Probability-Informed Wind Engineering against Synoptic and Non-Synoptic Wind Hazards

Credits (CFU)	Total contact hours	Role in PhD Civ. Eng., Env engr.	Role in PhD Mech. Eng., etc.	Prerequisites
3.0	18	General Elective	General Elective	a) Engineering PhD students in good standing b) Basic background in structural mechanics, structural dynamics and fluid mechanics, or advanced courses in engineering or physics

Description: The course will discuss latest developments in the field of probability-informed wind engineering against wind hazards. The course will briefly review wind fields, turbulence and aerodynamic loads in wind engineering due to synoptic (hurricane) and non-synoptic (thunderstorm) wind hazards. Dynamic analysis methods under stationary and nonstationary random wind loads will be employed to examine damage to the structure. Probability principles will be applied to the design of tall buildings and long-span bridges. The course will also introduce the basic principles of life-cycle structural integrity assessment due to wind hazards. Lectures will examine fundamentals and engineering applications. Lectures will be in English.

Course Delivery: course will be offered in a hybrid format. Synchronous, in-person lectures will be offered to PhD students at Univ. of Genoa. On-line video-streaming lectures will also be available to other students.

Course schedule: Three weeks of classes from May 17th 2023 to May 30th, 2023.

Schedule	Dates and times	Classroom
Week 1	Wednesday, May 17, 11am-1pm and 4pm-6pm Thursday, May 18, 4pm-6pm	A13, A4, A13
Week 2	Monday, May 22, 10am-12pm and 4pm-6pm Tuesday, May 23, 2pm-4pm	A13, A4, A13
Week 3	Monday, May 29, 10am-12pm and 2pm-4pm Tuesday, May 30, 10am-12pm	A13, A13, A13

(Note: each lecture will start at the exact time, indicated above)

Instructor: Luca Caracoglia, Department of Civil and Environmental Engineering, Northeastern University, Boston MA, USA, lucac@coe.neu.edu
Office hours: via ZOOM by appointment: https://northeastern.zoom.us/my/lucanu

Recommended Textbooks and Readings (*books are recommended and not mandatory*):

Books

Analytical methods in vibrations, L. Meirovitch, MCGraw-Hill, New York, NY, USA, 1970.

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

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

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

Wind effects on structures (4th edition), E. Simiu, and D.H. Yeo, John Wiley and Sons, New York, NY, USA, 2019.

Journal papers

Life-cycle cost assessment of vertical structures under nonstationary winds: Downburst vs. tornado loads, V. Le and L. Caracoglia, Engineering Structures, Vol. 243, 2021, 112515, https://doi.org/10.1016/j.engstruct.2021.112515.

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, DOI: 10.1061/AJRUA6.0000999.

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

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.

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.

Other Supplementary Materials: notes will be distributed to students at the beginning of the course.

Topics & Learning Objectives

Topic [time allotted]	Students will be able to:
Fluids Engineering Fundamentals – Review [2 hours]	1. Explain and apply principles of fluids engineering, recall momentum and fluid transport equations (Bernoulli's principle, Navier Stokes Equations) in both water and incompressible air. 2. Describe principles of flow pressures and forces around bluff bodies, flow separation, wakes. 3. Describe principles of dynamic similarity (Reynolds number, etc.) 4. Examine drag and lift forces around bluff bodies, drag crisis, etc.
Dynamics, Random Vibrations and Structural Wind Engineering – Review [2 hours]	5. Explain and apply fundamentals of physics and dynamics: particles and rigid bodies, Newton's Laws, elemental beam theory. 6. Explain and apply theory of static and dynamic instability. 7. Analyze mechanics oscillators, 1 or 2 degrees of freedom - 1DOF & 2DOF, which can aptly describe fluid-structure interactions.
Principles of synoptic wind engineering load analysis and design [4 hours]	8. Characterize wind turbulence of stationary, synoptic winds through turbulence spectra (e.g., the Solari spectrum). 9. Explain the principles of Davenport wind loading chain for linear systems (aerodynamic admittance, mechanical admittance); apply the Davenport wind loading chain to 1DOF and 2DOF generalized structures; generalize results to multi-DOF structures 10. Peak effect factor by Davenport and its further developments. 11. Fundamentals of Equivalent Wind Spectrum Technique (Solari)
Principles of non-synoptic (thunderstorm) wind engineering load analysis and design [4 hours]	12. Introduce modeling of non-stationary, non-synoptic Thunderstorm wind fields. 13. Analyze wind loads and structural response due to thunderstorm downburst loads 14. Extend the theory of Equivalent Wind Spectrum Technique to thunderstorm wind loads (Solari)
Tall building structures: lifecycle and probability-informed wind engineering for synoptic and non-synoptic wind hazards [2.5 hours]	15. Explain principles of wind-induced vibration and fluid-structure interaction for slender, tall building design. 16. Wake excitation and vortex shedding effects of cross flows in building design.

