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Western

WindEEE Research Institute
Engineering, Energy & Environment

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Contents

Preface

The WindEEE Research Institute has been renewed in July 2014 for a 5 year period "recognizing the excellent progress that has been made with the Institute and the research it carries out, as a key strategic priority for Western" (VP Research).

The WindEEE Dome became fully operational in October 2014. Full attention is now paid to the operational phase ensuring that both high caliber research and industry projects are secured. A Marketing Plan has been completed in collaboration with the Ivey School of Business in March 2016. This was followed by a Business Plan developed in 2017, again in collaboration with Ivey. During the last two years, the team started work on developing an efficient administrative framework including:

- time-tracking system,
- project management guidelines,
- facility policies and procedures,
- other necessary tools and related documentation.

This ongoing process aims to ensure:

- adoption of best practices in governance,
- facilities and equipment are effectively and efficiently operated and
- optimal use by both internal and external users.

The Institute has been instrumental in helping the University efforts to hire a Western Research Chair in Urban Sustainability. Professor Hassan Peerhossaini, from Université de Paris Diderot-Paris VII, was hired in this function in January 2018 and started adding scientific value to the research produced by the Institute directly affiliated faculty members.

At Western, WindEEE continues to increase its membership of more than 20 researchers from Western, hosted in 3 departments of the Faculty of Engineering (Civil, Mechanical and Electrical Engineering) as well as Faculty of Science (Applied Mathematics and Geography) and the Ivey School of Business.

Nationally, in order to expand its pan-Canadian research base, WindEEE RI consulted with Western Research Services and has dedicated (starting with 2018) a limited IOF-based funding to invite researchers from across Canada to apply for a WindEEE Innovation Fund. New partnerships have now been developed with Ocean Network Canada (ONC), University of Victoria (UVic), University of Windsor while we continue extending our collaboration with the Wind Energy Institute of Canada (WEICan), and UTIAS at University of Toronto.

At the international level, several research programs have been completed or are under development with partners from Europe, Americas and Asia. In collaboration with these partners WindEEE has now secured international research funding from prestigious agencies such as the European Research Council, the National Institute for Standards and Technology (NIST- USA), and Project 111 (China). Collaborative graduate programs are already in place with the Danish Technical University (DTU) and University of Genova, Italy as well as with universities in South America through the CONACYT program. Other such programs are currently under development with Tongji University and Chongqing University in China, and the Polytechnic University of Bucharest, Romania. Based on WindEEE RI collaborations, Professor Giovanni Solari (University of Genova) and Professor Jakob Mann (Danish Technical University) have lectured graduate summer 2017 and 2018 courses at Western. The presence of these top international researchers enriches the research activities at Western Engineering and at Western in general. Their courses, together with the graduate courses taught by our best faculty, are part of the Graduate Program in Wind Engineering which is one of the only two existing programs worldwide.

Since 2015, WindEEE is recognized by the Group of Senior Officials (GSO) as part of Global Research Infrastructures, a dedicated closed working space established by the European Commission called CIRCABC on which it started collaborating with global members. In 2016, WindEEE RI has become a member of SATA, the world Subsonic Aerodynamic Testing Association. WindEEE RI was also successful in attracting a large base of research collaborations at the national level. In 2017 the Institute created the WindEEE Innovation Grant which is meant to provide researchers across Canada with competitive access to the WindEEE facilities to prove innovative concepts in wind research. In 2018 WindEEE has been invited to present its activities at the International Conference of Research Infrastructures held in Vienna, Austria under the auspices of the European Research Council.

During 2017-2018 period alone, the WindEEE RI core faculty group continued their research outcomes producing 35 international journal publications, 20 conference proceeding publications and approx. 2 M$ in research funding. The core group faculty members at WindEEE RI have collectively trained 43 graduate students (31 Ph.D; 12 M.Sc.) as well as 3 Postdoctoral Fellows during this period.

Both the Research and Industry Funded Research projects at WindEEE RI continue to increase. R&D contracts with the insurance industry have been extended and are presently matched through NSERC CRD and OCE applications. New collaborations with transmission lines design companies are presently being signed. A large research program with the National Institute of Standard and Technology (NIST) and ARA (US) has been completed. A new European Research Council (ERC) funding program is presently secured. A new collaboration with the Institute for Catastrophic Loss Reduction has been started.

The WindEEE Governance Structure has been amended to better reflect the nature of operations and funding. The Advisory Board has been totally dedicated to Industry Partners and has now Hanny Hassan as President and AVP Research Mark Daley as Vice-Chair.

The first meeting of the revised Advisory Board took place in October 2017 followed by a meeting in November 2018. The WindEEE Research Board has now been re-structured in an International Research Board to better reflect the high level of international interest manifested in WindEEE. The first meeting of the Board took place in October 2018. Meanwhile the Canadian Research Membership has been extended and the next annual meeting is planned for February 2019.

WindEEE RI has now excelled in demonstrating its capacity to do world class research, to attract the best groups and scholars internationally and to secure research and industry funded projects. With sustained growth, the Institute continues to strive to accomplish its Vision: to be a global leader in wind research and innovation.

Horia Hangan

December 2018 /London, Canada

Governance Structure

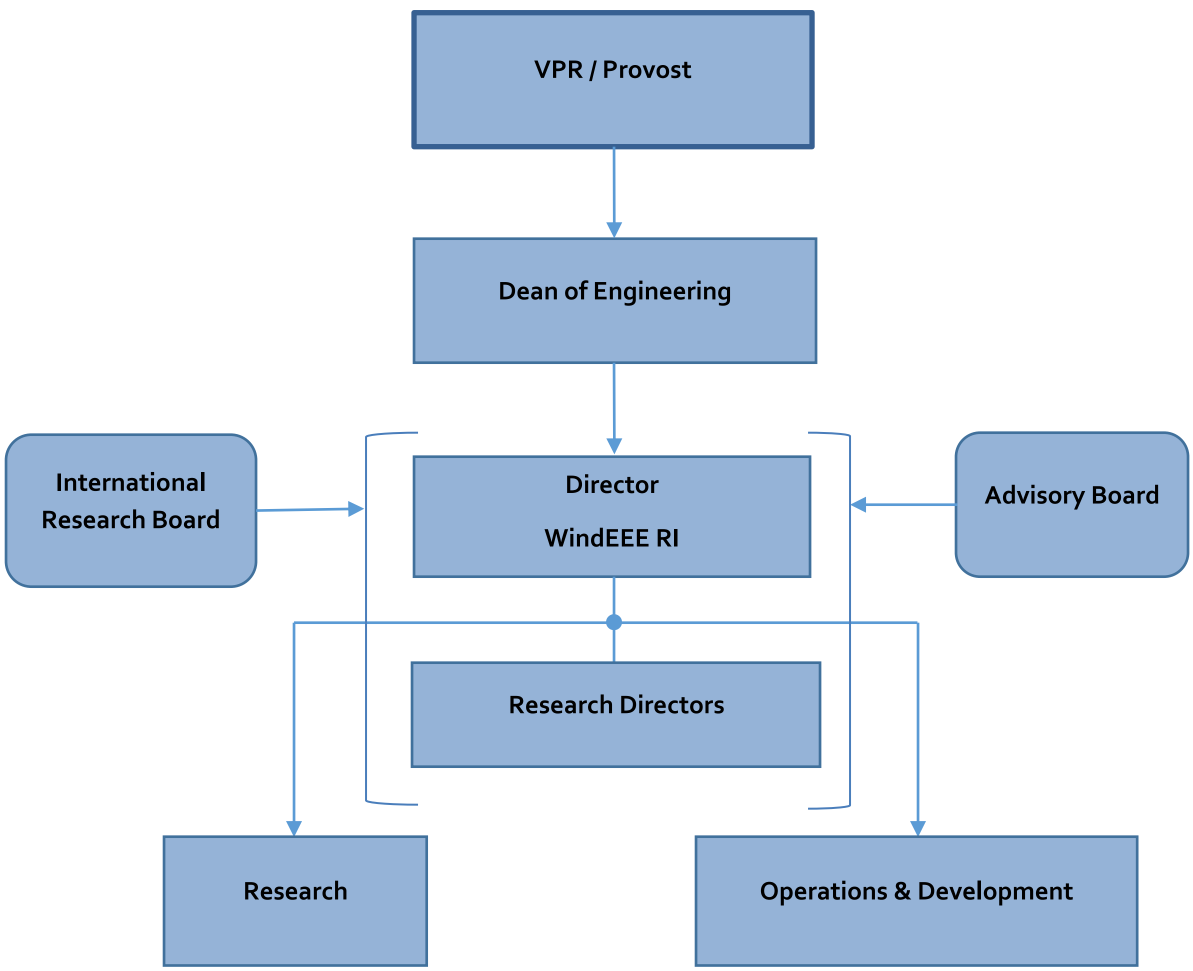
The **Governance Structure** provides both internal and external direction, innovative input and expert advice to the Institute in order to facilitate its development at Western and towards a National and International Institute, see Figure 1. Two external Boards provide the necessary inputs to the Director of the Institute: the Advisory and the International Research Boards.

The **Advisory Board** (AB) advises the Director of the Institute on progress and advancement in areas related to WindEEE activities. The board reports on Industry, International Institutes and Government with a global perspective along with providing advice on potential sources of funding.

Since 2014, the Advisory Board meets once a year and Members from Industry, and Government organizations are nominated for three (3) year terms. They are listed in WindEEE RI Advisory Board.

The **International Research Board** (IRB) advises the Director and the Research Directors on the progress and advancement of the wind engineering, energy and environment sectors, with a scientific perspective. The International Research Board meets once a year and reviews the research activities of the Institute.

The Members of the International Research Board of the WindEEE RI are nominated for three (3) year terms. They are listed in WindEEE RI International Research Board.



People

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Professor and Director of WindEEE Research Institute

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Dynamics of Thunderstorm Winds

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Extraction of Coherent Structures from Tornado-Like Vortices via POD Method

A. Kassab – PhD Candidate, Supervisor: Dr. H. Hangan
Simultaneous Pressure and PIV Measurements on Low-Rise Buildings

M. Enus – PhD Candidate, Supervisor: Dr. H. Hangan
Development of Large Scale Particle Tracking Methods

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Experimental Simulation of Tornadoes and Scaling Properties

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Computational Wind Engineering

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Novel Aeroelastic Testing Method Development at Windeee Dome

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Adaptive Architectural Forms and Progressive Aerodynamics

A. Melaku – PhD Candidate, Supervisor: Dr. G. Bitsuamlak
CFD Based Aeroelastic Analysis of Tall Buildings

B. Nighana – PhD Candidate, Supervisor: Dr. G. Bitsuamlak and Dr. F. Tariku (BCIT, Canada)
Solar Thermal and Phase Material Integration with Building Envelope

M. Ayalew – PhD Candidate, Supervisor: Dr. G. Bitsuamlak
Performance Based Wind Design Frame Work for Tall Mass Timber Buildings

M. Younis – PhD Student, Supervisor: Dr. G. Bitsuamlak
BIM Integrated Sustainable and Resilient Building Design Frame Work

M. Kahsay – PhD Candidate, Supervisor: Dr. G. Bitsuamlak and Dr. F. Tariku (BCIT, Canada)
Optimization of Fenestration Configuration in Buildings for Thermal Performance

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Enhanced Building Energy Performance Evaluation

T. Hunegn – PhD Candidate, Supervisor: Dr. G. Bitsuamlak
Aerodynamic optimization of long span bridge sections

A. Gairola – PhD Student, Supervisors: Dr. G. Bitsuamlak and Dr. H. Hangan
Numerical and WindEEE modeling of tornado flow structure and its effect on communities

C. Howlett – PhD Student, Supervisor: Dr. G. Bitsuamlak
Aero-Structural Optimization of Tall Buildings

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Performance Based Design Framework for Tornado

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Drone Enabled Environmental Fluid Mechanics Modeling

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Hybrid numerical and experimental wind and earthquake modeling

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Climate Responsive Architecture

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Performance Based Design of Buildings under Wind Loading

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Modelling and Testing of Progressive Failure of Transmission Line Structures

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Optimization of Design of Transmission Lines under Downburst

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Non-Linear Flutter Behavior of Cable-Stayed Bridges

M. Ramadan – PhD Candidate, Supervisor: Dr. A. El Damatty and Dr. K. Dai (Tongji University, China)
Performance of Wind Turbines under Tornados and Downbursts

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Failure Analysis of Transmission Line Structures under Downbursts

N. Niazi – PhD Candidate, Supervisor: Dr. A. El Damatty
Failure Analysis of Transmission Line Structures Under Tornadoes

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Behavior of Extra Tall Wind Turbines under Extreme Load Events

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Application of Supply Chain Demand in Transportation Engineering

C. Santos – PhD Candidate, Supervisor: Dr. A. El Damatty and Dr. M. Pfeil (University of Rio De Janerio, Brazil)
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A. Enajar – PhD Candidate, Supervisor: Dr. A. El Damatty
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M. Hamada – PhD Candidate, Supervisor: Dr. A. El Damatty
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K. Dennis – PhD Candidate, Supervisor: Dr. K. Siddiqui
Characterization of Three-Dimensional flow structure in Boundary Layers over a Flat Plate

S. Jevnikar – MESc Student, Supervisor: Dr. K Siddiqui
Investigation of Flow Behavior in the Transient Liquid Phase of a PCM Thermal Storage

K. Teather – MESc Student, Supervisor: Dr. K. Siddiqui
Investigation of Pore-Scale Phase Change Process in PCM-Embedded Porous Media

M.Mahaffy – MESc Student, Supervisor: Dr. K. Siddiqui

Z. Charran – MESc Student, Supervisor: Dr. K. Siddiqui
Design and Characterization of Optical Guide for Concentrated Solar Energy Trasmission

M. Kuska – MESc Student, Supervisor: Dr. K. Siddiqui
Investigation of Aquaculture Pond’s Thermal Regulation via Geothermal Ground Loop

Z. Habibi – PhD Candidate, Supervisor: Dr. H. Peerhossaini
Mechanics of Active Fluids

Facilities and Equipment

WindEEE Dome

The Wind Engineering, Energy and Environment (WindEEE) Dome, see Hangan (2014), is the world's first 3D wind chamber, consisting of a hexagonal test area 25m in diameter and an outer return dome 40m in diameter. Mounted on the peripheral walls and on top of the test chamber are a total of 106 individually controlled fans and 202 louver systems. Additional subsystems, including an active boundary layer floor and "guillotine" allow for further manipulation of the flow. These systems are integrated via a sophisticated control system which allows manipulation with thousands of degrees of freedom to produce various flows including straight flows, boundary layer flows, shear flows, gusts, downbursts and tornados. A pair of 5m diameter turntables as well as removable contraction systems accommodate a wide variety of test objects and wind speeds for testing inside and outside.

The WindEEE facility is certified LEEDs Silver and includes office space for industry, researchers, staff and graduate students as well as meeting and conference spaces for collaboration. WindEEE is located within the Advanced Manufacturing Park (AMP) in the South East corner of London, ON.

Model WindEEE Dome (MWD)

The Model WindEEE Dome (MWD) is a 1:11 scale version of the WindEEE Dome. The MWD was originally used as part of the design validation for the full scale facility and underwent significant flow studies. The MWD has many of the same features as the full scale WindEEE Dome and is able to produce the same flow scenarios. The model is located on the main Western University campus at the Boundary Layer Wind Tunnel Laboratory. Because of its inexpensive operation and maintenance costs, the MWD will continue to serve as a tool for preliminary test validation/set-up, fundamental tornado research and demonstrations.

Testing Capabilities

The WindEEE Dome can accommodate multi-scale, three dimensional and time dependent wind testing that no other facility can reproduce. WindEEE can be operated in a variety of configurations:

Straight Flow Closed Loop

- Straight flow closed loop utilizing one wall of 60 fans (4 high X 15 wide)
- Up to 30m/s with removable contraction
- Test section 14m wide, 25m long and 3.8m high
- Removable slotted wall assemblies
- All types of naturally occurring horizontal flows including: uniform, gusting, sheared and boundary layer flows
- Active floor roughness control
- Wide variety of scales up to 1:1

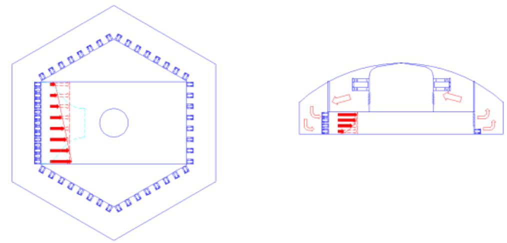


Figure 1 – Straight Flow Closed Loop

Straight Flow Open Loop

- Open mode utilizing 60 fans in reverse
- Uniform, gusting, sheared and boundary layer flows
- Up to 40m/s with removable contraction
- 5m diameter high capacity turntable
- Outdoor test platform with
- Wind driven rain, debris and destructive testing
- Access for very large full scale test objects

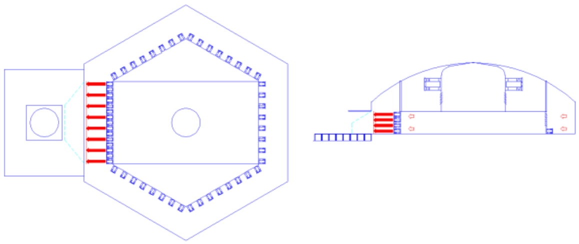


Figure 2 – Straight Flow Open Loop

Tornado

- Replication of EF0-EF3 tornados
- Properly scaled tornado flow
- Geometric scale 1/50 to 1/200
- Velocity scale 1/3 to 1/5
- Variable swirl ratio
- Adjustable vortex diameter up to 4.5m
- 2m/s maximum tornado translation speed
- Floor roughness control

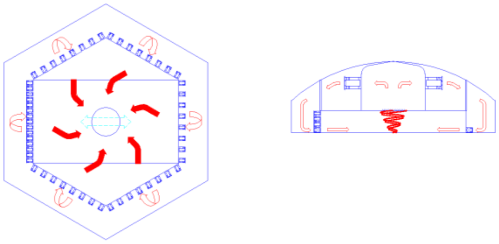


Figure 3 – Tornado

Downburst/Microburst

- Variable jet diameter (max 4.5m)
- Geometric scale ~1/100
- 2m/s maximum downburst translation speed
- Max 50m/s horizontal velocity
- Variable downburst offset and jet angle
- Combined horizontal and downward flows

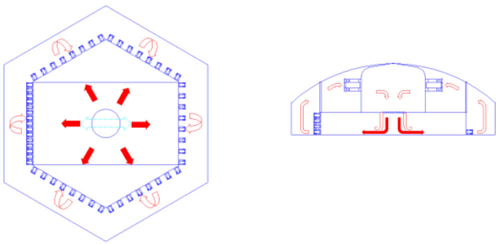


Figure 4 - Downburst

Example Uses

WindEEE has been utilized for many different types of projects and we are always discovering new uses for the facility and equipment. Just like the design of the facility, many of WindEEE's capabilities are unique in the world. WindEEE allows for the first time comparative testing of atmospheric boundary layer, downburst and tornado flows at the same scale. This allows for comparison of loads and responses of a given structure when exposed to these different wind events.

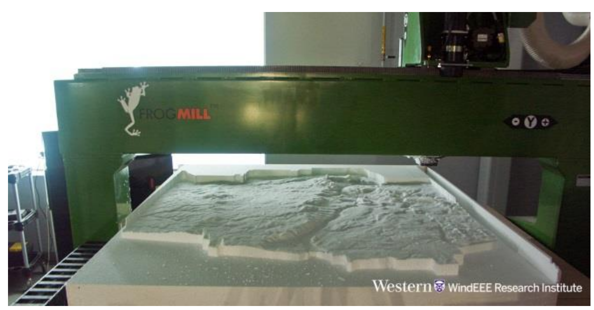
All of WindEEE's different flow configurations can be used to determine pressures and dynamic response of various structures. Scale models of buildings (residential, commercial, industrial, hospital, high-rise), bridges, transmission towers, wind turbines and many others can be tested. Various techniques are used to simulate the effect of surrounding buildings, topography and canopy in order to replicate the local site conditions.

WindEEE can also be used to test large scale, prototype or full scale objects to a wide variety of wind fields. Applications range from testing of full scale solar panels and small wind turbines, large scale topographic and canopy models, large and full scale wind turbine components (blades, towers), building components, environmental measurement devices, unmanned flying vehicles, etc.

Equipment

The WindEEE Facility is furnished with a suite of equipment, instrumentation and data acquisition systems to fabricate scale models and facilitate all types of wind related research and testing, including:

- High speed/high precision pressure scanning system
- Cobra probes
- 6 DOF force balances (multiple ranges)
- Pollution/scent dispersion system
- Multi camera Particle Image Velocimetry (PIV)
- Mobile LIDAR
- Full scale monitoring systems (masts, weather station, anemometers)
- Adjustable rain rake
- 6 DOF probe traverse system
- National Instruments data acquisition systems
- CNC hotwire
- CNC router
- FDM 3D printer



Computational resources

WindEEE also has powerful computational resources and actively participates in SOSCIP (soscip.org).

