1. Introduction to geophysical aerodynamics and boundary layer circulation, applied fluid dynamics
2. Synoptic and non-synoptic (thunderstorms, tornadoes) wind flows
3. Introduction to atmospheric turbulence for scientists and engineers

Module 2: Wind engineering analysis

4. Probability theory, random variables and random processes. Frequency domain analysis.
5. Bluff body aerodynamics, classification of structural pressure loads, discussion on the fundamental properties of random processes (e.g., ergodicity)
6. Estimation of structural dynamic response subjected to stationary random loads in the frequency domain, peak load and response. Introduction to engineering problems involving non-stationary effects.

Module 3: Special topics

7. Fluid-structure interaction problems in wind engineering
8. Introduction to performance-based wind engineering (PBWE) and design.

SCHEDULE OF CLASSES (16 HOURS, 3.0 CFU)

1. *(Tue) June 7*, 11:00 to 13:00 CEST, Review of applied fluid mechanics, geophysical aerodynamics, atmospheric circulation, stable vs. unstable fluid flows (2 hours – Room 2C)
2. *(Tue) June 7*, 14:30 to 16:30 CEST, Introduction to atmospheric boundary layer synoptic winds, wind flow profiles and turbulence (2 hours – Room 2C)
3. *(Thurs.) June 9,* 11:00 to 13:00 CEST, Special wind flows: tropical cyclones (i.e., hurricanes), "medicanes", non-synoptic winds (thunderstorms, tornadoes) (2 hours – Room 2C)
4. *(Thurs.) June 9*, 14:30 to 16:30 CEST, Review of probability and statistics for scientists and engineers (2 hours – Room 2C)
5. *(Tue) June 21*, 10:00 to 12:00 CEST, Review of random vibrations, structural & dynamic wind engineering (2 hours – Aula Magna)
6. *(Tue) June 21*, 14:30 to 16:30 CEST, Wind-induced vibrations on infrastructural systems: derivation and examples (towers, tall buildings, long-span bridges, etc., 2 hours – Aula Magna)
7. *(Tue) June 28,* 11:00 to 13:00 CEST, Fluid-structure interaction phenomena for flexible systems: aeroelasticity (2 hours – Aula Magna)
8. *(Tue) June 28*, 14:30 to 16:30 CEST, Practical tutorial: Design of a wind – compliant structure (2 hours – Aula Magna)

PRELIMINARY SUGGESTED READINGS

Books

Dinamica delle strutture, G. Muscolino, McGraw-Hill, Milan, Italy, 2002 (in Italian)

Random data analysis and measurement procedures (3rd edition), J.S. Bendat, A.G. Piersol, John Wiley and Sons, New York, NY, USA, 2000

Random vibrations: analysis of structural and mechanical systems, L.D. Lutes, S. Sarkani, Elsevier Butterworth–Heinemann, Burlington, MA, USA, 2004

Wind Effects on Structures: Modern Structural Design for Wind (4th edition), E. Simiu and D.H. Yeo, Wiley-Blackwell, 2019.

Multi-hazard approaches to civil infrastructure engineering, P. Gardoni and J.M. LaFave Editors, Springer International Publishing, Switzerland, 2016

Urban resilience for emergency and response recovery, G.P. Cimellaro, Springer International Publishing, Switzerland, 2016

Journal papers

Estimating life-cycle monetary losses due to wind hazards: fragility analysis of long-span bridges, D.-W. Seo, L. Caracoglia, Engineering Structures, Vol. 56, 2013, pp. 1593–1606, DOI: 10.1016/j.engstruct. 2013.07.031

A unified framework for performance-based wind engineering of tall buildings in hurricane-prone regions based on lifetime intervention-cost estimation, W. Cui, L. Caracoglia, Structural Safety, Vol. 73, 2018, pp. 75-86, DOI: 10.1016/j.strusafe.2018.02.003

Computationally efficient stochastic approach for the fragility analysis of vertical structures subjected to thunderstorm downburst winds, V.Le, L. Caracoglia, Engineering Structures, Vol. 165, 2018, pp. 152-169, DOI: 10.1016/j.engstruct.2018.03.007

Unified stochastic dynamic and damage cost model for the structural analysis of tall buildings in thunderstorm-like winds, L. Caracoglia, ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, Vol. 4, No. 4, 2018, 04018043 (17 pages), DOI: 10.1061/AJRUA6.0000999.

Exploring the impact of "climate change" on lifetime replacement costs for long-span bridges prone to torsional flutter, D.-W. Seo, L. Caracoglia, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 140, 2015, pp. 1-9, DOI: 10.1016/j.jweia.2015.01.013

Layered Stochastic Approximation Monte-Carlo method for tall building and tower fragility in mixed wind load climates, L. Zhang, L. Caracoglia, Engineering Structures, Vol. 239, 2021, 112159, DOI: 10.1016/ j.engstruct.2021.112159.

BIO-SKETCH OF LUCA CARACOGLIA

Luca Caracoglia is currently an Associate Professor (with forthcoming promotion to Full Professor, effective September 2022) in the Department of Civil and Environmental Engineering of Northeastern University, Boston, Massachusetts, USA. He joined Northeastern University in 2005. Prior to this appointment, he was a post-doctoral fellow in the Department of Civil Engineering at Johns Hopkins University, Baltimore, Maryland (USA) in 2001-2002 and a post-doctoral research associate in the Department of Civil and Environmental Engineering at the University of Illinois (Urbana-Champaign, USA) in 2002-2004. He received his Ph.D. in Structural Engineering from the University of Trieste, Italy in 2001. He is currently a Fellow of the American Society of Civil Engineers (ASCE).

Luca Caracoglia's research and professional interests are in structural dynamics, random vibration, wind engineering, fluid-structure interaction of civil engineering structures, nonlinear cable network dynamics, wind energy and wind-based energy harvesting systems. He directs the Wind Engineering Research Group (https://web.northeastern.edu/wind/). He has been author/co-author of 92+ peer-reviewed journal publications and book chapters (published or in press) and more than 120+conference proceedings / presentations in these fields. He has taught courses at the undergraduate and graduate levels in: Statics/Solid Mechanics, Structural Analysis, Steel Structure Design, Pre-stressed Concrete, Bridge Design, Wind Engineering and Wind Energy Systems. For his research, Luca Caracoglia received the NSF-CAREER Award for young investigators in 2009.

Luca Caracoglia is currently a member of the Board of Directors of the American Association for Wind Engineering (AAWE), and a member of the Executive Board of the ANIV – Italian National Association for Wind Engineering. He served as a member of the International Executive Board of the International Association for Wind Engineering (IAWE) in 2012 – 2017. He co-chaired the 3rd Workshop of the American Association for Wind Engineering in 2012 (AAWE2012), and co-chaired the 8th International Colloquium on Bluff Body Aerodynamics and Applications (BBAA VIII) in 2016.

Luca Caracoglia currently serves as an Associate Editor for the ASCE Journal of Bridge Engineering and the Journal of Fluids and Structures (Elsevier). He is also a member of the editorial board for the following journals: Engineering Structures (Elsevier), Structural Control and Health Monitoring (Wiley), Structural Safety (Elsevier) and Wind and Structures (Techno-Press).