	17. Apply principles of life-cycle analysis to the design of tall buildings due to downtime and multi-source wind damage.
Long-span bridges: lifecycle and probability-informed wind engineering for synoptic wind hazards [2.5 hours]	18. Explain principles of wind-induced vibration and fluid-structure interaction for bridge decks and towers (streamlined and bluff). 19. Introduce aeroelastic phenomena for bridges. 20. Define and describe torsional divergence (1DOF); recognize bridge decks subjected to this issue (aerostatic). 21. Define and describe coupled flutter theory (2DOF); recognize bridge systems sensitive to this phenomenon (aerodynamic). 22. Apply principles of life-cycle analysis to the design of long-span bridges.
Tutorial: application of flow-induced vibration principles to structural design [1 hour]	23. Class Tutorial on flow-induced vibration in thunderstorm winds (Matlab).

Program-level outcomes that students will attain

Student outcome	***Assessed via:***
1. identify, formulate, and solve wind engineering problems by applying principles of engineering, science, and mathematics	Homework project assignment

Exams and assignments

A homework project will be assigned to the students at the end of the first week of the course. Students will be required to familiarize with MATLAB software environment to complete the assignment. Student will submit a *homework report* along with a computer code by the end of the course (electronic submission). The homework report will be in the form of a conference paper (approximately 8 pages). Evaluation of student performance will be based on the content of the report, its originality and preparation.

Policies on neatness and academic honesty

University of Genoa policies on neatness and academic honesty will be adhered to.

Grading formula

Project assignment (100%). Grades A (excellent) through D- (fair). Specific scale will be provided to students upon request.

Instructor's bio-sketch

Luca Caracoglia is a Full Professor in the Department of Civil and Environmental Engineering of Northeastern University (NU), Boston, Massachusetts, USA. He joined Northeastern University in 2005.

Luca Caracoglia's research and professional interests are in structural dynamics, random vibrations, fluid-structure interaction of civil engineering structures, nonlinear cable network dynamics, wind engineering, 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 95+ peer-reviewed journal publications and book chapters (published or in press) and more than 110 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. 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 in 2012 – 2017. Luca Caracoglia also serves on four US national, technical committees of the American Society of Civil Engineers (ASCE). For his accomplishments in the field of civil – structural engineering, Luca Caracoglia was granted the title of Fellow ASCE (held by 3% of the ASCE members) in September 2020. He co-chaired the 3rd Workshop of the American Association for Wind Engineering in 2012, and co-chaired the 8th International Colloquium on Bluff Body Aerodynamics and Applications, held at NU in 2016.

Luca Caracoglia currently serves as an Associate Editor the Journal of Fluids and Structures (Elsevier), the premier technical publication for researchers interested in fluid-structure interaction. Furthermore, he serves as an Associate Editor for the ASCE Journal of Bridge Engineering. He is also a member of the editorial board for the journals Engineering Structures (Elsevier), Structural Control and Health Monitoring (Hindawi-Wiley), Structural Safety (Elsevier) and Wind and Structures (Techno-Press).

Finally, Luca Caracoglia was granted two concurrent Full Professor habilitations (accreditations) by the Italian Ministry of Public Instruction, University and Research (MIUR) in 2019: 1) Scientific Discipline ICAR 08/B3, Civil Engineering/Structural Design, 2) Scientific Discipline ICAR 08/B2, Civil Engineering/Structural Mechanics.