References

Hangan, H., 2014. "The Wind Engineering Energy and Environment (WindEEE) Dome at Western University, Canada", Wind Engineers, JAWE, Vol. 39pp.350

Research

1. Wind Engineering

- Tornado wind loading on essential buildings
- Tornado induced external and internal pressures on low rise buildings
- Downburst effects on utility transmission lines
- Wind loading on full scale roof mounted solar panels
- Wind effects on ground mounted solar panels
- Destructive testing on prototype buildings
- Numerical simulations of tornadic and downburst flows
- Finite Element Analysis of collapse modes due to wind

2. Wind Energy

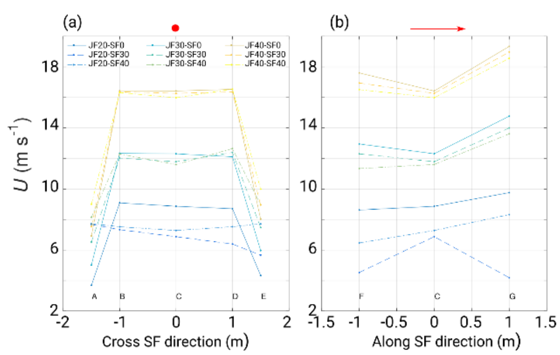
- Aerodynamic testing of smart blades
- Aeroelastic testing of model scale wind turbines
- Topography and canopy effects
- Full-scale campaigns

3. Wind Environment

- Wind resource assessment in complex urban environments
- Smart cities and buildings
- Wind-driven rain/snow
- Pollution-dispersion studies
- Effect of complex flows on unmanned flying objects

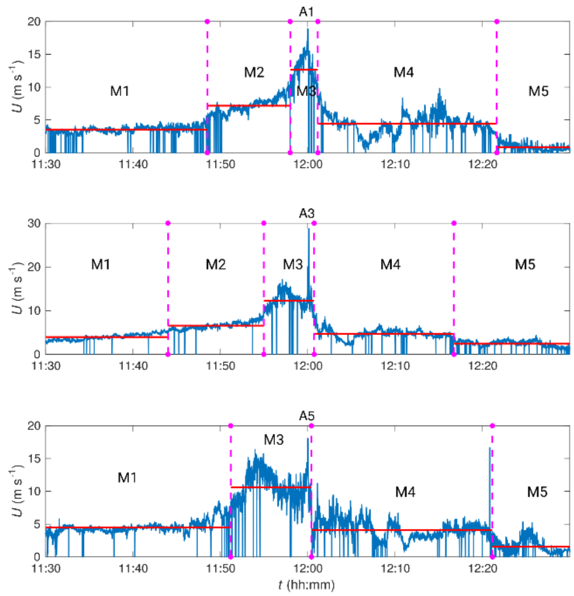
Transient Behavior in Impinging Jets in Crossflow with Applications to Downburst Flows

Thunderstorm winds and their interaction with structures are transient. The transient nature of downbursts is related to their embedment into stationary atmospheric boundary layer (ABL) winds. This paper introduces a signal analysis technique for the detection of abrupt changes in wind velocity time series with transient features. The detection method is then applied to explore the superposition between a straight wind and a downburst-like outflow. To study this interaction, the WindEEE Dome at Western University simultaneously produced straight and impinging jet flows in a closed-circuit mode of operation. The strength and characteristics of these two flows (when simultaneously produced) are studied herein for nine different flow rate ratios between the two types of flows. Figure below shows the velocity profiles at the jet exit (i.e., bell mouth) in the across-along-straight flow directions.



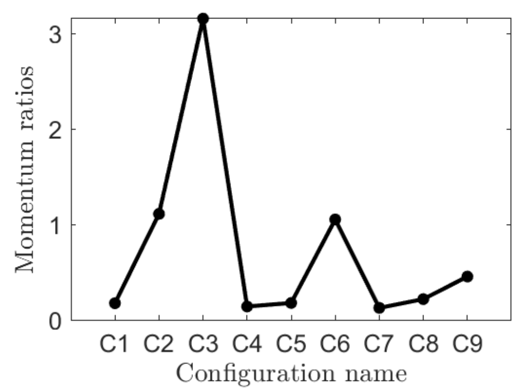
Velocity profiles at the bell mouth exit for nine different configurations of jets and straight flows in the WindEEE Dome. (a) Across- and (b) along-straight flow directions.

The method defined for detection of abrupt changes in velocity signals is used to determine the beginning of the impinging jets, as well as the slowdown of the ABL winds. In addition, the proposed methodology is tested for the case of a real downburst event recorded in Livorno, Italy, on 1 October 2012. The method accurately identifies abrupt changes in both mean and standard deviation of velocity signals in transient flows.



The abrupt changes (vertical dashed lines) in the mean estimated for the real dowunbrst measured in Livorno, Italy, in 2012.

The largest interference between ABL and downburst winds occurs when both flows are weak.



Momentum ratios for nine different configuration of the simultaneously produced jets and straight flow winds in the WindEEE Dome.

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Producing Larger Scale Experimental Tornadoes

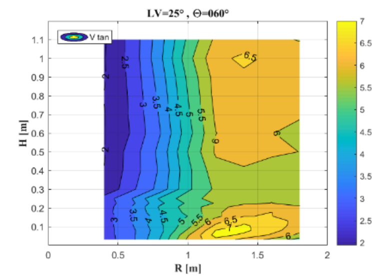
With the increasing frequency of intensive tornadoes, the study of tornadoes is one of the most pressing research needs in the wind engineering community due to killing people and left more homeless. These recent catastrophes have led researchers to investigate the characteristics of this phenomenon in more depth.

The proper scaling of tornadoes is a quintessential part of any experimental or numerical study on the effects of tornadic winds on buildings and structures. That is why, physically simulated tornadoes need to satisfy the proper geometric, kinematic, and dynamic similarities with the real events. Some of the main parameters encountered in tornado scaling are the geometric ratios of the radii and heights of the maximum tangential velocity of the full scale and modelled tornadoes. Therefore, the scaling procedure requires the detailed wind speed measurements of tornado flow fields in both wind simulators and real atmosphere. The former is presented in this paper.

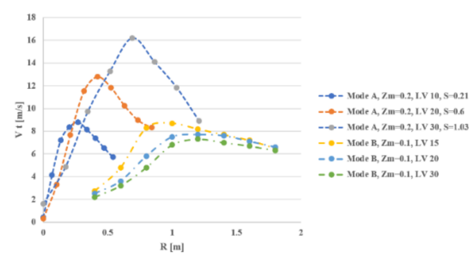
Laboratory simulations of tornado-like vortices have the advantage of controlled conditions and repeatability. The Wind Engineering, Energy and Environment (WindEEE) Dome at Western University is a large-scale and three-dimensional wind testing chamber capable of producing highly transient and non-synoptic winds such as tornadoes and downbursts. In the WindEEE Dome, a variety of wind systems can be generated by manipulating a system of 100 dynamic fans and louvers installed on the peripheral walls of the hexagonal test chamber, as well as by using the 6 large fans situated in the upper plenum above the test chamber.

Up until now, all tornados produced in the WindEEE Dome have been characterized with the length scales in the range between 1/300 and 1/150 by just using upper 6 fans and louvers. This research introduces a new experimental method for creating the larger scale models in the range of 1/150 to 1/50 by using the first method and peripheral fans.

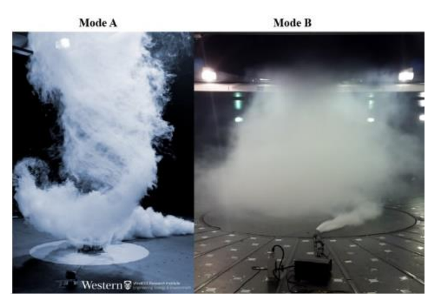
The simulated tornadoes in the WindEEE Dome from scaling point of view are compared against six volumes of single-Doppler radar data obtained from tornado events. Moreover, the overall flow structure of the experimentally produced tornadoes is compared against the full-scale data. In this regard, the WindEEE is capable to simulate real tornadoes with lower heights for maximum tangential velocity ($z_{max} \left| V_{t,max} \right.$) with length scale around 1/50. On the other hand, by using roughness elements on the floor of chamber, other events can be simulated for length scale around 1/100. It was concluded that the WindEEE Dome large-scale tornadoes correspond to EF0- to low-end EF2-rated twisters in nature. These finding are of particular importance in the field of experimental investigation of tornado actions on structures.



$V_{t,max}$ contour for different heights and radii



Comparing $V_{t,max}$ for Mode A & B



Flow visualization comparing Mode A & B

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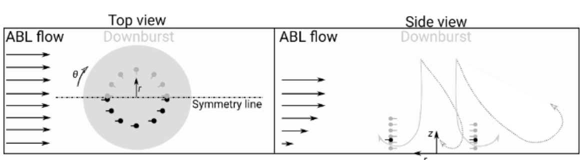
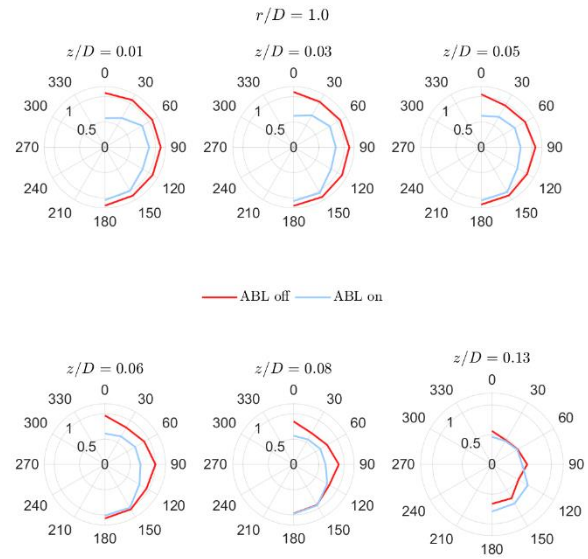
The Interplay Between Background Atmospheric Boundary Layer Winds and Downburst Outflows. A first Physical Experiment

This research studies the interaction between downburst outflows and the background atmospheric boundary layer (ABL) winds close to the surface. Downburst is a buoyancy-driven downdraft of cold air that emerges from cumuliform clouds and results in a vigorous starburst outflows upon reaching the surface. Currently, there are neither satisfactory analytical models nor experimental results on the highly complex interaction between these two wind systems. One of the advanced modes of the WindEEE Dome operation, at Western University in Canada, enables the simultaneous generation of downbursts and ABL winds. In accordance with the WindEEE Dome capabilities, an experiment is designed to address this long-standing question on the relationship between ABL winds and downbursts.

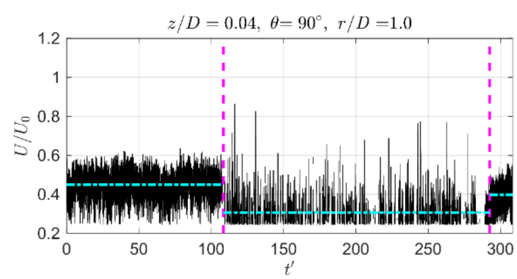


Experiment setup from top and side views. The grey probes are used to measure downburst out-flow while the black probe is used to measure ABL winds. Notice that the downburst probes al-ways point towards the centre of the turntable. In the side view panel, the dotted downburst line is a schematics of a downburst distorted by the ABL winds

This results are presented for the interaction between downburst and ABL winds for seven azimuthal positions in respect to the incoming ABL wind direction and six heights. The results show that the traditional approach of adding ABL winds to downburst outflow as either vector or algebraic sum is inaccurate for all heights and azimuth angles. A new empirical relationship between downbursts with and without ABL winds is presented herein.



Mean downburst wind speed as function of height ($\boldsymbol{z/D}$) and azimuth angle ($\boldsymbol{\theta}$) with (blue) and without (red) ABL winds. Here, $\boldsymbol{D = 3.2\ m}$ is the downdraft diameter and $\boldsymbol{\theta}$ is the direction of ABL winds.



An example of time series of ABL winds at $\boldsymbol{\theta = 90°}$. The magenta lines show the beginning and end of the downburst while the cyan lines are the mean speeds of ABL winds prior to, during, and after the downburst.

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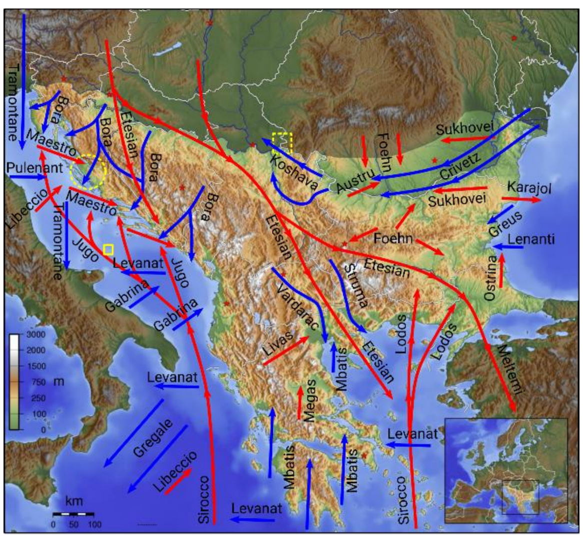
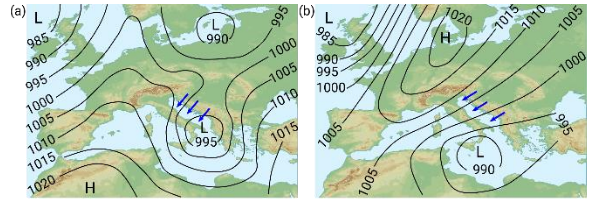
Local Winds of Balkan Penninsula

The Mediterranean is characterized with a large number of local winds. One region in the Mediterranean—the Balkan Peninsula or simply the Balkans—is particularly rich with local winds of different types including downslope and upslope winds, gap flows, and thermally-induced breezes from land to sea and vice versa. This study is the first comprehensive review of all currently known local winds in the Balkans—with coastal winds reviewed separately from inland winds. Besides providing the main climatological and dynamics characteristics of these winds, this paper also hints on the existence of various connections between several local winds that have not been reported previously. In total, this article lists twenty-seven different local winds above the Balkans with seventeen and ten being coastal and inland winds, respectively.



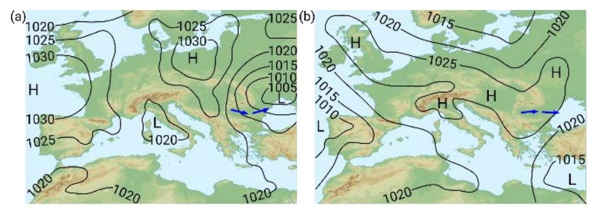
Schematics of cold (blue) and warm (red) local winds of the Balkans

By far, the most researched local wind in the Balkans has been the Adriatic bora that blows along the Croatian coast. Interestingly, there are more papers investigating bora than the number of studies on all other winds in the Balkans. Local winds over the Adriatic have been explored more than the winds above the Aegean, and these, in turn, were investigate more often than the winds that blow over the Ionian and Black Seas.



Schematics of mean sea level pressure maps of typical synoptic situations during (a) cyclonic and (b) anticyclonic bora wind

The most researched inland wind is the koshava wind that blows over the northern and central Serbia. Typical synoptic situations for most local winds are also provided with the note that the synoptic precursors of few local winds have not previously been documented. Lastly, this article discusses the prospects for further research in this field with the emphasis on the investigation of potential relationships between different local winds in this region.



Schematics of mean sea level pressure maps of typical synoptic situations during the nemere wind.

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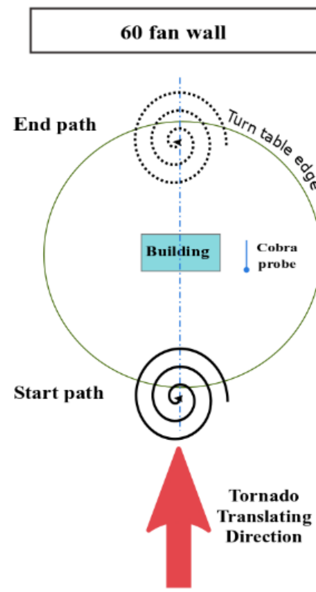
Tornado-Induced Internal and External Pressures on a Low-Rise Building with Multiple Openings

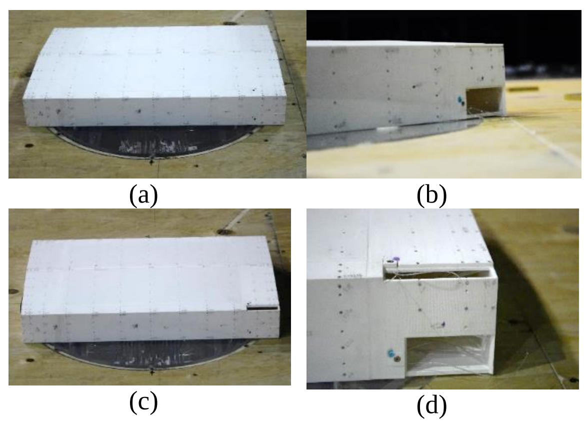
Internal pressures-induced in buildings due to the presence of leaks, openings or sudden break of a window caused by wind-borne debris during tornadic events are considered one of the major causes of the large number of fatalities and the massive destruction to properties, particularly low-rise buildings which accounts for almost 70% of the residential buildings. The net wind loads on buildings during tornado occurrence, which is a combined effect of internal and external pressures, exceeds the design wind loads and causes the building to collapse partially or totally. Although the standard building codes, e.g., ASCE 7-16 has updated wind maps with considering tornadic winds in tornado-prone regions, the pressure coefficients values are based on atmospheric boundary layer (ABL) flows, similarly in NBCC 2015 as well, which relates to the deficiency of such codes in designing structures specially in tornado-prone regions.

Hence, a comprehensive study of the tornado-induced internal and external pressures on low-rise buildings is crucial. External and internal wind pressures on a low-rise building were measured experimentally to investigate the effect of different openings on the pressure coefficients.

The building model employed in this study was chosen from the NIST aerodynamic database. Four opening arrangements were examined: uniform leakage, uniform leakage with dominant opening on the large wall, uniform leakage with dominant opening on the roof and uniform leakage with dominant opening on both the wall and roof. The building was located along the path of a translating tornado with EF-2 rating. The building's large wall was normal to the tornado path. Peak internal pressure coefficients for different opening configurations will be investigated. The correlation between internal pressures as well as internal and external pressures will be analyzed. In addition, external pressure coefficient distributions on the surfaces of the building will be investigated. Both internal and external pressure coefficients from this study will be compared with those for ABL flow from the NIST database.



Schematic of the experimental setup



Building model with openings: (a) uniform leakage, uniform leakage with dominant opening on (b) the large wall, (c) the roof and (d) both the wall and roof

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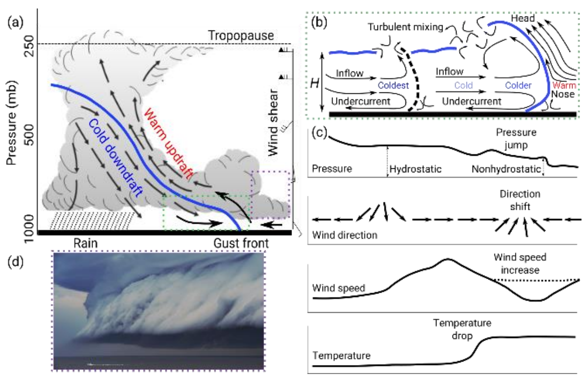
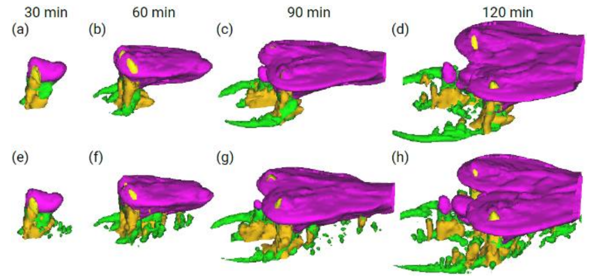
Implementation of a Gust Front Head Collapse Scheme in the WRF Numerical Model

Gust fronts are thunderstorm-related phenomena usually associated with severe winds which are of great importance in theoretical meteorology, weather forecasting, cloud dynamics and precipitation, and wind engineering. An important feature of gust fronts demonstrated through both theoretical and observational studies is the periodic collapse and rebuild of the gust front head. This cyclic behavior of gust fronts results in periodic forcing of vertical velocity ahead of the parent thunderstorm, which consequently influences the storm dynamics and microphysics.



a) Schematics of mature cumulonimbus cloud with the main dynamics outlined. (b) Closer look at the gust front relative flow. (c) Changes in several surface meteorological parameters associated with a gust front passage. (d) A photograph of shelf clouds overseeing a gust front in Australia (courtesy of Nick Moir, with permission).

This research introduces the first gust front pulsation parameterization scheme in the WRF-ARW model (Weather Research and Forecasting-Advanced Research WRF). The influence of this new scheme on model performances is tested through investigation of the characteristics of an idealized supercell cumulonimbus cloud, as well as studying a real case of thunderstorms above the United Arab Emirates. In the ideal case, WRF with the gust front scheme produced more precipitation and showed different time evolution of mixing ratios of cloud water and rain, whereas the mixing ratios of ice and graupel are almost unchanged when compared to the default WRF run without the parameterization of gust front pulsation. The included parameterization did not disturb the general characteristics of thunderstorm cloud, such as the location of updraft and downdrafts, and the overall shape of the cloud.



Supercell development without (top row) and with (bottom row) the gust front pulsation scheme. Different colors represent the mixing ratios of snow (purple, 8×10^{-2} g kg^{-1}), graupel (yellow, 4.5 g kg^{-1}), rain (orange, 5×10^{-1} g kg^{-1}) and cloud water (green, 5×10^{-2} g kg^{-1}). The cloud ice (blue, 4×10^{-2} g kg^{-1}) is not visible in this figure due to being encapsulated in cloud snow.

New cloud cells in front of the parent thunderstorm are also evident in both ideal and real cases due to the included forcing of vertical velocity caused by the periodic collapse of the gust front head. Despite some differences between the two WRF simulations and satellite observations, the inclusion of the gust front parameterization scheme produced more cumuliform clouds and seem to match better with real observations. Both WRF simulations gave poor results when it comes to matching the maximum composite radar reflectivity from radar measurement. Similar to the ideal case, WRF model with the gust front scheme gave more precipitation than the default WRF run. In particular, the gust front scheme increased the area characterized with light precipitation and diminished the development of very localized and intense precipitation.

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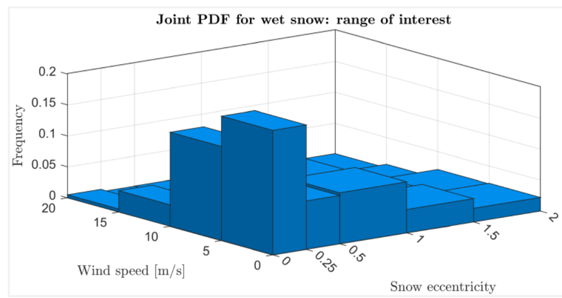
Combined Wind and Ice Effects on Transmission Lines

The ice accretion on network equipment and structures is a worldwide phenomenon which usually takes place in mountainous areas where temperature can drop below the freezing point or where wet snow is experienced. This natural event varies in form and relevance in relation to the atmospheric climatic conditions and can be particularly detrimental for overhead transmission line systems, affecting their operations and thus causing major problems to the society.

When ice and snow accumulate on cylindrical shaped structures they may naturally produce asymmetrical geometries. Potentially, these conductors could be aerodynamically unstable if exited by a wind load of a certain speed and angle of attack. The combined effect of wind and ice, or snow, can therefore cause conductors to oscillate in low frequency and large amplitude motions. The instability, known as galloping, yields cyclic dynamic loads which can cause severe damages to conductors, insulators, hardware and towers.

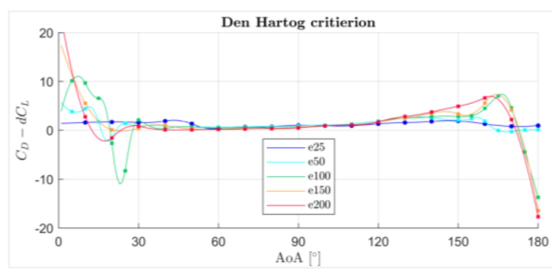
The development of the galloping is investigated on the basis of a statistical approach which refers to the climatic dataset of the site of interest and field observations of this type of motion. A parametric study in which wind and ice loads are differently combined is therefore conceived, so that to enhance understanding of the influence of each variable involved on the occurrence and the importance of the related instabilities. The analysis of the aerodynamic characteristics of the line, corresponding to the different loads combinations proposed, is carried out both by means of physical and numerical modelling. The instability conditions are evaluated, and compared by referring to Den Hartog's and Nigol's theories. The dynamic response of the system is restricted to the case of vertical galloping and computed by employing the linear theory of free vibrations of a suspended cable by Irvine. Eventually, a risk analysis for the site of interest is carried out to provide with a summary of the findings obtained through the work conducted and a useful tool for the selection of the most suitable control methods to be employed to limit or prevent the galloping.

Icing on transmission lines



Joint PDF for wet snow

Different ice shapes



Den Hartog criterion for different ice eccentricities

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Characterization of Large Scale Experimentally Produced Downburst Flows

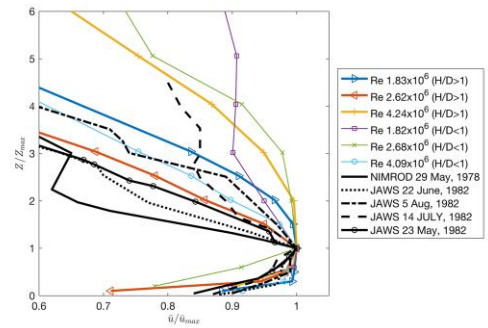
Downburst is defined as a sudden and strong downdraft of cold air originating from a cumulonimbus cloud which upon reaching the ground surface develop intense gusts. Due to their vigorous nature, downbursts can cause fatal airliner accidents as well as damages to the ground mounted structures. Downbursts are more frequent than tornadoes and are reported to be the most destructive winds in inland North America.

This study investigates the mean and the turbulent features of the experimentally produced downbursts with respect to height-to-diameter (H/D) ratios and Reynolds numbers (Re). Point velocity measurements with high temporal resolution are obtained using Cobra probes for H/D = 1.2 and H/D = 0.8, as well as for a range of the values of Re (between Re = 1.82 $\times 10^6$ and Re = 4.24 $\times 10^6$).

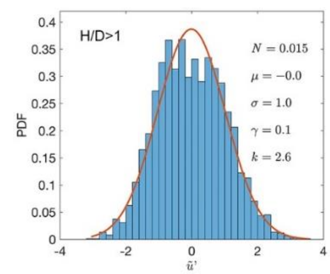
Wind velocity data were decomposed into the transient mean and transient turbulence components based on the criteria outlined in the literature. A wide range of proper values for the moving average times (T_{avg})—from 0.01 to 0.3 s—was investigated with respect to several criteria: (1) characteristics of running mean and residual fluctuations, (2) joint Fourier transforms of running mean and residual fluctuations, and (3) mean, standard deviation, skewness and kurtosis of reduced turbulent fluctuations. Based on this analysis, T_{avg}= 0.1 s was deemed to be the proper averaging time for the simulated downbursts in the WindEEE Dome.

Profiles of time varying means of radial velocities with height are calculated for different values of Re and normalized profiles are compared against previously published full scale data. At similar Reynolds number, the profiles corresponding to H/D>1 have a more pronounced “nose” shape when compared to the ones for H/D<1. Overall, the profiles corresponding to the case of H/D>1, especially at lower Re (1.82×10^6 to 2.68×10^6) show better comparison with the existing full scale data.

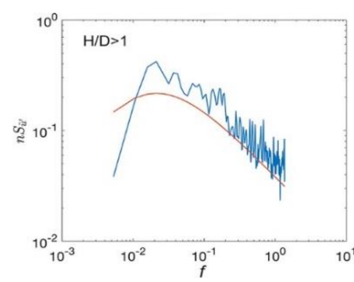
This study analyzes the turbulence characteristics of laboratory simulated downbursts similarly with full scale downburst data analysis found in the literature. Probability distribution function of the reduced turbulent fluctuations for all cases matches reasonably well with Gaussian distribution. Spectra of the reduced turbulent fluctuation is also matched with the existing analytical model and good agreement is found for all cases except for H/D<1 with Re = 1.82×10^6.



Normalized velocity profiles from full scale events are plotted against the experimentally generated downbursts in the WindEEE Dome



PDF of the reduced turbulent fluctuations for Re = $2.62{\times}10^6$



PSD of the reduced turbulence fluctuations matched against the analytical model for Re = $2.62{\times}10^6$

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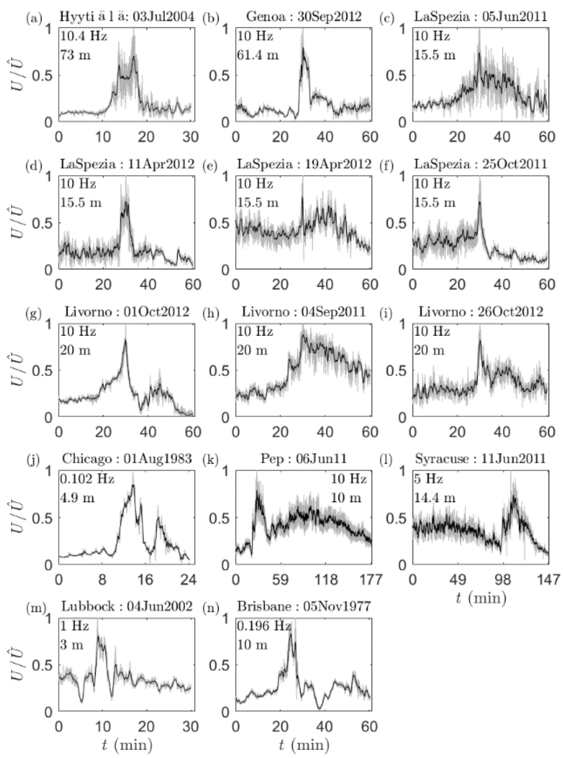
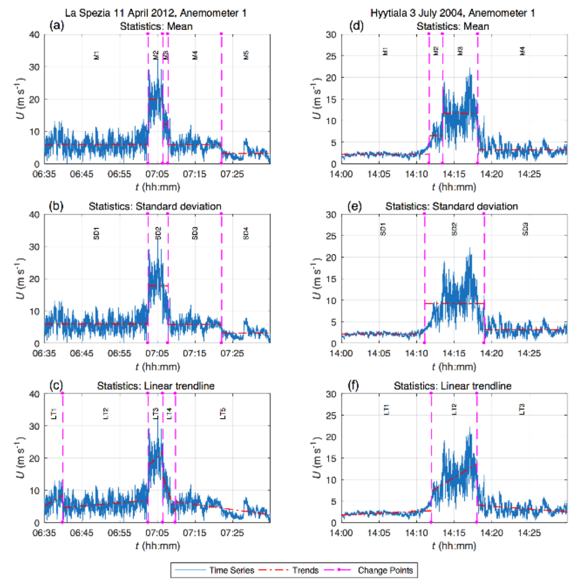
Investigation of Abrubpt Changes in Thunderstrom Wind Records

This study investigates the transient nature of 14 thunderstorm winds from around the world—9 from Europe, 4 from the United States, and 1 from Australia. Since most of the events were recorded by several anemometers, a total of 37 thunderstorm wind speed records are used in the analysis. The transient features of thunderstorm winds were examined by introducing an objective method for detection of change points in the time series.



Thunderstorm events investigated in this research. Grey and black lines are instantaneous wind speeds and their 30-s moving means, respectively. Anemometer sampling frequency (in Hz) and height (in m) shown in each plot. All velocities are normalized with the peak velocity.

The methodology divides the time series into different segments, each characterized with a statistically significant difference between two adjacent segments. The point between two adjacent segments is called a change point. The segmentation is based on the following properties of the isolated segments: mean (M), the standard deviation (SD) and the linear trend (LT).



Three segmentation methods applied to downburst records from La Spezia, Italy, (right column) and Hyytiälä, Finland (right column).

On average, the duration of the first broad peak associated with thunderstorms was 6.5 minutes. In the investigated sample of downburst time series, the ramp-up time, defined as the time between the start of the downburst determined using the introduced method for change point detection)and the peak wind speed, was below 1 min in more than 50% of the cases using the M statistics in segmentation. The typical number of segments in an hour long thunderstorm wind records is 3–4 using the M approach and 2–3 employing the SD method.

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Underlying Mechanism of Wandering Phenomenon in Tornado-Like Vortices Using Novel Techniques Dynamic POD and Dynamic ICA

Regardless of the type of vortex chamber, many tornado simulators generate flows that reveal the same flow patterns, and a general agreement about the variations of the flow structures with swirl ratio is achieved. However, very little is known about the underlying physics of the flow.

This lack is attributed to several obstacles and one of them is vortex wandering phenomenon. In small swirl ratios, vortex is randomly moving which leads to overestimation of core radius and underestimation of maximum tangential velocity. Distribution of vortex center at the different time is shown in Figure 1. The experiment was done by PIV in a model of WindEEE Dome.

The underlying mechanism of wandering is not investigated yet, and it's not clear if this phenomenon is the results of wind-tunnel fan unsteadiness or it is an inherent characteristic of the vortex.

Here, we applied the novel techniques Dynamic POD and Dynamic ICA on the velocity field of tornado vortices. These techniques are able to extract the dynamic coherent structures of the turbulent flow. A sample of animated movie of POD mode 1 at the different time lags (α) is provided in Figure 3. The animated movie of the static coherent structures (shown in Figure 2) can help us to look into the underlying mechanism of wandering phenomenon and find out the mechanisms dominating the tornado-like vortex.

In the next step, we model the effects of wandering on the velocity field analytically.

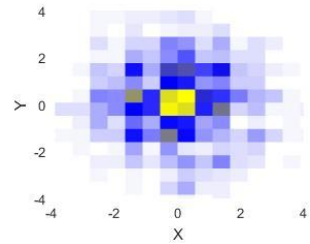

Figure 1. Normalized histogram of instantaneous vortex center position with respect to the mean position. X and Y are the distance from the mean position of the vortex center.

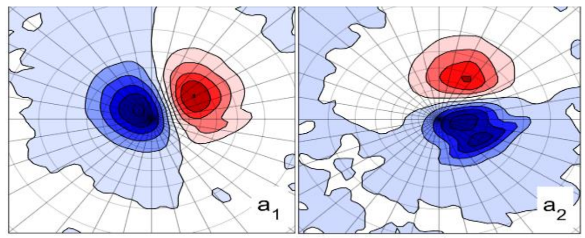

Figure 2. The first two ICA modes of the vorticity field. Positive (negative) values of vorticity are shown in blue (red) color.

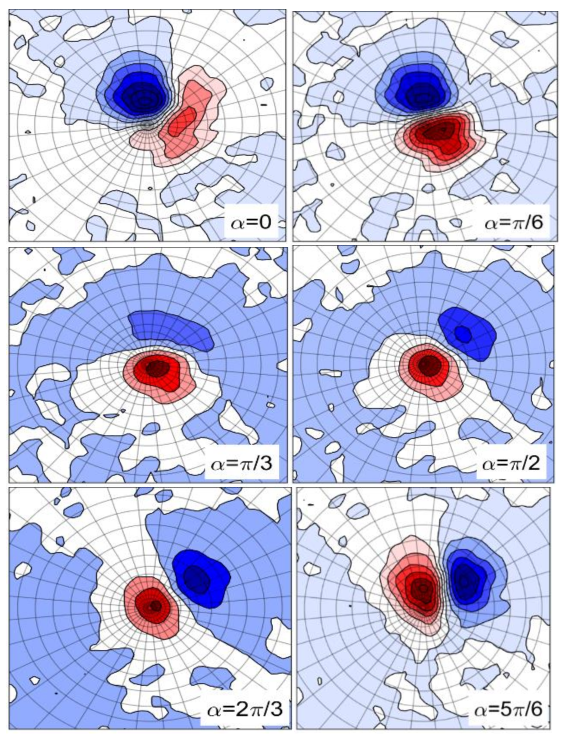

Figure 3. Dynamic-ICA mode 1 at six different phase shifts (α), representing time-lag. Positive (negative) values of vorticity are shown in blue (red) color.

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A Novel Approach for Downburst Scaling in Experimentally Produced Downburst-Like Impinging Jets

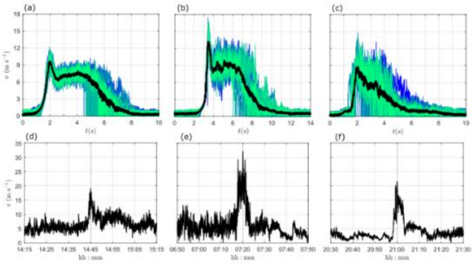
Downbursts are intense thunderstorm winds that can be found in most, if not all, regions around the globe. Apart from their importance in cloud dynamics and thunderstorm lifecycle, downbursts are often a severe hazard for man-made structures, airplanes, and environment. An accurate experimental investigation of downburst winds requires the proper geometric and kinematic scaling between the model downburst (*m*) created in a wind simulator and the full scale downburst event (*p*; i.e., prototype downburst). This study makes a threefold contribution to further understanding of downburst outflows. First, the article introduces a new scaling methodology for downburst outflows based on the signal decomposition techniques of p and m downburst wind records. It was demonstrated that the velocity scale can be expressed as:

$$\Lambda_v(T_m) = \frac{\bar{v}_{\max,p}\gamma_p(t_p)}{\bar{v}_{\max,m}\gamma_m(t_m)} \cdot \frac{1 + \bar{I}_{v,p}\mu_p(t_p)\tilde{v}_p'(t_p)}{1 + \bar{I}_{v,m}\mu_m(t_m)\tilde{v}_m'(t_m)},$$

where all the variables in the nominator correspond to the *p* even, while the variables in the denominator correspond to the *m* event. In other words, the velocity scale is a product of the proper scale for the mean flows, $\boldsymbol{M_v(T_m)}$, and the proper scale for the fluctuating part of the flows, $\boldsymbol{F_v(T_m)}$, i.e.:

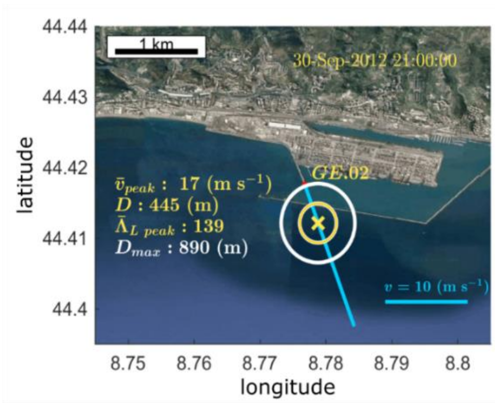
$$\boldsymbol{\Lambda_v(T_m) = M_v(T_m) \cdot F_v(T_m)},$$

Second, the study describes in details a large set of m downbursts produced in the WindEEE Dome simulator at Western University, Canada, and critically discusses their similarity with a large set of p events detected in the Mediterranean.



Examples of downburst outflows in the WindEEE Dome (top) and full scale events (bottom). The black line in the top row is the average of 20 experiment repetitions.

Third, using the proposed scaling methodology, this paper attempts to partially reconstruct two p downburst events recorded in Genoa and Livorno, Italy. In total, 17 p and 1400 m downburst outflows are investigated herein, which represents the largest database of p and m downbursts combined. The similarity between p and m downbursts is quantitatively demonstrated for both mean and fluctuating components of the flows. The scaling method is verified by accurately predicting the known anemometer height of p events using m downburst measurements.



Partially reconstructed downburst event in Genoa, Italy, using the WindEEE Dome measurements in conjiction with full scale anemometer data and the proposed scaling methodology.

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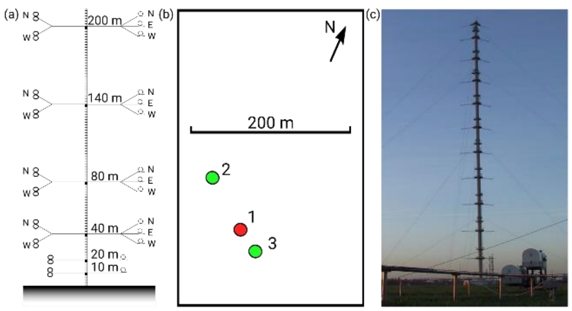
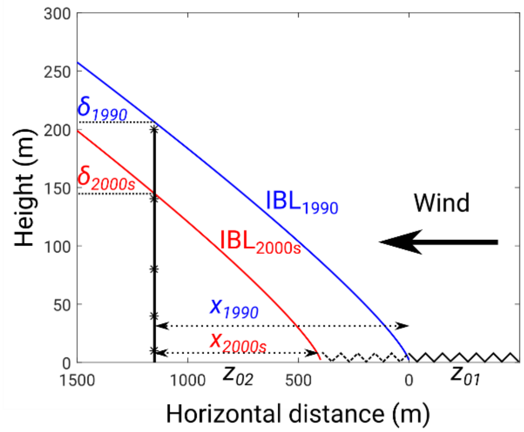
Homogeneity Analysis of Wind Data from 213 m high Cabauw Tower

Homogeneous meteorological data are a prerequisite for a reliable climatological studies. This paper investigates the homogeneity of wind data from 213 m high Cabauw tower located in the Netherlands. The wind measurements are conducted at 10, 20, 40, 80, 140 and 200 m above ground.



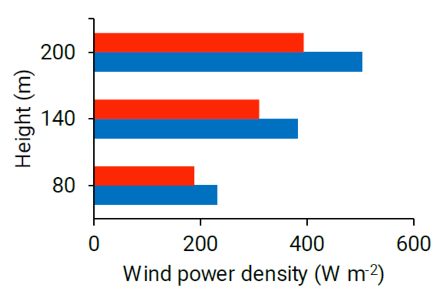
(a) Schematics of Cabauw 213 m tower together with installed wind measuring equipment. Measurements at 20 m and 10 m levels are conducted at auxiliary masts 2 and 3 (green circles in (b)). The main tower is the red circle in (b). A photograph of the tower is shown in (c).

The analyzed data cover the period from February 1986 to January 1997, and from April 2000 to December 2015. This study presents the first homogeneity analysis of wind data from a tall meteorological mast. Homogeneities of wind speed and wind direction series were investigated independently using the ReDistribution Method. Overall, the wind measurements at Cabauw tower are very homogeneous. The only wind speed inhomogeneity was detected at 200 m above ground and it seems to be, at least to a certain extent, caused by the rapid expansion of the town of Lopik in the 1990s.



The average internal boundary layer heights in the years 1990 (blue line) and the 2000s (red line). The vertical black line with stars shows the position of Cabauw tower and the instrumentation heights, respectively.

Lopik's growth to the west, however, only influenced the east winds on the Cabauw tower. Small inhomogeneities in wind direction data were detected at 20, 40 and 80 m levels, whereas a fairly large inhomogeneity was observed at 10 m above ground. Several potential causes of inhomogeneities in wind direction data are discussed, but the major contributor could not be determined with certainty. In addition, the homogeneity of real measurements from Cabauw tower is compared against the synthetically created wind data for Cabauw tower using the Monte-Carlo method of random sampling. The results show that the detected anomalies are not due to the random noise in the time series.



Power density of east winds before (blue) and after 2000 (red) at the highest three levels on Cabauw tower.

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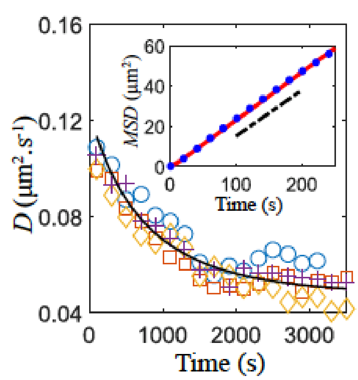
Active Fluids: Time Dependence of Diffusion Coefficient

Fuels make up 66% of global energy demand. Developing CO_2 neutral fuels for reducing greenhouse gas and therefore circumventing climate change is one of the most serious challenges nowadays. Biofuels offer a transition towards a renewable world of energy supply and production. However, the first generation of biofuels comes in competition with food supply, since a majority of them are produced directly from food crops. The second generation of biofuels is produced from lignocellulosic biomass. However, converting the woody biomass into fuel requires costly technologies involving pre-processing and therefore, the second-generation biofuels cannot yet be produced economically on industrial scale.

Drawbacks of the first and second-generation biofuels have urged a transition towards the third-generation biofuels derived from non-feed stocks microorganisms such as bacteria and microalgae. Treatment of microorganism suspensions comprising self-propelled particles - known as **active fluids** - however faces the science of fluid mechanics to a new challenge. Contrary to the conventional fluid flows in which one needs gradients of pressure, velocity and temperature to break equilibrium and drive the flow, in active fluids, cells as the microstructural elements of the fluid convert the chemical energy of nutrients into mechanical energy for driving the flow. Therefore, by using their molecular motors microorganisms in active fluids can develop complex spontaneous fluid motions in the absence of external gradients. Active fluids display properties that differ fundamentally from the passive fluids. Unique physical phenomena—as enhanced Brownian diffusivity, viscosity reduction, active transport and mixing or the extraction of work from chaotic motion—result from the activity of the microorganisms and locally inject energy into the system.

Surface diffusion of the model cyanobacterium *Synechocystis* sp. PCC 6803 during the incipient stages of cell contact with a glass surface in the dilute regime was studied. We observe a twitching motility with alternating immobile « tumble » and mobile « run » periods, resulting in a normal diffusion described by a continuous time random walk with a coefficient of diffusion D. Surprisingly, D is found to decrease with time down to a plateau. This is observed only when the cyanobacterial cells are able to produce released extracellular polysaccharides, as shown by a comparative study between the wild-type strain and various polysaccharides-depleted mutants. The analysis of the trajectories taken by the bacterial cells shows that the temporal characteristics of their intermittent motion depend on the instantaneous fraction of visited sites during diffusion. This describes quantitatively the time dependence of D, related to the progressive surface coverage by the polysaccharides. Since the estimated surface fraction of visited sites and the diffusion coefficient evolve with similar timescales, we propose a model for the decrease of the diffusion coefficient based on the deposition of EPS on the surface. This suggests new strategies for controlling bio-film formation in active fluids. *This work was recently published in Phys. Rev. E.*

Synechocystis sp. PCC 6803



Symbols: temporal evolution of the diffusion coefficient for five different experiments. Black line: proposed model.

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Computational aeroelastic assessment of flexible structures using high fidelity fluid-struction interation models

Tall buildings are prevalent in cities of the world because of the advantage they provide in using land space efficiently. The current trend in the evolution of these structures has been primarily driven by the need to build higher. Complemented by the advancements in use of lightweight construction material, new structural systems and design methodologies, the current generations of tall buildings are becoming lightweight and flexible. As a result, they are becoming highly vulnerable to wind induced dynamic actions due to the reduced mass, stiffness and damping. The current state-of-the-art approach to assess the dynamic action of wind on such structures is to undertake aeroelastic experiment in the wind tunnel. In the past few decades, however, coupled with growing computational power, Computational Fluid Dynamics (CFD) has been extensively used to study tall building aerodynamics. In the current study, high fidelity multiphysics simulation is proposed to include the prediction of the aeroelastic response of tall and slender buildings. To demonstrate the performance of the proposed approach, the numerical models will be validated against full aeroelastic experiments in boundary layer wind tunnel.

The proposed research work aims to contribute to the development of computational framework to estimate the aeroelastic response of tall building using fluid-structure interaction algorithms. This is achieved by developing efficient fluid-structure interaction algorithm that is optimized for aeroelastic response prediction of tall buildings.

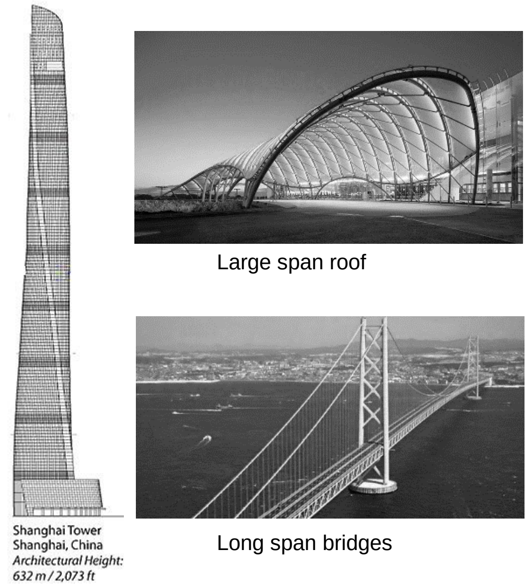

Figure 1. Different types of flexible civil structures

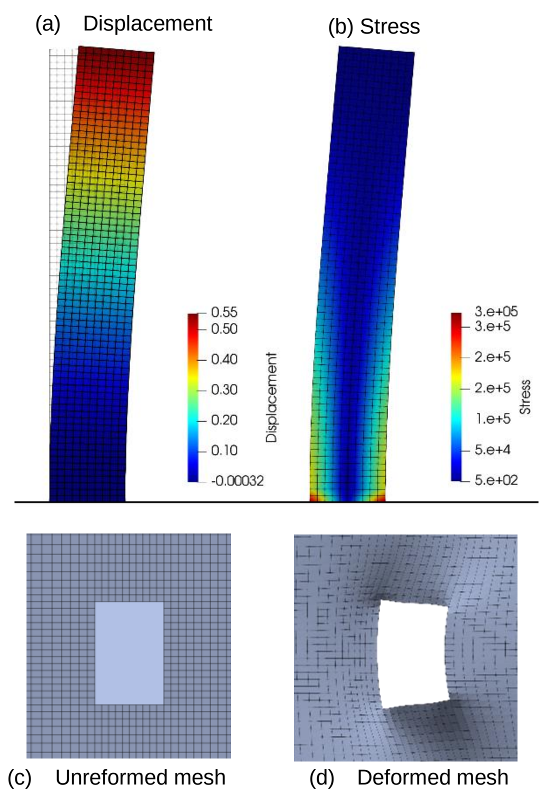

Figure 2. Result of fluid-structure interaction for CAARC model under wind load: structural response (a), stress(b), unreformed mesh(c) and deformed mesh (d)

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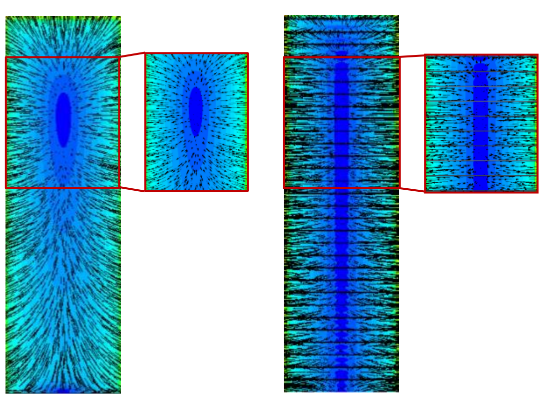
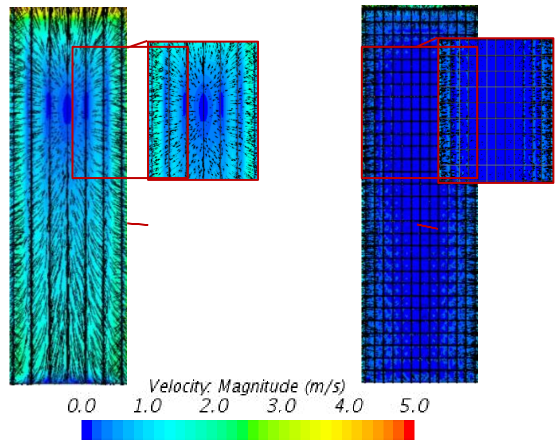
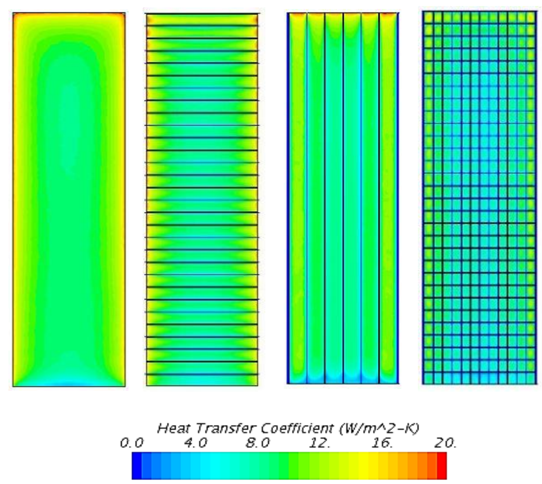
Effect of external shading on building convective heat transfer

Many high-rise buildings have intricate architectural details such as a balcony, a mullion, or an egg-crate on their façade systems. The façade system interacts with the microclimate in a complex manner that affects the convective heat transfer coefficient (*CHTC*) greatly. To date, the *CHTC*s correlations used by building energy simulations are primarily derived from the experimental and numerical analysis carried out on low-rise building with smooth façade surfaces. However, the external shading elements have a significant effect on the *CHTC*. Therefore, the application of the existing-*CHTC*s for non-smooth facades and high-rise buildings may not be accurate. By conducting a computational fluid dynamic simulation for airflow and heat transfer around buildings with and with out external shading elements, the CHTC values were estimated. The shear stress transport (SST) *k-w* closure model was used for turbulence modeling. The following observations are made: i) airflow speed increases with height that increases the CHTC, ii) the effect of external shading on the CHTC is significant, for instance, for a 1 m deep of shading element, the *CHTC* value decreased compared to a smooth surface by 13%, 22%, and 46% for horizontal, vertical, and egg-crate shading elements, respectively. The rate at which heat dissipates from a smooth façade is greater than facades with shading elements. This is primarily due to higher surface airflow over smooth façade compared to those hindered by shading elements. This shows the importance of consideration of façade details in estimating heat losses from buildings.

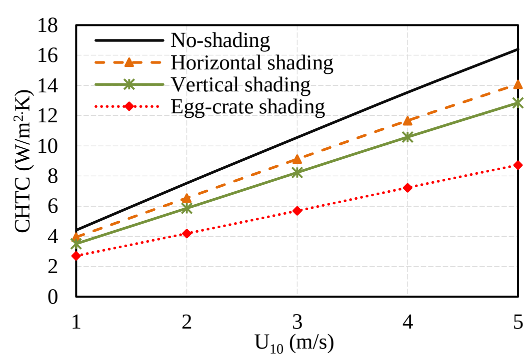




Wind velocity vector and contour plot (Ref. wind speed 3 m/s at the inlet)



Surface-averaged CHTC for a) without shading b) horizontal shading c) vertical shading d) egg-crate shading (ref. wind speed of 3m/s at the inlet)



Surface-average CHTC comparison on a) horizontal shading, b) vertical shading, and c) egg-crate shading

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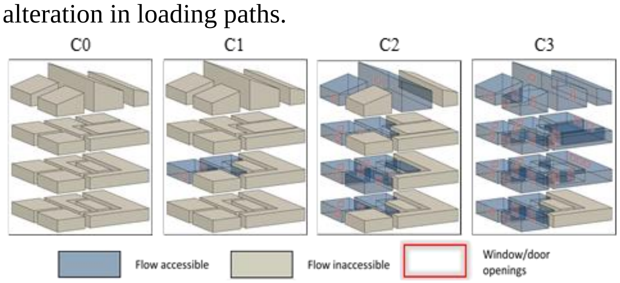
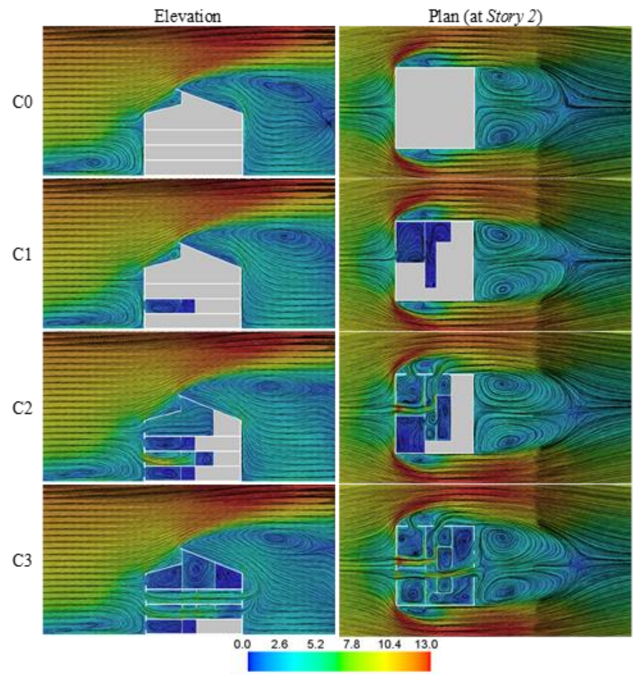
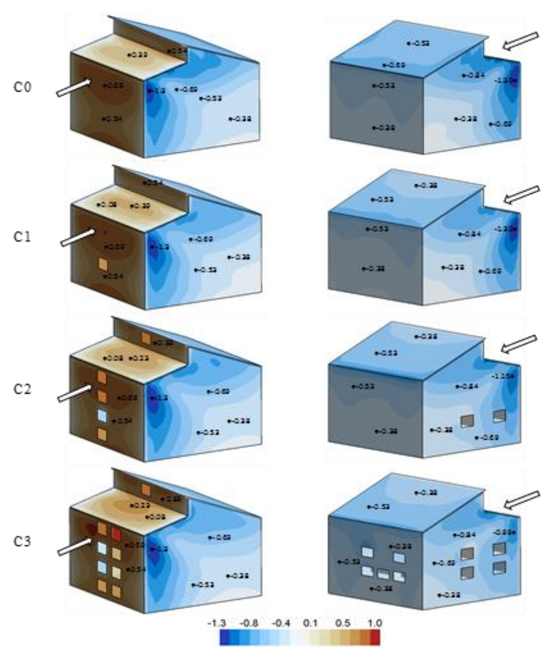
Progressive Collapse Aerodynamics of Low-rise Buildings

At high wind velocity areas, it is common to witness significant damages on low-rise buildings caused by hurricanes and other extreme wind events. These damages start at high pressure zones or weak building components (e.g. windows or cladding), and then cascade to other building parts. The state of the art in experimental and numerical aerodynamic load evaluation is assuming buildings as intact envelopes where wind acts only on the external walls. This assumption fails to explain the effect of: (i) openings on the external façade, (ii) internal partition walls, and (iii) load sharing between internal and external walls. However, during extreme events, non-structural components (e.g. windows and doors, roof tiles) could fail allowing the wind flow to enter the building envelope, which alters flow field and redistributes the wind loads on building walls and roof. Changing the loading scenario of wind can subject the internal walls to additional lateral loads, which potentially can exceed their load capacities; internal walls are typically designed for lower capacities compared to external walls. In the present work, an anticipated damage development scenario is proposed for a four-story building with a stepped gable roof. LES is used to examine the change in the internal and external wind flows for different levels of damage (starting from a totally sealed building until reaching a case with failure in most windows and doors). Examining different damage levels shows the progressive aerodynamic change, which results in elevating the overall wind-induced load up to 1.9 times compared to the undamaged case. This study demonstrates that damages in non-structural components can increase the wind risk on the structural elements due to the alteration in loading paths.



Zoning Diagrams for the Proposed Scenarios





Coefficient of Pressure Contours for AoA= 0°

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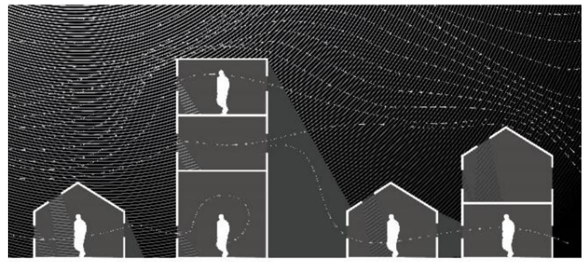
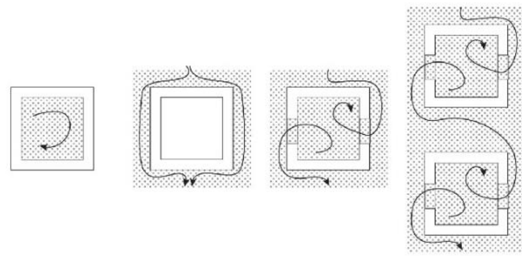
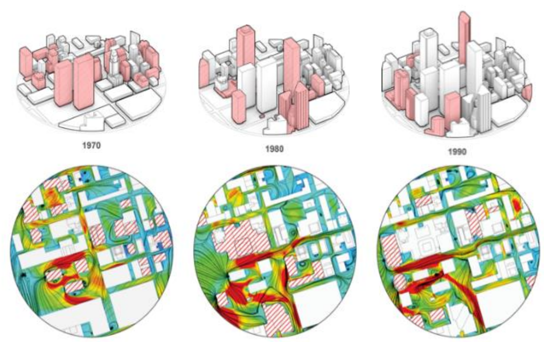
A framework for the multi-scale design of sustainable and resilient communities



Each building impacts the other and alters the relationship between climate and person



Scales of design: interior, exterior, interior/exterior, combination of buildings



Changes in Mean Velocity at Pedestrian Levels over

As buildings in cities grow taller and use more energy (30% energy consumption/reliance from buildings in Canada alone) and natural weather events are becoming more frequent and intense, it has become apparent that there is a need to understand the relationship between buildings and weather (specifically wind) more accurately. Instead of designing buildings individually, they can be designed to work together as an organism, where each building plays its role in order to reduce energy consumption (sustainable) and collectively recover from wind events (resilience). To do this, wind as a parameter that affects pedestrian level winds, loads and ventilation must be integrated not only in the beginning of the design process, but throughout. We can ensure this, by creating a framework that identifies these multi-scale interactions.

To create this framework, a combination of computational and physical testing methods will be utilized. The study will analyze the ventilation, loading, and pedestrian level winds on and around an isolated building, of different shapes with its interior functions laid out. The computationally results will then be validated with wind tunnel tests. From there, fully designed surrounding buildings will be added and studied in a similar manner. This expansion will mimic the growth of typical cities; in each step adding the infrastructure needed by any city. At each iteration, the relationship between the buildings will be identified, setting the bounds to this framework.

The framework will be tested on three case studies, a) a previously developed city such as Toronto, b) a current developing city such as Hamilton and c) a brand new city being developed currently.

This framework will expose invisible relationships to a multidisciplinary audience that includes architects, city planners, engineers, and other disciplines that have the power to impact cities on a global scale and improve the interaction between the elements of the city and the environment.

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Advanced Building Envelope Systems: Validation of Cross-Flow in Bi-fluid Building Integrated Photovoltaic/Thermal System (BIPV/T)

BIPV/T's are advanced building envelope systems that combine the functionalities of the building enclosure, solar cells and thermal collector in one product. BIPV/T systems are therefore complex systems in that the useful thermal and electrical energy output is dependent on a combination of climatic, envelope, insulation, covering, absorber configuration, and operational parameters. It is therefore necessary to develop concepts that facilitate efficient energy extraction.

Multiple Bi-fluid collector concepts have been proposed (Figure 1). The key principle of operation of these concepts is the perpendicular flow of fluid in the pipes relative to the direction of air flow (i.e. cross-flow arrangement). This cross-flow arrangement, intensifies the turbulence in the air flow channel and consequently, the convective heat transfer coefficient is increased. The capacity to enhance the heat transfer for each of the concepts will be compared by detailed computational fluid dynamics (CFD) simulation. The concepts will be evaluated under peak solar conditions and the derived thermal and electrical efficiency will be compared.

The reliability of the CFD model to effectively simulate the complex cross-flow structure is validated with experimental work in literature (Skullong et al. 2015). In this work, transverse square ribs of various was investigated for their effect on forced convective heat transfer in a solar air heater channel. The derived Nusselt number and friction factor were utilized as performance indicators. The single rib arrangement is simulated for benchmarking of the Numerical model as represented in Figure 2. The CFD model incorporating the Shear Stress Transport (SST) model is effective in capturing the complex cross flow structure such that the dimensionless heat transfer coefficient and friction factor are predicted with tolerance limits of the experimental setup as seen in Figure 3 (i.e ± 6% for the Nusselt number and ± 8% for the friction factor).

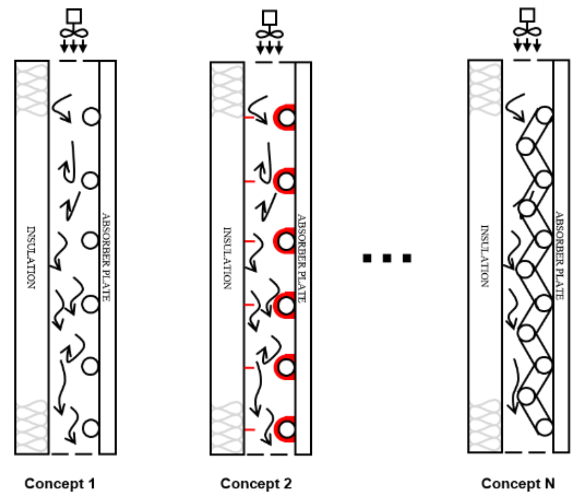

Figure 1: Schematic of possible bi-fluid BIPV/T collector concepts

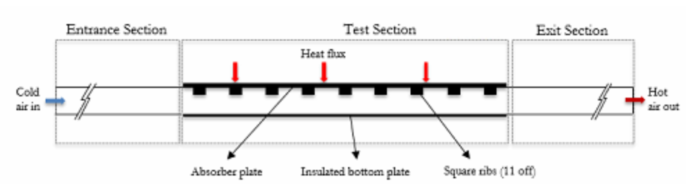

Figure 2: Cross-section of computational domain

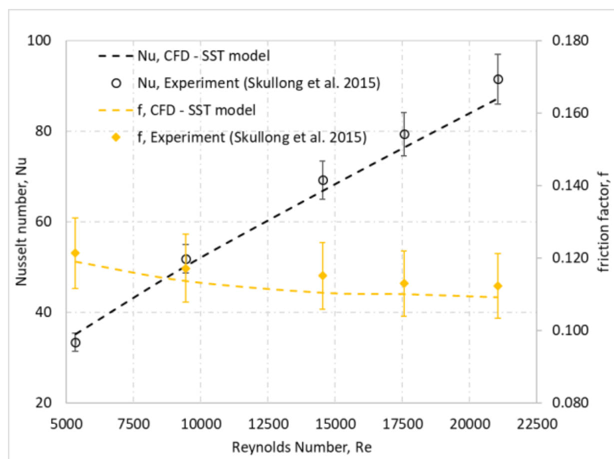

Figure 3: Comparison of numerical and experimentally derived Nu and f

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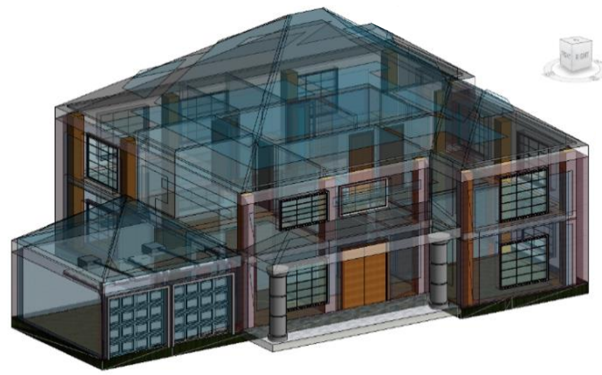
Climate responsive BIM integrated sustainable and resilient building design framework

In this study, we propose a framework that identifies and examines the conceptual relation between building design and climate both from the perspective of energy efficiency and their ability to resist extreme wind hazards. This in turn helps promoting a single goal that encompasses the dual concepts of sustainable and resilience-based design for environmental loads, which is the main goal of climate responsive building design. The assessment matrix will be energy and thermal efficiency and the ability to withstand extreme climate wind loads. The outcome from the proposed framework will be validated through post occupancy measurement from the Boundary Layer Wind Tunnel and WindEEE Dome. The repository of the computational and experimental data will be used to train an artificial intelligence model that can be alternatively used in the design process. Preliminary work is on progress to develop a BIM model for a wood building located in Toronto. The energy simulation was performed for the house and modifications were implemented to improve the energy performance.



BIM model for residential building

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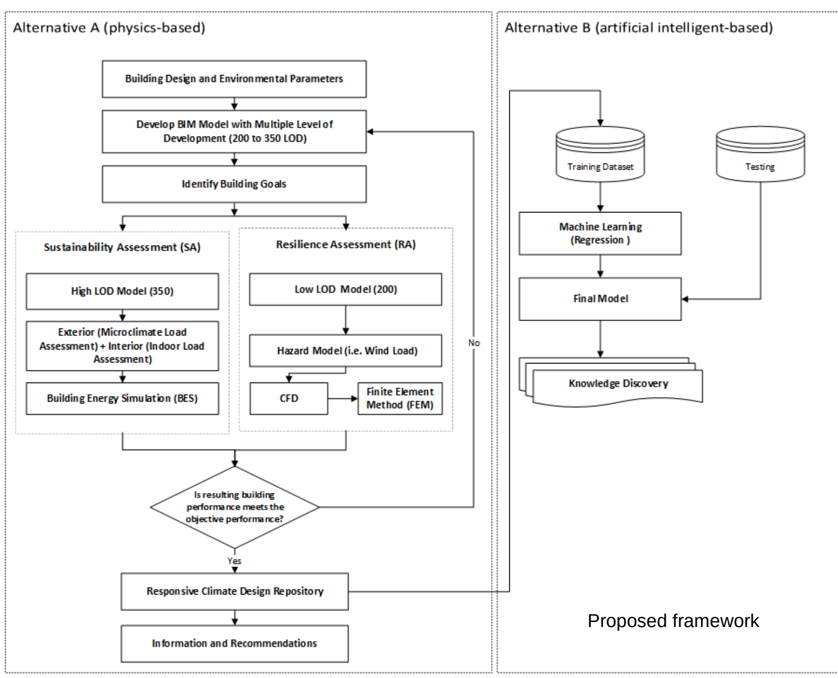

Proposed framework

Numerical vibration control study of wind turbines using vertical semi-active magnetorheological dampers

The use of wind turbines for renewable energy generation has been continually increasing in recent years; as of 2017, the global wind energy capacity was increased to a total of 540GW [1]. However, modern wind turbine designs still have room for improvement: the lifespan of turbines are generally limited by fatigue loading cause by wind-induced fatigue, there are numerous examples of turbines failing under intense wind loading [2] and research indicates that seismic loading can be equally dangerous [3].

Vibration control can be used to address both of these issues. This report introduces a study about the use of vertical semi-active magnetorheological (MR) dampers for vibration control of wind turbines. Semi-active damper control has been shown to have improved response compared to passive damping systems [4]. The proposed MR dampers are placed vertically near the bottom of the tower (Figure 1) as it is the location of greatest relative deformation of the tower wall.

This research numerically studies a 33DOF lumped-mass finite element model of a 65kW wind turbine. 3000kN MR dampers are approximated using the Modified Bouc-Wen numerical model (Figure 2). Time histories of service wind loads applied to an operational turbine, high-intensity wind loads applied to a parked turbine and seismic loading with service wind loads applied to an operational turbine are considered for a total of 114 wind load cases. Four damper control systems (two passive and two semi-active) as well as an undamped turbine are considered (Table 1), more details on each can be found in [5]. The preliminary results of this study are presented in this report (Table 2) for two layers of MR dampers and loading along cardinal directions. These preliminary results suggest that a properly tuned semi-active control (the CO controller) can be used to reduce vibrations, particularly for parked cases where aerodynamic damping isn't present. However, further configurations of MR dampers remain to be considered. Additionally, experimental testing techniques such as hybrid testing could be used to validate the results in the future.

[1] Global Wind Energy Council (2017), Global Wind Statistics 2017; Brussels, Belgium.
[2] Chou, J.S., and W.T. Tu (2011), "Failure analysis and risk management of a collapsed large wind turbine tower", *Engineering Failure Analysis*. 18, 295-313.
[3] Mardfekri, M., and P. Gardoni (2015), "Multi-hazard reliability assessment of offshore wind turbines", *Wind Energy*. 18(8), 1433-1450.
[4] Dyke, S.J., et al. (1996), "Modeling and control of magnetorheological dampers for seismic response reduction", *Smart Materials and Structures*. 5, 565-575.
[5] Jansen, L.M., and S.J. Dyke (2000), "Semi-Active Control Strategies for MR Dampers: A Comparative Study", *Journal of Engineering Mechanics*. 126(8), 795-803.

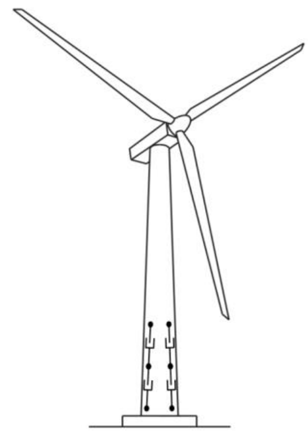

Figure 1: Turbine with vertical MR dampers

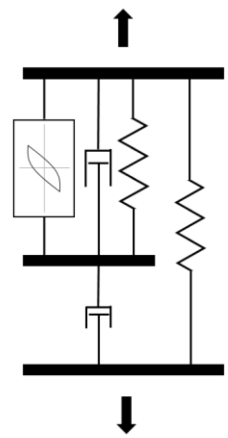

Figure 2: Modified Bouc-Wen Damper Model

Table 1: Vibration Control Methods and Abbreviations

Undamped (UD)
Passive - Minimum Voltage (PMn)
Passive - Max Voltage (PMx)
Minimum Energy Semi-Active Controller (ME)
Clipped Optimal Semi-Active Controller (CO)

Table 2: Average Top Lateral Displacement and Acceleration Reduction

A) Service Wind Loads				
Control Method	Displacement		Acceleration	
	vs UD	vs PMX	vs UD	vs PMX
PMn	2.4%		1.8%	
PMx	9.1%		8.4%	
ME	6.6%	-7.1%	5.7%	-1.2%
CO	10.3%	1.2%	9.3%	0.5%

B) High Intensity Wind Loads				
Control Method	Displacement		Acceleration	
	vs UD	vs PMX	vs UD	vs PMX
PMn	3.0%		5.4%	
PMx	17.2%		32.9%	
ME	17.2%	-0.1%	30.9%	-2.3%
CO	17.3%	0.2%	34.7%	1.1%

C) Seismic with Service Wind Loads				
Control Method	Displacement		Acceleration	
	vs UD	vs PMX	vs UD	vs PMX
PMn	6.1%		3.5%	
PMx	26.9%		22.3%	
ME	22.3%	-6.2%	22.1%	-0.2%
CO	27.3%	0.6%	22.8%	0.7%

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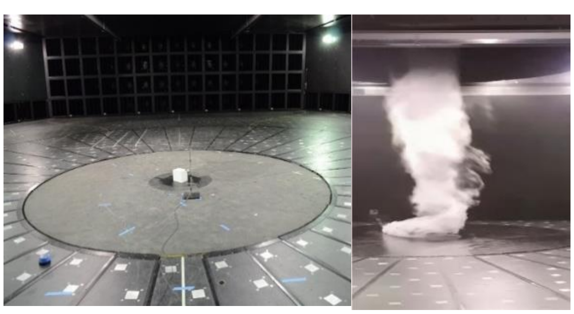
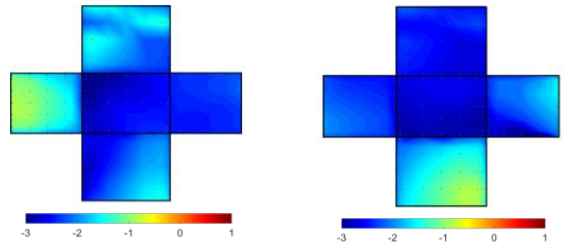
Structural performance of multi-story mass-timber buildings under tornado-like wind field

Tall mass-timber buildings utilize engineered wood panels to form their main gravity and lateral load resisting systems, which makes them lighter and more flexible than buildings made from concrete, masonry or even steel. In general, drift sensitive components of tall mass-timber buildings could be susceptible to damages due to increased deflection when subjected to extreme wind storms like violent tornadoes. This paper assessed the structural performance of a multi-story mass-timber building, which was designed using the customary 1-in 50 years design wind speed of the 2010 National Building Code of Canada with a load factor of 1.4, under experimentally simulated tornado-like wind fields. In the study, wind loads were obtained from laboratory simulations of tornado-like wind field and atmospheric boundary layer flow at Western University, Canada. Tornadic wind loads from the laboratory tests were scaled to five Enhanced Fujita wind speeds, representing various levels of damage. Dynamic structural analyses were carried out in time-domain to include the possible amplification due to the dynamic component of the excitation and assess floor level inter-story drift and shear force demands for various parameters. The varied parameters were tornado intensity level, the orientation of the building (aerodynamic direction), and critical damping ratio. Based on the obtained results, the vulnerability of drift sensitive components of the study building under tornado-like wind field was estimated. It is shown that strong tornadoes may pose significant damage to drift sensitive non-structural components of multi-story mass timber buildings. Finally, roadmaps to improve the design of mass-timber buildings in tornado-prone areas are forwarded.

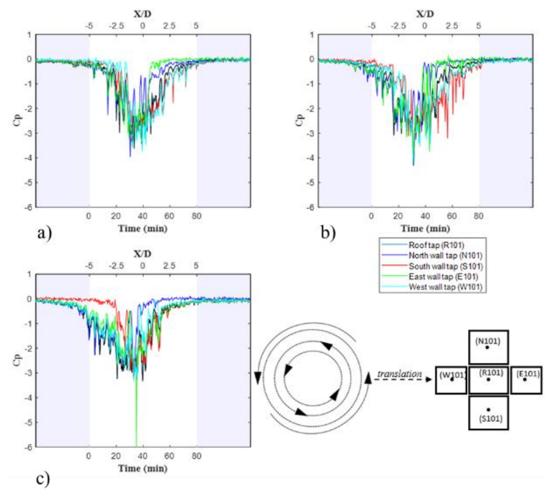


Test set-up at WindEEE Dome

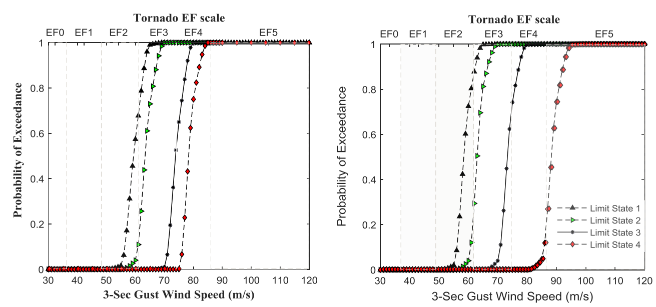


(a) (b)

Mean Cp distribution for core radius location for a) 0°; b) 90°



Variation of the measured C_p values with time and location of tornado with respect to the building model for various building orientation: (a) 0º; (b) 30º; (c) 90º



(a) (b)

Drift exceedance fragility curves for two types of tornado-like vortices: a) Stationary; b) Translating

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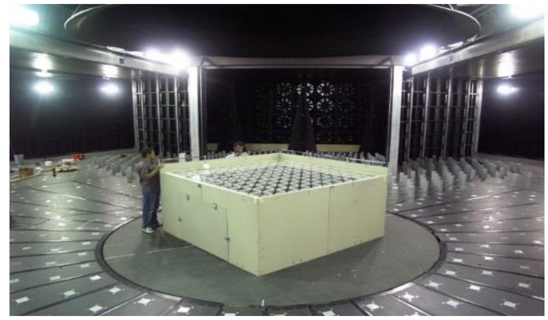
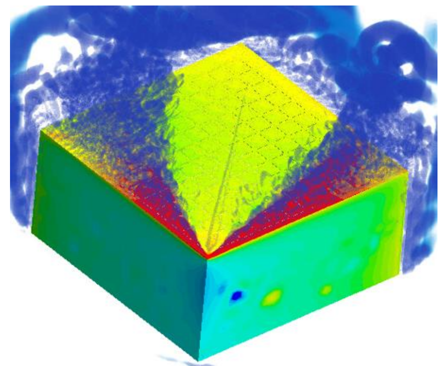
Pressure equalization of roof paver systems on buildings with complex roofs

Roof pavers are a popular choice to transform the roof of a building into a usable space. They are often used in cities with warm climates. However, these places are often more exposed to extreme wind events like hurricanes. This becomes a problem because roof pavers are not attached to the roof and are only able to resist uplift and overturning by their own self-weight and pressure equalization. It is therefore critical to understand how exterior and cavity wind loads change with different roof conditions.

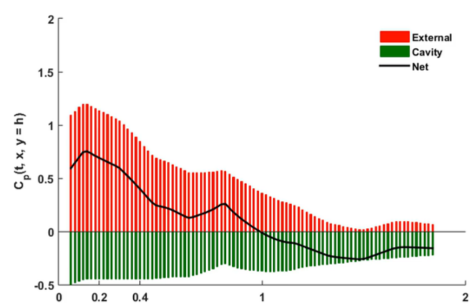
Currently at WindEEE, the state of the art roof paver testing was conducted on the square, flat-roofed model shown. These tests were performed at a 1:3 scale, something made possible by WindEEE's unique size and layout. From there, computational fluid dynamics (CFD) simulations were created representing that same model at the same scale. The CFD results were validated by the experimental tests performed at WindEEE. The results from the CFD simulations are valuable because they provide greater pressure data resolution and can be used for parametric studies and to visualize the flow field around the pavers better than is possible experimentally.

This report presents some preliminary results of those CFD simulations as well as the vision for future pressure equalization tests. The authors are currently working to investigate how changing the plan aspect ratio of a building affects the loading and pressure equalization capacity of the roof pavers. Past studies have been performed on square (1:1 aspect ratio) buildings and the authors are currently working to study 1:1.5, 1:2, and 1:4 aspect ratio buildings. The study also investigates how the existence of a blockage on the roof affects the wind loading of the roof paver system. The obstructions have been classified as either small (like an HVAC system) or large (like a podium-style high rise building). CFD simulations are being conducted and validation of those will be done at WindEEE and the BLWTL.


Experimental model tested at WindEEE


CFD Simulation of model under cornering wind


Streamlines of air flow in CFD model



Sample Instantaneous centerline pressure measurement

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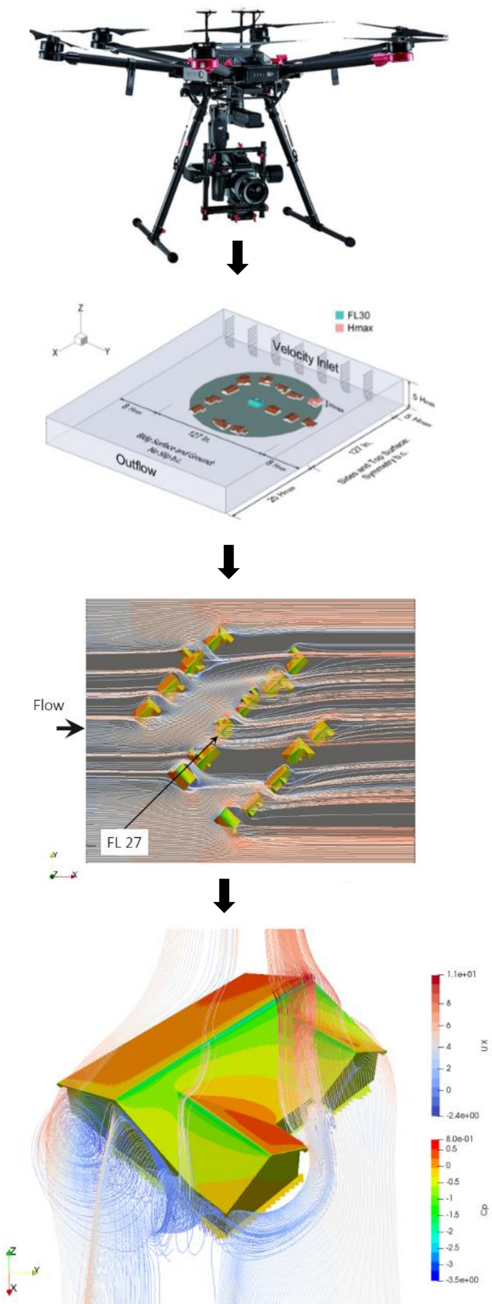
Drone enabled computational fluid dynamics for urban area modeling



Embracing sustainability and maintaining resiliency of Canada's built environment against natural hazards is necessary to sustain the wellbeing and prosperity of our communities. Sustainable building design in Canada, the second largest country in the world with diverse geography characterized by climate extremes, mostly revolves around energy efficiency and resiliency (i.e. ability to withstand the climate loads and re-bounce quickly after climate induced interruptions). Accurate site and building specific information are required to assess climate loads such as wind, for example, during structural or natural ventilation design or for building energy simulation.

The main objective of this project is to develop an automated site-specific 3D urban modeling useful for urban climate studies. For this purpose, various remote sensors installed on Unmanned Aerial Vehicle (UAV) will be used to collect topology and surface data. Accurate urban climate modeling and their automation through UAV mounted remote sensing is expected to transform the state-of-the-art in sustainable and resilient building design.

This research will depict wind flow, which results due to high-rise buildings using a computational fluid dynamics (CFD) Reynolds Averaged Navier Stokes (RANS) and Large Eddy Simulation (LES) approach that shows a simulation on OPENFOAM while buildings of various height will be considered in an urban setting.

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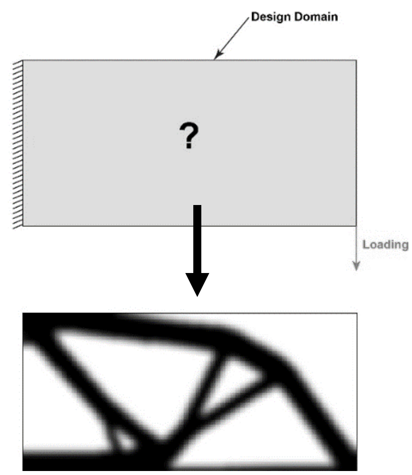
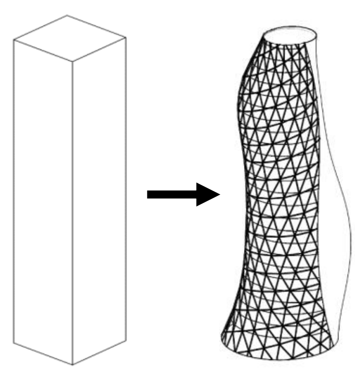
Aero-Structural Optimization of Tall Buildings

Recent trends in city development have shown a dramatic increase in the construction of tall buildings. Buildable space within cities is becoming limited, forcing designers to expand upwards by creating taller and more slender buildings. These buildings are more susceptible to wind-induced forces, and the design for wind performance commonly govern the structural systems. Designers have been pushing the limit of the current design practices and structural systems in order to create taller buildings. A key limitation within the current design process of tall buildings is the separation of disciplines. The exterior shape, i.e. the architecture, and structural system are designed separately from each other while the dynamic response of the structure is affected by both. Tall building design problems are multidisciplinary. A design framework, which combines the exterior form and the internal structural system and optimizes them as a single unit is needed to address the limitations within the current design practice. Topology optimization has been used to improve structural systems and exterior forms within aerospace engineering. Topology optimization determines the optimal material distribution to resist the applied loads while using less material. This method is adopted to produce structural systems for tall buildings in order to improve stiffness while remaining lightweight. The framework optimizes both the structural system and the exterior form while conforming to the architectural and structural engineering constraints. The multidisciplinary aspect of the optimization process is managed within the BIM environment. BIM allows data from different designers (architects and engineers) to be collected in a single model and then be accessed by everyone. The optimization objective(s) and constraints from each designer can be indicated within the model, using the parties' respective terminology. The 3D model, along with the micro-climate and structural parameters required will be exported to both the simulation methods. The wind loads, and the aerodynamic responses will be determined using CFD. The structural system of the tall building will be represented using FEM. Through the optimization process, any alterations made to the exterior form or the structural system will update the BIM model. Connecting the CFD and FEM simulations to the BIM model ensures that the exterior form and structural system are coupled, creating the aero-structural dynamic optimization framework. The proposed framework will outline the importance of multidisciplinary aero-structural optimization while designing tall buildings. Rather than optimizing separate components (exterior geometry and structural system) of the building, the different components will be optimized as a single unit enhancing the performance at a system level. Designers will be able to use the framework to create safer, cost-effective tall buildings, which reach greater heights while using less material.



Simple Cantilever Topology Optimization Example



Conceptual Aero-Structural Optimization for Tall Buildings

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Scalability and efficiency of ABL flow CFD simulation on HPC: Case of OpenFOAM on Graham and Niagara clusters

The accuracy of any wind simulation, whether it is experimental or computational, is measured by the level of its statistical resemblance of the simulated wind field to full-scale case. To do this in CFD simulation of ABL flows, it requires running transient simulations (LES) for long enough that the higher order statistics such as spectra and Reynold's stresses have reached steady-state (or stationery). This causes the need for relatively long simulated time. Short simulation result in lack of lower frequency part of the wind spectra as shown by label A in Fig 1. Longer time could be achieved easily with larger time steps. However, that affects the higher frequency part of the spectra as shown in label B of the same figure. This gets worse when there is bluff-body in the flow.

Due to this high computational need, HPC is a very good option to run simulations over large number of processors in parallel. OpenFOAM, which is an open source CFD tool, is one of widely used tools for large problems. Compute Canada provides several HPC resources for research purposes. To optimize the selection of platform, performing speedup and efficiency tests of the tools tailored to the specific problem is important.

The scalability and performance tests were done using ABL simulation of WERFL (Texas Tach University) building at different mesh densities (Small: 4m, Medium: 18m and Large: 250m) on Graham and Niagara clusters. The computational domain was prepared in accordance with the COST recommendations. For the current stage of the test, RANS simulation was used for comparison. Since the time required per iteration was used, it can be scaled to LES using simple ratio of time per iteration for each.

The results shown in Fig. 2 indicate that large problem sizes are highly scalable and efficient with larger number of processors. Moreover, Graham is more suitable for our problem type. In both systems, the biggest loss is in the serial simulation cases.

Two major conclusions from the results are: (i) OpenFOAM has bad scaling for few processor numbers. (ii) Graham is relatively better in speedup and efficiency as compared to Niagara.

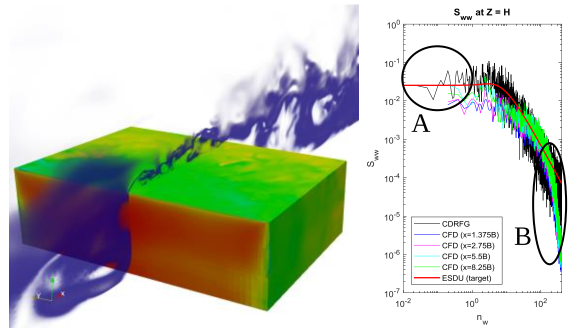
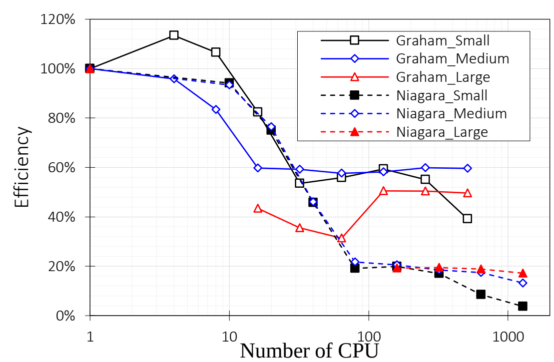
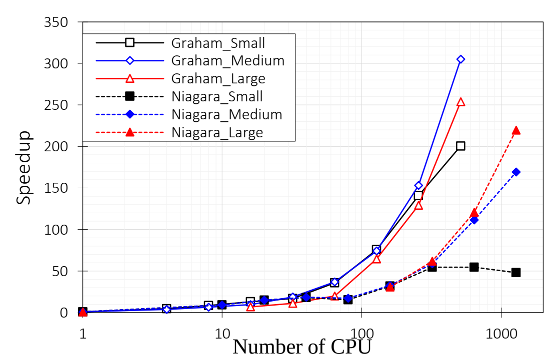


Fig. 1: Sample turbulent flow over a section and vertical spectra with insufficient computational parameters



(a)



(b)

Fig. 2: Efficiency (a) and speedup (b) of OpenFOAM on Graham and Niagara HPC clusters of Compute Canada

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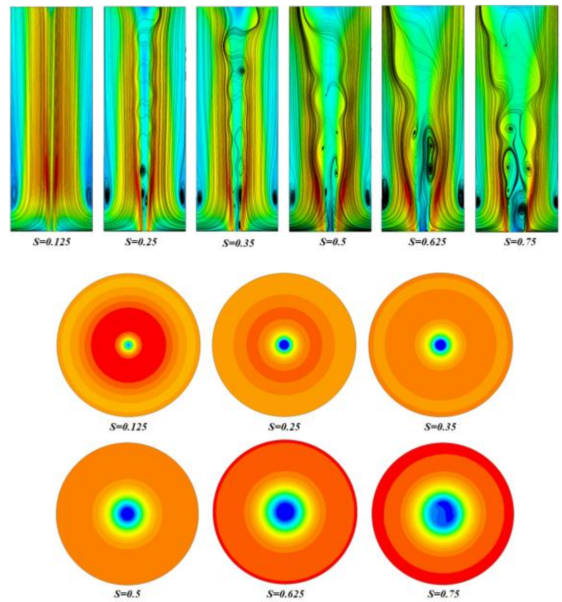
Numerical simulation of tornado-like vortices for wind load evaluation: towards neighbourhood scale assessment

US has been ranked number one in terms of average annual tornado occurrences with over 1200 every year between 1991 and 2010. Canada, on the other hand, with an average of 100 tornadoes every year is a distant second on that list [1]. One of the biggest challenges in studying tornadoes is lack of field measurements because of the local, unpredictable and violent nature of tornadoes.

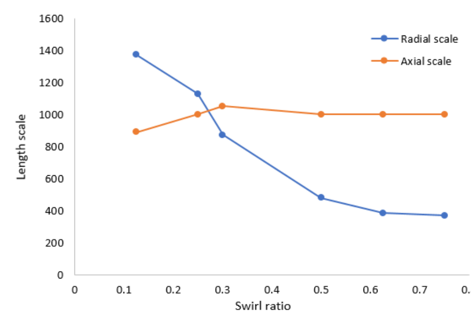
Numerical and experimental simulation of tornadoes have proven to be viable alternatives to study tornadoes due to shortage of field measurements. For engineering applications, forced convection driven (as opposed to thermodynamically driven) simplified numerical models are utilized to simulate "tornado-like" vortices for studying their impact on built environment and interaction with ground. These simulated "tornado-like" vortices can mimic the effects of real tornadoes depending on how accurately the geometric, kinematic and dynamic scaling criteria are satisfied. Past studies have shown the insignificance of dynamic scaling for highly turbulent flows, therefore the current state-of-the art in scaling simulated vortices requires matching two length scales (radial and axial) with respect to a target full-scale event.

This report presents some preliminary results of a study in which vortices with different swirl ratios are simulated using computational fluid dynamics (CFD). The simulated vortices are then scaled to different full-scale events based on matching radial and axial length scales obtained using the location (radial and axial) of the overall maximum tangential velocity. Further, as a validation of the numerical methodology, the pressure distribution on a building surface obtained using CFD is also compared with experiments conducted at WindEEE. The authors are currently extending this work for developing a framework for replicating tornadoes at neighbourhood-scale based on consistent characterization and scaling of vortices simulated using CFD. The framework would also be validated by a series of experiments to be conducted at WindEEE Dome.

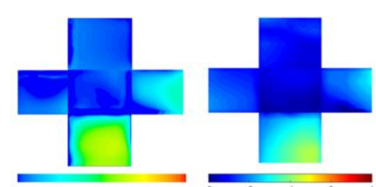
[1] *U.S. Tornado Climatology* Retrieved from: https://www.ncdc.noaa.gov/climate-information/extreme events/us-tornado-climatology



Flow-structure evolution with swirl ratio



Scaling of simulated vortex



Numerical Experimental

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Convective heat transfer coefficients for buildings in an urban like setting

The external convective heat transfer coefficient (CHTC) is known to be one source of significant uncertainty in building energy consumption evaluations. Several researchers report high uncertainty in the local microclimate, which is further impacted by the presence of neighboring buildings. Investigation concerning the impact of built density (aggregation or rarefaction) on convective heat transfer from buildings in an urban like setting is the focus of the present study. CFD based investigation of several array of cubical buildings with different packing density (12 cases), in different flow regimes (3 cases from isolated flow, 5 from wake interference flow, and 4 from skimming flow regimes); and set of simulations on one case of isolated cube is carried out. The study aims to investigate the influence of urban packing density on the external CHTC for buildings. A second moment turbulence closure scheme, Reynolds stress turbulence model, is applied to solve the equations of flow. The inlet properties are obtained from Engineering Standard Data Unit. The simulation procedure and tools were validated through previous experimental as well as CFD work. The results indicate behavior of CHTC vary from regime to regime. The general trends in the isolated flow regime is sharp change with changes in density; whereas in the interference and skimming flow regimes the CHTC gently decreases with increase of canopy density. Finally, Correlation for estimating CHTC in these three regimes is proposed. The findings of this study are considered to contribute in the bridging of what is generally known as the 'performance gap' in the building energy performance sector.

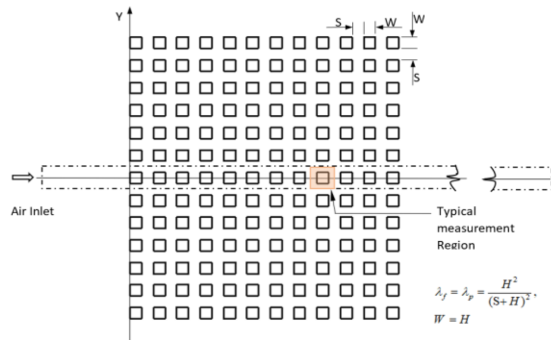

Figure 2. The building array with the study section (broken line) and important dimensions indicated - plan view

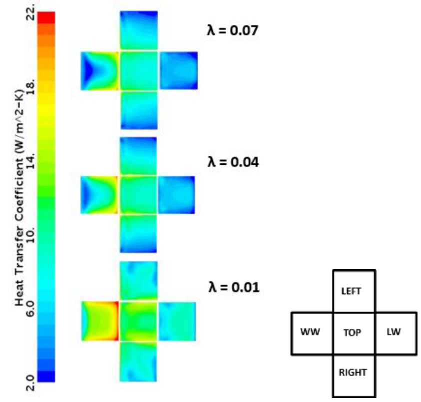

Figure 1. CHTC at different canopy densities (λ is density)

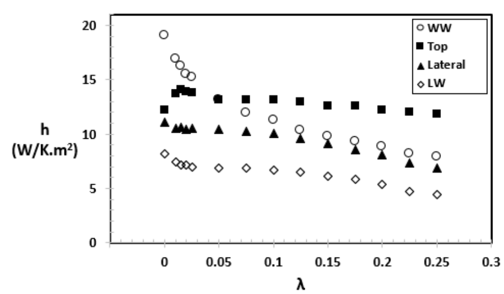

Figure 3. CHTC versus canopy density for each building surface

Surface	Isolated flow regime	Interference cum skimming flow regime
Windward	$h = 5.87 u_{10}^{m}(192.4\ \lambda^2 - 12.88\lambda + 1)$	$h = 5.87 u_{10}^{m}(0.73 - 1.33\lambda)$
Top	$h = 3.72 u_{10}^{m}(-488\ \lambda^2 + 17.11\lambda + 1)$	$h = 3.72 u_{10}^{m}(1.12 - 0.6\lambda)$
Lateral	$h = 3.32 u_{10}^{m}(164.3\ \lambda^2 - 5.92\lambda + 1)$	$h = 3.32 u_{10}^{m}(1.06 - 1.68\lambda)$
Leeward	$h = 2.51 u_{10}^{m}(224.8\ \lambda^2 - 11.33\lambda + 1)$	$h = 2.51 u_{10}^{m}(0.97 - 1.6\lambda)$

Figure 4. Correlations proposed to estimate CHTC

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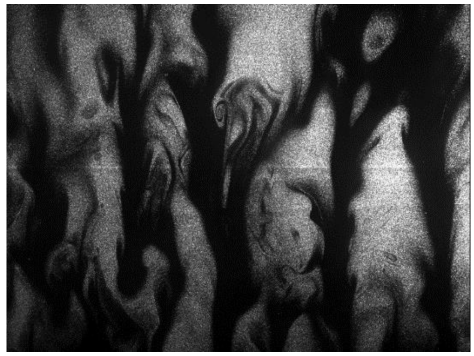
The Influence of Wall Heating on Three-Dimensional Turbulent Boundary Layer Flow Dynamics

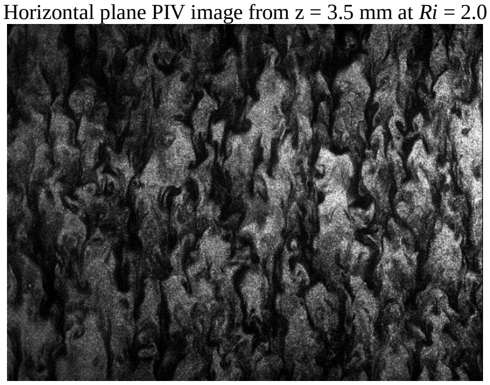
In many engineering and environmental applications, the boundary layer encountered is turbulent and involves heat transfer. The atmospheric boundary layer is one such application in the field of wind engineering. In this flow, heat transfer from the Earth's surface into the atmosphere drives the buoyant force to interact with flow inertia and the viscous shear force. It is of interest to wind engineering field to study the interaction of these forces as it greatly influences the transportation of heat, momentum (e.g. dynamic wind loading on structures) and species (e.g greenhouse gases and particulate matter) through the boundary layer. The objective of this research is to improve the fundamental understanding of the heated turbulent boundary layer flow dynamics utilizing multi-plane PIV.

Experiments are performed in a closed loop low-disturbance wind tunnel. The test section is 46 cm by 46 cm in cross section and 114 cm long with walls made of clear acrylic for visualization. The smooth horizontal bottom wall is heated between 45 °C and 90 °C while the free stream velocity was varied between ≈ 1.0 m/s and ≈ 7.5 m/s to study the flow behavior over a range of Richardson numbers (*Ri*) varying from 2.0 to 0.01. The multi-plane PIV technique was used to capture two-dimensional velocity fields in vertical (x-z), cross (y-z) and horizontal (x-y) planes.

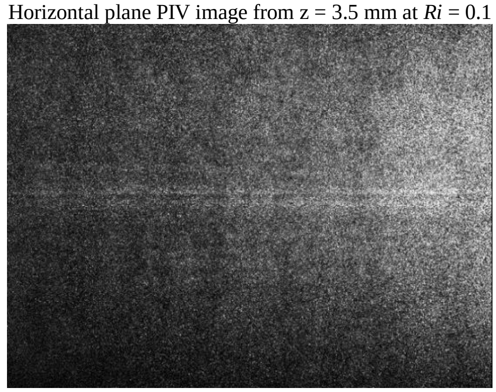
Results show that the change in Richardson number has a significant influence on the turbulent flow behavior in all three planes. This is illustrated through some sample results below. At *Ri* ≈ 2.0, prominent thermals indicated by large dark regions in PIV images were observed over all measurement planes. In both vertical and cross plane images, thermals were found to detach and rise from the bottom wall. In the horizontal plane at z = 3.5 mm, long stream-wise oriented bands associated with thermals were visualized. Decreasing *Ri* to ≈ 0.1 at z = 3.5 mm in the horizontal plane showed the geometry of the stream-wise thermal bands became significantly more complex, influenced by the higher intensity of turbulent motion. At *Ri* ≈ 0.01 horizontal plane PIV images depicted very faint thermal regions suggesting turbulent mixing is transporting surrounding fluid into the thermal. Current work is focused on a thorough investigation of the turbulent dynamics present in these experiments and comparing findings to tests without heat transfer.



Horizontal plane PIV image from z = 3.5 mm at *Ri* = 2.0



Horizontal plane PIV image from z = 3.5 mm at *Ri* = 0.1



Horizontal plane PIV image from z = 3.5 mm at *Ri* = 0.01

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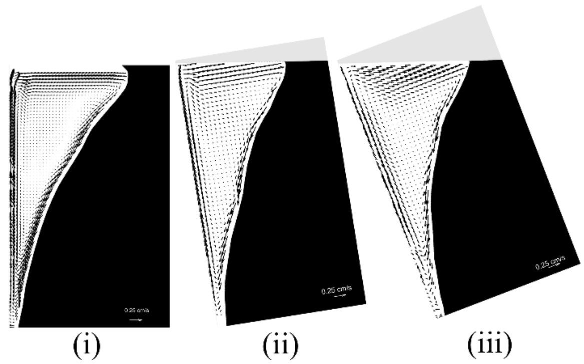
Investigation of the Flow Behavior in PCM-based Energy Storage Systems using Particle Image Velocimetry

Renewable energy technologies are attractive alternatives to fossil fuels to meet the growing global energy demand. However, the existing renewable technologies do not yet have the efficiency to compete with fossil fuels. Latent heat thermal energy storage (LHTES) is a potential option to increase the efficiency of renewable energy technology by storing excess heat during off-peak, and utilizing it during times of on-peak demand. LHTES systems using phase-change materials exploit the enthalpy of phase change, increasing the energy capacity over systems utilizing sensible heat storage alone. A major obstacle to the widespread adoption of PCM-based LHTES is the high resistance to heat transfer, an inherent material property. A thorough understanding of the nature of heat transfer is necessary to design efficient TES systems utilizing PCMs, however, the buoyancy driven convective flows in the melted regions of the PCM are not well understood at this time. A better understanding of the heat transfer to PCMs will allow more efficient designs of the associated TES systems.

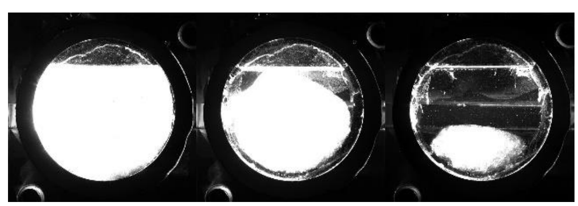
The present studies are focused on characterizing the flow in the liquid PCM domain during the melting process. Particle image velocimetry (PIV) was used to obtain two-dimensional velocity fields within the liquid domain of the enclosed PCM.

The study conducted by Jevnikar reports on the characterization of both transient flow and transient thermal behavior of phase change material (PCM) during solid-liquid phase change (melting) through experimental investigation. Two specific aspects of the current work, both important in the field of LHTES, are to investigate the influence of the flow behavior within liquid PCM on the melting and heat transfer processes, and the impact of heat source orientation on the underlying melting and heat transfer processes. The results show that the fluid velocity is critical for both the heat transport within the liquid domain and the overall melting pattern and rate.



Flow velocity field in the liquid PCM domain at 120 minutes of melting at three enclosure tilt-angles: (i) 0-degrees, (ii) 8-degrees and (iii) 18-degrees. The black region corresponds to the solid PCM domain and white region to liquid PCM.

An attractive method to transfer heat to a PCM is by using a PCM and metal foam composite. The study conducted by Teather involves a pore-scale analysis of the heat transfer to the PCM embedded in the foam. Preliminary results of this study show heat transfer is initially conduction dominated until a thin layer of melted PCM forms near the boundaries. At this point, two vortices driven by buoyancy form at the sides of the pore. This convective region of heat transfer accelerates the melting local to the vortices. As the melting proceeds and the unmelted PCM continues to sink to the bottom, a large region of melted PCM forms above. At this time, the flow becomes mostly stagnant, and the melting slows as it is dominated by conduction until completely melted.



Development of the melt front in a circular enclosure heated from the walls, 5 degrees above melting. The white region is unmelted PCM. (Left – 30 minutes, centre – 135 minutes, right – 225 minutes)

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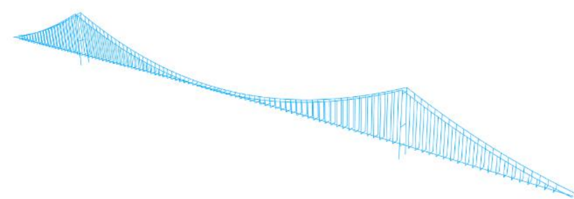
Effect of Structural Nonlinearities on Flutter of Super-Long-Span Bridges

Flutter, an aeroelastic instability, is a determining factor for the design of suspension and cable-stayed bridges. This is even more critical for super-long-span bridges such as the Messina Strait Bridge with an overall span of 3.3 km. The assessment of flutter is currently based on a linear structure due to the ease of usage of frequency-domain analysis. However, such bridges could exhibit structural nonlinearities at high wind speeds, especially geometric nonlinearities. As demonstrated by mathematicians, nonlinear geometric effects in cable-supported bridges could lead to nonlinear structural dynamic phenomena that are not considered in the design of long-span bridges. These phenomena could interact with the aeroelastic forces that are responsible of flutter, hence they could influence flutter stability. Therefore, this project aims at evaluating the effect of structural nonlinearities on the dynamic and flutter stability of super-long-span bridges.

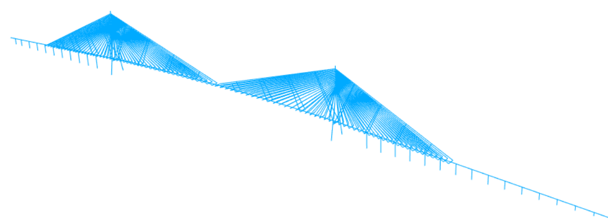
Numerical and experimental approaches are considered for evaluating the susceptibility of long-span bridges to nonlinear dynamic instability phenomena. So far, finite element models have been developed for existing single-box girder bridges, i.e., the Great Belt East Bridge, a suspension bridge, and the Normandy Bridge, a cable-stayed bridge. During an internship in the summer 2019 under the supervision of Prof. Fabio Brancaleoni, numerical models will also be developed for the Messina Strait Bridge and the Stonecutters Bridge, multi-box girder bridges.

Using these models, a simplified and practical approach has been developed in order to provide initial information on nonlinear structural dynamic phenomena. Afterwards, nonlinear time-domain analysis will be utilized for validating the simplified analyses and confirming the susceptibility of these bridges to nonlinear dynamic phenomena. Then, nonlinear time-domain flutter analysis will be used to assess numerically the effect of structural nonlinearities on flutter stability. These analyses will be validated experimentally using nonlinear section model tests.

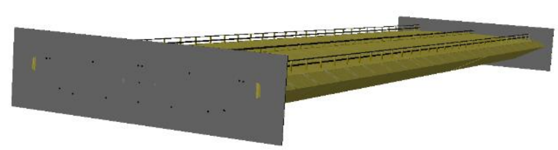
This project would provide analysis techniques to bridge engineers for assessing nonlinear dynamic phenomena and their interaction with aeroelastic effects in long-span bridges. This will allow safer bridge designs with respect to flutter, especially in the case of super-long-span bridges.



Finite element model of the Great Belt East Bridge



Finite element model of the Normandy Bridge



3D rendering of a section model for the Great Belt East Bridge

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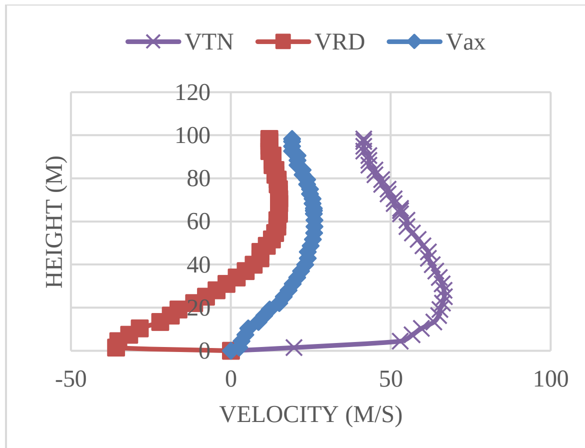
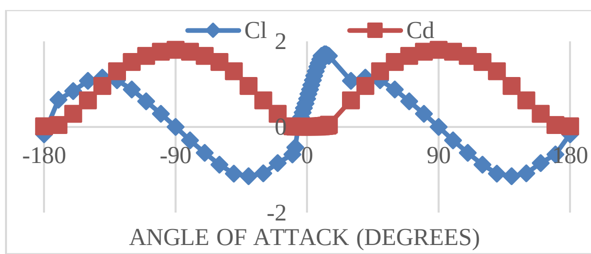
Effect of Tornado Wind Loads on Horizontal AxisThree-Blade Wind Turbine Towers

Wind turbine towers are designed to resist synoptic wind loads as per the recommendations in the current codes and guidelines, which do not consider high intensity wind events in the form of tornadoes during design. High intensity winds such as tornado wind fields have a localized nature that makes spotting the critical locations and parameters that lead to peak forces on the wind turbine tower and blades, a challenging task. As a result, a built in-house numerical model is developed to simulate a three-blade horizontal axis wind turbine tower exposed to three-dimensional tornado wind fields. Extensive parametric studies are conducted using the presented numerical model to determine the critical tornado configuration that leads to peak moment acting on wind tower and on each of the three blades (root moments). A comparison to the extreme wind load case scenario stated in the current codes and guidelines is been conducted as well.

The main purpose of the current stage of the study is to investigate the response of the wind turbine tower and the three blades under tornado wind loads to determine the most critical configuration for the F2 tornado wind field that results in the maximum bending moment at the tower's base and at the blades' roots. Moreover, the configuration that results in the least response is tracked as well for each pitch angel. Therefore, a parametric study consists of 1176 load cases has been conducted representing an F2 tornado moving in space around the wind turbine tower with varying radial distances R, radial angles θ and the pitch angles β of the blades as well. The range of the radial distance R was chosen from 12 m to 288 m with an increment of 12m while θ was chosen from 0 to 90°. Another analysis for the wind turbine tower under the extreme wind conditions (inflow wind speed 50 m/s) which is mentioned in the available guidelines [IEC2005] has been performed alongside with all the cases recommended by IEC. Thereafter, the values from the parametric study have been compared to the extreme case to give an insight of the effect of the tornado wind field on the wind turbine in comparison with the extreme normal wind load scenario. Under extreme wind loads, its recommended by the guidelines for the configuration of the wind turbine blades to be in the feather state to reduce the wind load on the blades and the tower, however; in our research we included different pitch angles to the analyses to check the behavior of the wind turbine under that nonconventional wind load compared to normal wind fields. The investigated wind turbine has a circular hollow steel tower of 61.8 meters height with diameter of 4 meters, 25mm thickness at the base and 3 meters diameter with 10mm thickness at the top of the tower. The tower was divided into 22 segments with different diameters and thicknesses accordingly. Each blade that is 34 meters long was divided into 16 segments as well.



Components of tornado wind field velocities; the radial V_{RD}, the tangential V_{TN} and the vertical V_Z for R= 120 m & theta= 0



Airfoil data for the blade section

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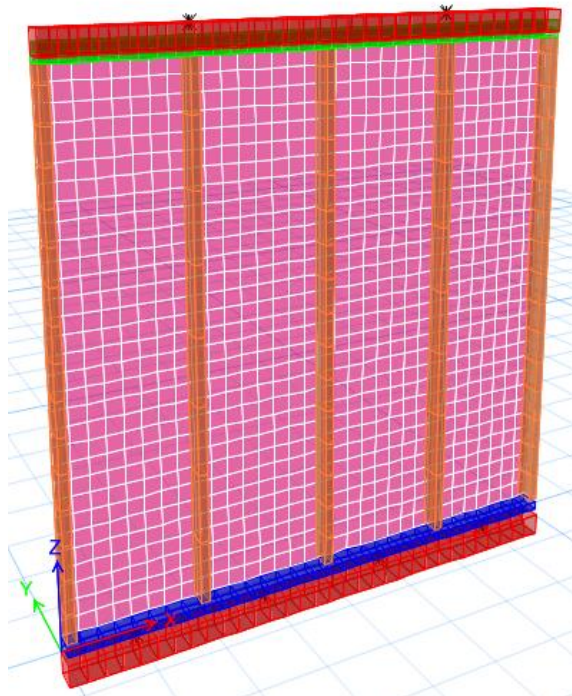
Lateral Performance of Light-Framed Wood Shearwalls subjected to Lateral Loads

The majority of residential and industrial housing in the Canada are made from the Light-Framed Wood Structures. The National Building Code of Canada (NBCC) limits using this structural system for buildings up to 18 m height or six storeys due to fire safety. Moreover, these structures has been designed based upon the element-by-element structural analysis and the nonlinearity in materials and nailed-base connections is ignored.

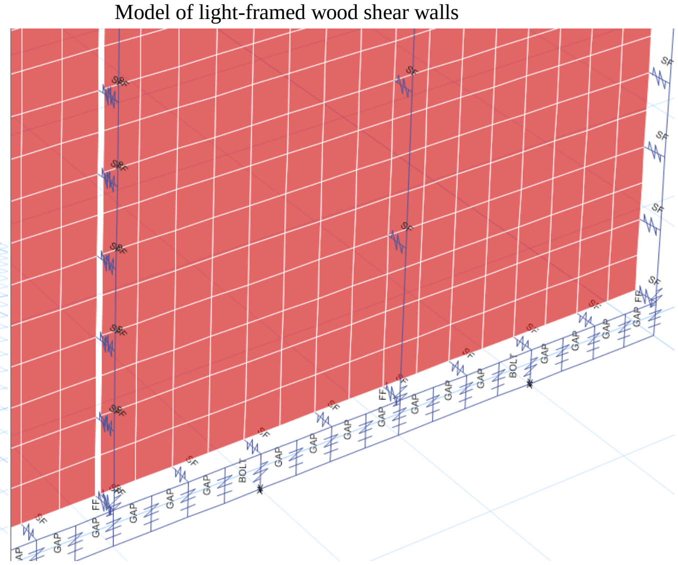
The main objective of the current study is to assess the nonlinear lateral performance of Light-Framed Wood Shear walls (LFWSs) subjected to the earthquake or wind loads. As the first stage of research, a detailed finite element model was developed to simulate the nonlinear behavior of LFWSs and verified with experimental data. Then, a comprehensive parametric study was conducted to determine the most sensitive parameters on lateral performance of LFWSs and address further experimental tests if needed to fully understand the nonlinear behavior of LFWSs.

In order to picturing the nonlinear behavior of LFWSs, the series of experimental tests including materials, nailed base connections, shear buckling capacity of shear wall segment and full scale multi-story wood shear wall will be performed subjected to lateral loads. Accordingly, the results will be used to develop an accurate numerical tool to simulate the nonlinear behavior of LFWSs.

The outcome of the research will provide extensive information regarding the overall behavior of LFWSs under wind and seismic loads that can be referenced by different design codes, not only in Canada but also worldwide.



Model of light-framed wood shear walls



Magnified base connections of the model

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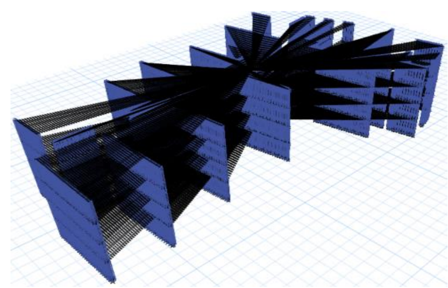
Behaviour of Multistory Wood Shear Wall Structures Under Wind Loads

The behavior of wood structures under wind load is calculated using static linear analysis as per NBCC 2015, which resulting in excessive use of materials because nonlinearity of the material is not used. The nonlinear static analysis (pushover analysis) is well applied in seismic ductile design, however it is rarely used in analysis of structures under wind loads, even though it is a good compromise between computational efficiency and accuracy. Earthquake is short-term action and it lasts few seconds, but the wind load might last a while depending on the wind load type. The rare use of pushover analysis for wind engineering is probably because the structure might fail from repetitive inelastic deformation under such long-term wind loads. However, for wood shear wall structures dominated by short-term wind loads (e.g. downburst and tornado), pushover analysis is still a good tool to study their behavior.

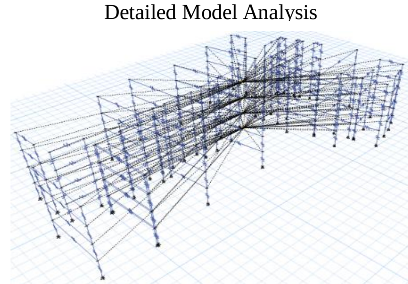
This research is based on a project which is now under construction in Oakville. It has a hybrid structural system with four timber structure floors over two concrete structure floors. A detailed FEA procedure was proposed and verified by Niazi *et al*. (2018) to model a 2D wood shear wall. This procedure was adopted to model the 3D Oakville project. Modal analysis and pushover analysis were completed. Field test was also conducted and the test found the natural frequency of the building is 3.4 Hz, while it is 0.5 Hz in analysis because currently the hold-down system is not added to the model. And the research only focuses on shear walls while the real structure has some other structural elements (e.g. columns, beams, and etc.).

One problem of the detailed FEA procedure is that it is too time-consuming because it accounts for all the structural details (e.g. stud, post, sheathing panels, nails, plates, and etc.). This makes it not practical in both academic research and industrial application. A simplified "Two-link Elements" method was proposed based on the pushover analysis result of detailed analysis, and it is capable to obtain exactly the same pushover analysis result for each 2D shear wall. For the global behavior of the 3D Oakville project, the simplified method over-estimates the stiffness in 10 % and strength in 20%. The benefit of the simplified analysis is remarkable, it takes only 10 seconds while the detailed analysis takes 20 hours.

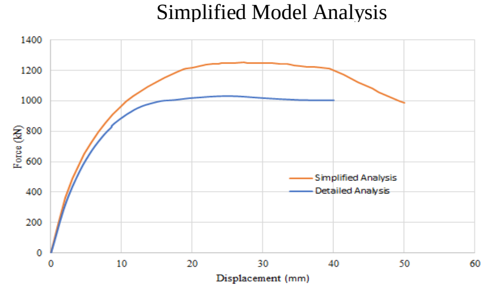
Further investigation will be undertaken to study what causes this difference. And a database which consists of simplified 2D models accounting for commonly used timber shear wall details will be established. This database allows people to select the simplified model and combine them to form a 3D model using any FEA software to obtain the global pushover result. And this result can be transformed to wind speed-displacement curve. Performance based design can also be conducted based on the same performance level drifts as recommended by ASCE 41-13.



Detailed Model Analysis



Simplified Model Analysis



Comparison of results in detailed and simplified analysis

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Progressive Failure of Transmission Lines due to Tornadoes

High Intensity Wind (HIW) events including tornadoes and downbursts cause 80% of the global weather-related failures of TL as reported by Dempsey and White (1996). The White House in Washington in 2013 estimated that more than 600 power outages occurred due to severe weather causing an annual average of economy loss ranging between $18 billion to $33 billion. Such failures have triggered extensive research programs worldwide to study the tornado phenomenon and its effects on structures especially transmission lines (TL), due to the severe economic losses accompanying TL failures. El-Damatty's research team at Western University has been leading the world for the last fifteen years in studying the response of TL to HIW events. The reputable efforts exerted by the research team resulted in developing a unique software to study the failures of TL towers due to HIW. The software was validated using the results of the experiments conducted at Wind Engineering Energy and Environmental (WindEEE) institute which is the only three-dimensional wind testing facility worldwide.

However, a probabilistic approach is required to consider the progressive failure of TL caused by tornadoes to quantify the probability of failure due to tornadoes so that a new optimum design methodology can be produced.

The research project utilizes the unique numerical software developed by Damatty's research team to study the progressive failure of transmission line towers due to tornadoes to investigate different failure modes of a single tower and how those failure modes reflect on the progressive failure of other towers within the transmission line.

It is worth mentioning that Damatty's research team has conducted an aero-elastic experimental program in WindEEE to assess the effect of tornadoes on TL in November 2018 and further experiments will be conducted in January 2019.

The results of that project will be invaluable in terms of mitigating losses, which include repairs and income losses, encountered by electrical utility companies due to TL failures caused by tornadoes. The results of the project will help the industrial companies to make informed decisions regarding the design of new TL as well as strengthening existing TL towers.

The ultimate goal of my research project is mitigating the failures of (TL) due to HIW events through providing a framework for renovating the existing infrastructure of TL which will save billions of dollars as a result of possessing a more sustainable system.

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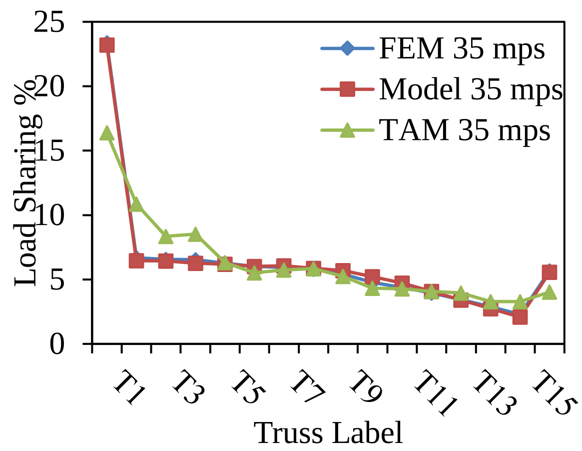
Closed-Form Solution for Light-Frame Structures under Uplift Wind Loads

Light-frame wood structures have the ability to carry gravity loads. However, their performance during severe wind storms has indicated weakness with respect to resisting uplift wind loads exerted on the roofs of residential houses. A common failure mode observed during hurricane events initiates at the roof-to-wall connections (RTWCs). The toe-nail connections typically used at these locations are weak with regard to resisting uplift loading. This research introduces the analysis of the toe-nail connections using a closed-form solution model for determining the distribution of the uplift wind loads on the supporting trusses. The new model simulates a whole gable roof truss as a rigid beam on an elastic foundation using statically indeterminate slope deflection equations that include shear deformation. This figure illustrates the percentages of the load sharing for all trusses at the time step associated with the ultimate pressure produced by the 35 m/sec wind speed. As depicted in this figure, the maximum load sharing difference of 0.43 % indicates a good match between the results obtained from the solution model and those produced using finite element method (FEM), which is considered the most reliable tool for modelling light-frame wood structures. In contrast, the tributary area method (TAM) analysis led to an underestimation for the end gable truss reactions, as showed in the figure.



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Progressive Failure of Transmission Lines under Downbursts

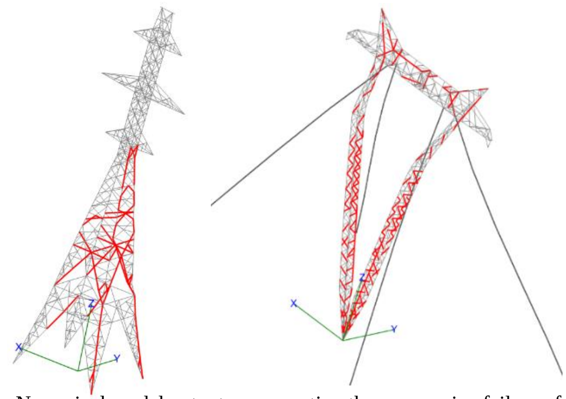
Electrical power networks are critical infrastructure elements necessary for the sustenance of power distribution in urban environments. A modern-day electrical network is comprised of several elements, of which, transmission towers are one of the primary modes of distribution.

Downbursts cause localized failure at an arbitrary segment of the transmission line which causes the collapse of the tower attached to the segment. When a suspension structure fails due to high wind, it imposes un-balanced loads on the adjacent two structures, thus creating longitudinal and transverse loads. These loads can far exceed the structure capacity and can trigger a failure event in the system. A large amount of energy is released and this released energy can cause catastrophic failures that can extend well beyond the location of the initial failure point. This kind of failure, which can exceed tens or even hundreds of structures from the initial failure location, is called a cascade failure. The damage of cascading failures can be catastrophic. There have been many cascading tower failures around the world. In Denmark, 167 towers collapsed in 1966. In January of 1975, 289 transmission line towers failed (cascaded) in Wisconsin, and in April of 1975, 69 structures cascaded in Indiana; in October of 1993, 17 cascaded in Arlington, Texas.

The above-mentioned cascaded failures of transmission towers presents a critical loading case often disregarded by the relevant codes and design engineers. Research have shown that a limited number of studies was devoted to provide an understanding on the failure of single and multiple transmission towers.

Considering the sparsity of information on this matter, and the critical nature of such structures, a novel numerical model that takes into account the nonlinearities of the system, is developed to simulate the cascaded failure of transmission lines.

The validation and corroboration of the model will be carried out through an extensive experimental program conducted at WindEEE, utilizing state-of-the-art in wind simulation and testing. Results from this work is believed to create a shift in the way transmission tower failures are perceived, and accounted for in the engineering of such structures.



Numerical model outputs representing the progressive failure of two different transmission towers.

Progressive failure of Transmission lines occurred in South Australia during Sept 2016 Thunderstorms.

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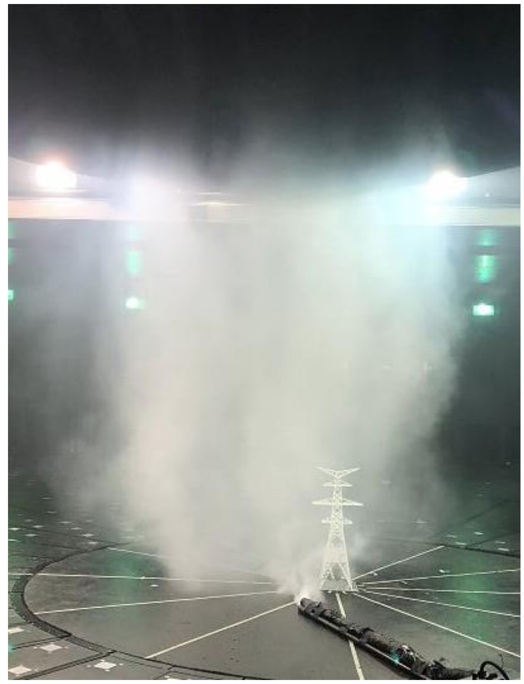
Behaviour of Transmission Line Structures under Tornado-Induced Wind Loads

Tornadoes, referring to swirling high-intensity winds, are a major threat to transmission line infrastructure worldwide. The United States and Canada are among the most active zones for tornadoes. Failures of transmission lines during tornadoes have been occurring more frequently, especially in Ontario, including incidents near Sarnia in 2003, 2006, and 2011, near Wawa in 2013, Woodstock 2016 and Ottawa 2018. Considering these facts, a comprehensive study has been triggered to mitigate such failures. The research includes numerical and experimental simulations of tornadoes and transmission line structures.

Using numerical simulations, structural response of multi-span self-supported and guyed transmission line systems under various mid-range tornadoes are investigated. Nonlinear three-dimensional finite element model is developed for both systems. Computational fluid dynamics (CFD) simulation is used to develop the matching tornado-like vortices. Using proper scaling approach for geometry and velocity, full-scale flow fields of various F2 tornadoes are simulated. The velocity fields are incorporated in the three-dimensional finite element models. Sensitivity analysis is conducted to assess the variation of the members' peak forces associated with the location of the tornado relative to the transmission line. The transmission tower members' peak internal forces due to various tornadoes are compared with corresponding values evaluated using the ASCE-74 manual of practice, which currently do not account for tornado-induced loads.

In addition to the mentioned parameters, there are several significant factors considering the tornado performance of transmission line systems and potential causes of past failures which are still unknown, namely dynamic effects, shielding effect on lattice transmission tower under non-synoptic tornado wind, fluid-structure interaction and experimental validation of the finite element model of transmission line structures. To address these currently unknown factors of transmission lines behaviour under tornado wind fields, an extensive set of integrative experimental examinations is conducted in WindEEE research institute.



Full aero-elastic transmission tower model under a simulated tornado conducted in WindEEE research institute

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Designing Efficient Transmission Line Systems through Studying their Failure

Failure of electricity transmission towers due to thunderstorms has been reported in every continent of the world. Thunderstorms produce a special type of wind event called downburst. It is a column of air that descends from the storm cloud, hits the ground, and then propagates radially with devastating wind speeds. Since transmission lines extend through huge horizontal distances, they are much more likely to be hit by a downburst compared to regular structures. This causes collapse of tower structures, and thus power outages that result in huge economic and social implications. A report by the White House states that similar failures cost between $18B to $33B over the course of 10 years.

Being a common incident across the world that intensifies with climate change, many researchers studied that topic for over a decade. Yet, it can be found that the literature has the following limitations:

Previous research was never fully applied due to its complexity. It requires knowledge of nonlinear dynamic analysis, which is not available in practice. Instead, practicing engineers depend on procedures offered by governmental design guidelines. The current design guidelines in the United States, also followed by Canada, lack any specific procedure for designing towers under downburst loading. The novelty of the current proposal lies in its ability to address the above limitations numerically, validate the results experimentally, and, most importantly, providing the outcome of this state-of-the-art research in an applicable format for practice.

Therefore, the current research aims to develop an experimentally validated numerical model to study the effect of downburst on transmission line systems beyond the trigger of failure. This will enable: 1) the characterization of the progression of failure on both local and global levels, 2) utilizing the obtained knowledge of local failure progression to propose design guidelines and 3) applying the knowledge of global failure to aid decision makers (utility companies) in their choice of tower strength distribution. This is the choice of where to add stronger towers along the line to contain failures within a size that can decrease the power outage time.

Dynamic nonlinear finite element analysis will be used to study the progression of failure through tower members. The model will be validated by a unique failure experiment at WindEEE, the world's leading thunderstorm experimental facility present at Western University. The aeroelastic experiment scale is unprecedented for downburst loading. This is why computational fluid dynamics is important to decide on the fan configuration that can produce a downburst with 1:25 scale. With the validated model, the tower members that are most significant for the stability of the tower will be highlighted.

To make sure these findings are accessible to practicing engineers, high performance computing will be utilized to run a comprehensive study that incorporates all the variables of downburst (size and location) and the design parameters of the line (tower and conductor sections and positions). The outcome of this study will be formatted to relate these parameters to design forces that practicing engineers can design for.

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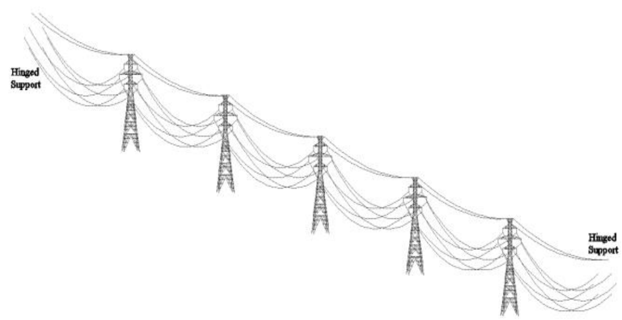
Angle and End Transmission Lines Towers behavior under Tornado Wind Load

Electrical energy plays a vital role in many aspects of daily life. United States and Canada are active zones for tornadoes with approximately 800 to 1,000 tornadoes per year. Tornado events are responsible for more than 80% of all weather-related transmission line failures worldwide. Despite this fact, the current codes of practice for transmission line structures do not account for wind loads resulting from tornadoes events. In these codes, the specified design wind loads are based on large scale storms with conventional boundary layer wind profile, which is different than the tornado profile. Thus, the behavior of angle and end lattice transmission towers will be assessed under tornado wind loads. The objective is to develop guidelines for designing transmission line structures to resist HIW events and to use these findings in codes of practice.



Schematic layout of the transmission line system model

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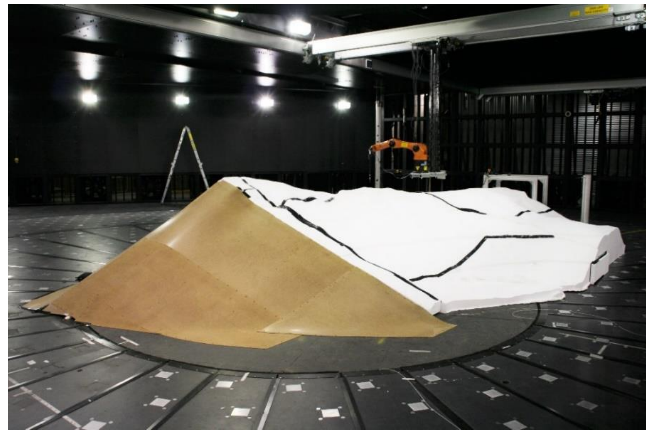
External and International Collaborations

Long Lake Hydroelectric Facility — Transmission Line Rebuild

The Long Lake Hydroelectric facility is located near Stewart, British Columbia, directly at the border with Alaska. The Cascade Creek water course is drawn from a partially glaciated watershed at the Long Lake dam via a gated intake and steel penstock. Power is produced in the powerhouse containing two horizontal axis, 2-jet Pelton machines. The electricity generated at about 240 m elevation is transmitted at 138 kV to the BC Hydro substation via a 3-conductor line on steel monopole-, H- and triple pole structures that crosses Mt. Welker at about 1,500 m above sea level. The Pacific Ocean is near at the Portland Canal which is situated mainly upwind into the prevailing Westerlies. The particular location of the line makes for very severe climatic conditions. For that reason Regional Power commissioned WindEEE to provide wind speed design input.

WindEEE approached the task with a combination of Computational Fluid Dynamics (CFD) modeling and experimental studies in the WindEEE dome. The CFD work was used to derive approach flow conditions for the experimental setup which consisted of a 1:1500 scale model subject to the appropriate inflow profile from various wind directions to determine the most severe flow conditions at the structure locations and at mid span. 50 year design wind speeds were estimated based on the experiments performed at the WindEEE Dome, Canadian Wind Energy Atlas and the available wind speed data from the nearby weather stations.

While some of the study work is directly applicable for design work, WindEEE is also embarking on the more generic task of comparing codified design approaches for transmission lines with the findings at Long Lake. In particular, the question of appropriate load combination factors taking into account both ice and wind loads on transmission lines is of interest and subject to ongoing research with the generous assistance of the Ontario Centre of Excellence (OCE), University of Western Ontario and Regional Power Inc.



The test model in the WindEEE Dome

Transport of Transmission Line Structure Components

Dressing of a Transmission Line Structure

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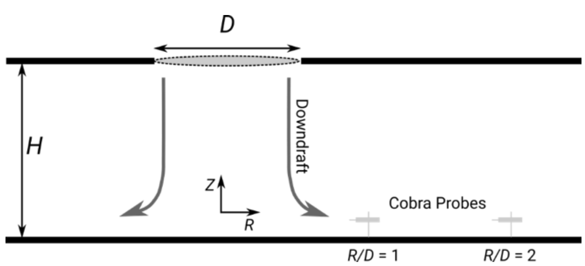
The THUNDERR Project — Wind tunnel experimentation on stationary downbursts

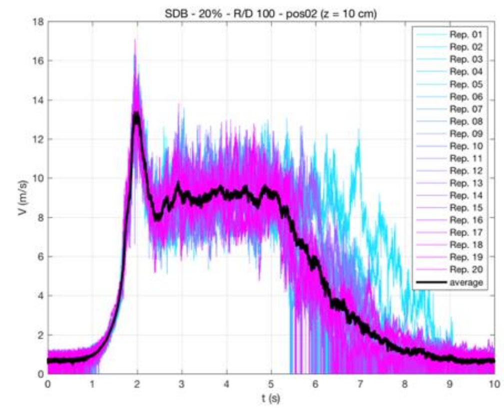
In the context of the European Project THUNDERR a scientific collaboration between the Wind Engineering and Structural Dynamics (Windyn) Research Group of the University of Genoa (Italy) and the Wind Engineering, Energy and Environment (WindEEE) Research Institute of Western University (Canada) has been established to study experimentally at the WindEEE Dome facility how the main geometrical and kinematic properties of downbursts are affected by different cloud base unsteady outflows of stationary thunderstorms.

In this study, experimental tests were carried out keeping fixed the position of the mouth bell, with an opening of 3.2 m, and using a jet velocity at the exit of the mouth of $\boldsymbol{V_{jet}} \approx \mathbf{9\ m\ s^{-1}}$, which is approximately 20% of the maximum rotation per minute (RPM) of the upper six fans. In order to simulate as close as possible the transient nature of real downbursts, the time of louvres to open and close was approximately 10 s. Each downburst experiment was repeated twenty times in order to build high statistical significance of the obtained results, as well as to account for the random nature of turbulent flow and its high dependency on initial conditions. Measurements were taken at 10 radial positions from $\boldsymbol{R/D = 1}$ to 2.



Experimental setup and measurement positions

For each position, the ensemble mean of the 20 repetitions were calculated, which was expected to represent the deterministic part of the signal. All ensemble means showed three main parts: (1) a sudden ramp-up followed by a rapid decrease of the wind speed, which determines the first maximum of the signal; (2) a plateau that can be more or less pronounced depending on the distance from the downburst centre; and (3) a tail during the downburst dissipation stage. In terms of turbulence, wind fluctuations increase suddenly at the beginning of the downburst ramp-up, then remain almost constant until the end of the plateau.



Time series of the wind speed measured at $\boldsymbol{R/D = 1}$. Black line is the ensemble mean of all repetitions

Moreover, fluctuations increase moving radially further from the downdraft centre whereas the mean wind speed decreases, leading to an increase of the turbulence intensity.

The downburst simulated so far were unsteady stationary phenomena without background flow. During a real downburst event, however, the flow field strongly interacts dynamically with the boundary layer and, eventually, it moves according to the translational velocity of its parent cloud. It is not clear whether the kinematic flow field resulting from the superposition of these three velocities will be just the summation of all the contributions or more probably the result of non-linear interactions at different time and spatial scales.

In the next future a set of new experiments will be performed at WindEEE Dome in order to study more complex, but also more realistic, meteorological conditions associated with real downbursts, such as the case of background flows superimposed to thunderstorm outflows and translating downbursts.

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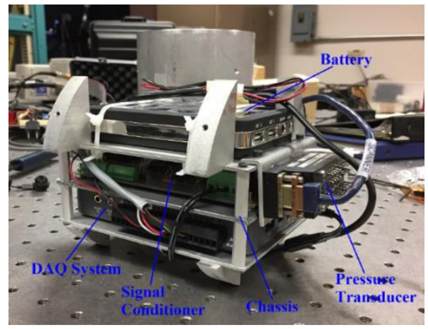
Scaled Wind Turbine Blades Designed to Produce Wakes Like that of an Industrial Scale Turbine

Wind turbine wakes cause 20-30% underperformance in modern wind plants. As a result, better wind plant layout could both improve performance and extend the lives of the blades due to reductions in unsteady loading. To achieve better wind plant layouts, better numerical models of wake evolution are needed. To develop such models, better understanding of wake development and evolution as well as validation data for the numerical models is needed. To address this, wakes from scaled wind turbines under controlled conditions are desired. Wind tunnels can provide controlled conditions, but are often too confined to allow proper development of the wind turbine wake. Another challenge is ensuring the essential physics of an industrial scale wind turbine are captured by the sub-scale turbine.

To address these challenges, a test of a scaled wind turbine in WindEEE using specially designed blades has been initiated. A 2-m diameter turbine was identified as a size that was large enough to produce realistic blade flows, but small enough to allow for wake evolution in WindEEE. WindEEE is an ideal test facility due to its large test section dimensions. The blades were designed using an inverse design methods to match the non-dimensional loading of the larger-scale turbine whose design it was based upon. Carbon fiber blades have been built based on this design.

To provide data suitable for both better understanding the wakes and providing data for validation of computational codes, both blade surface measurements and measurements in the wake of the turbine are desirable. Although wake measurements have been performed for turbines of this size, the current is the first known test where the wake and the blade pressures have been measured simultaneously. The blade pressure measurements required the development of a novel hub-mounted pressure measurement system.

Carbon fiber blades ready to install on the turbine. Note that only one of the three blades is instrumented.



Hub-mounted pressure acquisition system.

Wind turbine with blades installed in WindEEE

Smoke visualization of the wake

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Publications

1. Ashton R, Refan M, Hangan H, Iungo V. 2017 "Wandering corrections from PIV measurements of tornado-like vortices". Submitted to Wind & Structures.

2. Lemenand T, Della Valle D, Dupont P, Peerhossaini H. 2017. "Turbulent spectrum model for drop-breakup mechanisms in an inhomogeneous turbulent flow". Chemical Engineering Science 158: 41-49.

3. Lemenand T, Della Valle D, Habchi C, Peerhossaini H. 2017. "Micro-mixing measurement by chemical probe in homogeneous and isotropic turbulence". Chemical Engineering Journal 314: 453-465.

4. Dghim M, Momayez L, Ferchichi M, Peerhossaini H. 2017. "Development of Turbulent Wakes Evolving from Asymmetric Shear Layers". Heat Transfer Engineering 1-8.

5. Moussa T, Garnier B, Peerhossaini H. 2017. "Temperature measurement of flat glass edge during grinding and effect of wheel and workpiece speeds". Measurement Science and Technology 28(6): 065008.

6. Elawady A, Aboshosha H, El Damatty AA, Bitsuamlak G, Hangan H, Elatar A. 2017. "Aeroelastic Testing of Multi-Spanned Transmission Line Subjected to Downbursts". Journal of Wind Engineering and Industrial Aerodynamics 169: 194-216.

7. Elshaer A, Bitsuamlak G, El Damatty AA. 2017. "Enhancing Wind Performance of Tall Buildings Using Corner Aerodynamic Optimization". Engineering Structures 136: 133-148.

8. Ibrahim A, El Damatty AA, El Ansary A. 2017. "Finite Element Modelling of Pre-stressed Concrete Poles under Downbursts and Tornadoes". Engineering Structures 153: 370-382.

9. Musa A, El Damatty AA. 2017. "Design Procedure for Liquid Storage Steel Conical Tanks under Seismic Loading". Canadian Journal of Civil Engineering 44(9): 760-773.

10. Romanic D, Parvu D, Refan M, Hangan H. 2018. "Wind and tornado climatologies and wind resource modelling for a modern development situated in "Tornado Alley"". Renewable Energy 115: 97-112.

11. Junayed, C, Jubayer, C, Parvu, D, Romanic, D, Hangan, H. 2018. "Flow field dynamics of large-scale experimentally produced downburst flows". Submitted to Journal of Wind Engineering and Industrial Aerodynamics.

12. Hangan, H, Romanic, D, Jubayer, C. 2018. "Three-dimensional, non-stationary and non-Gaussian (3D-NS-NG) wind fields and their implications to wind-structure interaction problems". Accepted for publication in Journal of Fluids and Structures.

13. Jubayer C, Hangan H. 2018. "A hybrid approach for evaluating wind flow over a complex terrain". Journal of Wind Engineering and Industrial Aerodynamics 175: 65-76.

14. Romanic D, LoTufo J, Hangan H. 2018. “Transient behavior in impinging jets in crossflow with application to downburst flows”. Journal of Wind Engineering and Industrial Aerodynamics 184: 209-227.

15. Jubayer C, Romanic D, Hangan H. 2018. “Aerodynamic loading of a typical low rise building for an experimental stationary and non-Gaussian impinging jet”. Submitted to Wind & Structures.

16. Refan M, Hangan H. 2018. “Near Surface Exploration of Tornado Vortices”. Journal of Wind Engineering and Aerodynamics 175:120-135.

17. Vourc'h T, Peerhossaini H, Léopoldès J, Méjean A, Chauvat F, and Cassier-Chauvat C. 2018. “Slowdown of surface diffusion during early stages of bacterial colonization”. Physical Review E 97(3):032407.

18. Habchi C, Lemenand T, Della Valle D, Peerhossaini H. 2018. “Vorticity and convective heat transfer downstream of a vortex generator”. International Journal of Thermal Sciences 125: 342-349.

19. Habibi Z, Karami M, Jarrahi M, Shirani E, Peerhossaini H. 2018. “Some observations on the spatiotemporal orbits structure and heat transfer enhancement in pulsating flow”. International Journal of Thermal Sciences 125: 428-439.

20. Enajar FE, Jacklin RB, El Damatty AA. 2018. “Nonlinear Modeling of Roof to Wall Connections in a Gable-Roof Structure under Uplift Wind Loads”. Accepted in Wind and Structures.

21. Ibrahim I, El Damatty AA, Elawady A. 2018. “The Dynamic Effect of Downburst Wind Field Characteristics on the Longitudinal Forces on Transmission Towers”. Accepted in Frontiers in Built Environment.

22. Elawady A, Aboshosha H, El Damatty AA. 2018. “Aero-Elastic Response of Transmission Line System Subjected to Downburst Wind: Validation of Numerical Model Using Experimental Data”. Accepted in Wind and Structures.

23. Elansary AA, Nassef AO, El Damatty AA. 2018. “Optimum Design of Composite Conical Tanks under Hydrostatic Pressure”. Advances in Structural Engineering 21(13): 2030-2044.

24. Musa A, El Damatty AA. 2018. “Effect of Vessel Base Rotation on the Seismic Behavior of Conical Shaped Steel Liquid Storage Tanks”. Engineering Structures 166: 54-471.

25. Elawady A, El Damatty AA. 2018. “Critical Load Cases for Lattice Transmission Line Structures Subjected to Downbursts: Economic Implications for Design of Transmission Lines”. Engineering Structures 159: 213-226.

26. Elansary A, El Damatty AA. 2018. “Seismic Analysis of Liquid Storage Composite Conical Tanks”. Engineering Structures 159: 128-140.

27. Hamada A, King JPC, El Damatty AA, Bitsuamlak G, Hamada M. 2017. “The Response of a Guyed Transmission Line System to Boundary Layer Wind”. Engineering Structures 139: 135-152.

28. Bashar, M., Siddiqui, K. 2018. “Experimental investigationof transient melting and heat transfer behavior of nanoparticle-enriched PCM in a rectangular enclosure”. Journal of Energy Storage 18: 485-497.

29. Bezabeh MA, Gairola A, Bitsuamlak GT, Popovski M, and Tesfamariam S. 2018. "Structural performance of multi-story mass-timber buildings under tornado-like wind field”. Engineering Structures 177: 519-539.

30. Gairola A and Bitsuamlak, GT. 2018. "Numerical tornado modeling for common interpretation of Experimental simulators”. Journal of Wind Engineering and Industrial Aerodynamics 181: 85-103.

31. Kahsay, MT, Bitsuamlak GT, Tariku F. 2018. “Numerical analysis of convective heat transfer coefficient for building facades”. Journal of Building Physics 1-23.

32. Elshaer A and Bitsuamlak GT. 2018. "Multi-objective Aerodynamic Optimization of Tall Building Openings for Wind-Induced Load Reduction." Journal of Structural Engineering 144, 10, 04018198.

33. Nasir Z and Bitsuamlak GT. 2018. “Topographic effects on tornado-like vortex”. Wind and Structures, 27(2): 123-136.

34. Bezabeh MA, Bitsuamlak GT, Popovski M, Tesfamariam S. 2018. "Probabilistic serviceability-performance assessment of tall mass-timber buildings subjected to stochastic wind loads: Part I-structural design and wind tunnel testing". Journal of Wind Engineering and Industrial Aerodynamics 181: 85-103.

35. Bezabeh MA, Bitsuamlak GT, Popovski M, Tesfamariam S. 2018. "Probabilistic serviceability-performance assessment of tall mass-timber buildings subjected to stochastic wind loads: Part II-structural reliability analysis". Journal of Wind Engineering and Industrial Aerodynamics 181: 112-125.

Conferences

1. Jubayer C, Romanic D, Hangan H, "Aerodynamics of tornado-like vortices around a low-rise building". Engineering Mechanics Institute Conference, Boston, MA, USA, May/June 2017

2. Refan M, Hangan H, "Large scale experimental simulation and exploration of tornado-like vortices". Engineering Mechanics Institute Conference, Boston, MA, USA, May/June 2017

3. Hangan H, "Large scale physical simulations of 3D, non-stationary and non-Gaussian wind flows with applications to moving/deformable structures". Keynote Speaker, IUTAM Conference, Santorini, Greece, June 2018

4. Doddipatla L, Hangan H, Kopp G, Nong S, "Challenges in developing Tornadic Wind Loads for Large Industrial Buildings". MS25: Tornadoes and Tornado-Structure Interaction Considering Impacts on Community Resilience, Boston, MA, USA, June 2018

5. Ashrafi A, Romanic D, Chowdhury C, Hangan H, "Producing 1/100 and larger scale tornadoes in a wind simulator". Tornado Hazard Wind Assessment and Reduction Symposium (THWARTS), Il, USA, September 2018

6. Romanic D, Hangan H, "The interplay between background atmospheric boundary layer winds and downburst outflows. A first physical experiment". XV Conference of the Italian Association for Wind Engineering (IN-VENTO 2018), Napoli, Italy, September 2018

7. Burlando M, Romanic D, Hangan H, Solari G, "Wind tunnel experimentation on stationary downbursts at WindEEE". XV Conference of the Italian Association for Wind Engineering (IN-VENTO 2018), Napoli, Italy, September 2018

8. Junayed C, Jubayer C, Parvu D, Karami M, Hangan H, "Wind flow characteristics of a model downburst". Proceedings of the ASME 2018 5th Joint US-European Fluids Engineering, Montreal, QC, Canada, July 2018

9. Hangan, H, "Identifying and stimulating broader stakeholder involvement". International Conference on Research Infrastructure, Panel Member, Vienna, Austria, September, 2018

10. El Damatty AA, Ezami N, Hamada A, "Case Study for Behavior of Transmission Line Structures under Full-Scale Flow Field of Stockton, Kansas, 2005 Tornado". ASCE Electrical Transmission and Substation Structures, Atlanta, GA, USA, November, 2018.

11. El Damatty AA, Shehata A, Enajar A, Rosenkrantz J, El Ezaby FY, "Research for adaptive and sustainable structures". 8th International Conference on Environmental Effects on Buildings and People: Actions, Influences, Interactions, Discomfort, Keynote Lecture, Cracow, Poland, October, 2018

12. El Damatty AA and El Ezaby FY, "The integration of wind and structural engineering". The 2018 World Congress on Advances in Civil, Environmental, & Materials Research (ACEM18), Keynote Lecture, Songdo Convensia, Incheon, Korea, August, 2018

13. Niazi M, Hamada A, El Damatty AA, "Case Study of Seismic Load Reduction Factors on Equivalent Earthquake Loads for High-rise Buildings". The 6th International Structural Specialty, CSCE, Annual Conference, Fredericton, NB, Canada, June, 2018

14. Niazi M, El Damatty AA, Hamada A, "Sensitivity Study of Light-Framed Wood Shear Walls Subjected to Lateral Loads". The 6th International Structural Specialty, CSCE, Annual Conference, Fredericton, NB, Canada, June, 2018

15. Ibrahim I and El Damatty AA, "Validation of a Simplified Numerical Model to Compute the Dynamic Response of Conductor Systems to Downburst Loading". The 6th International Structural Specialty, CSCE, Annual Conference, Fredericton, NB, Canada, June, 2018

16. Jevnikar S and Siddiqui K, "The Influence of Heat Source Orientation on PCM Flow Behaviour during Phase Change". 5th Joint US-European Fluids Engineering Summer Conference, Montreal, QC, Canada, July, 2018

17. Toxopeus K and Siddiqui K, "Turbulent Flow Characteristics over Offset-Wall Confined Columns in a Channel at Low Reynolds Numbers". 5th Joint US-European Fluids Engineering Summer Conference, Montreal, QC, Canada, July, 2018

18. Dennis K and Siddiqui K, "Multi-Plane Characterization of the Turbulent Boundary Layer". 5th Joint US-European Fluids Engineering Summer Conference, Montreal, QC, Canada, July, 2018

19. Dennis K and Siddiqui K, "A Multi-Color Technique for Three-Dimensional Flow Characterization", Canadian Society for Mechanical Engineering Congress, Toronto, ON, Canada, May, 2018

20. Bitsuamlak G, "AI Applications in Climate-Resilient and Sustainable Architectural Engineering". AI for Government Summit, Toronto, ON, Canada, October 2018

Grants

Power Collective Inc. / $ 27,000 / 2017
Performance Testing of Ridgeblade Industrial (RB2) Wind Turbine
Horia Hangan

Canada Foundation for Innovation John R. Evans Leaders Fund and OCE / $ 500,000 / 2017
Printing adaptive aerodynamic and aeroelastic test models
Girma Bitsuamlak

SOSCIP R&D Challenge, NSERC CRD and OCE/ $ 235,000 / 2017
Printing adaptive aerodynamic and aeroelastic test models
Girma Bitsuamlak

Vineland Research and Innovations Centre / $ 21,000 / 2017
Energy Modeling of Greenhouses
Kamran Siddiqui

Applied Research Associates, Inc. / $ 152,000 USD / 2018
Development of Tornado Design Criteria for Buildings and Shelters Subject to Tornado Induced Loads
Horia Hangan

ImpactWx / $ 130,750 / 2018
Horia Hangan

Ontario Centres of Excellence (OCE) VIP1 and Centric Engineering / $ 25,000 / 2018
Assessment of Application Heavy Timber Construction for Low-Rise Buildings
Ashraf El Damatty

Natural Sciences and Engineering Research Council of Canada (NSERC) / $ 145,000 / 2018
Characterization and Development of PCM-based Thermal Energy Storage Systems
Kamran Siddiqui

Western University Start-Up / $ 300,000 / 2018
Hassan Peerhossaini

NSERC Discovery Accelerator / $ 360,000 / 2018
Novel Computational and Experimental Wind Engineering Approaches for Community Level Performance Assessment
Girma Bitsuamlak

Honors and Awards

2017

American Association of Wind Engineering-Industry Innovation Award
Horia Hangan

Short Course, Novel Physical Simulations, Universidad de la Republica Uruguay, Montevideo, Uruguay
Horia Hangan

Invited Keynote Speaker, International High-end Forum on Structure Engineering and Wind Engineering, Chongqing, China.
Ashraf El Damatty

Adjunct Professor, Cairo University, Egypt
Ashraf El Damatty

2018

Best Journal Paper Award, American Association for Wind Engineering
Horia Hangan

Invited Professor, Institute de Mécanique des Fluides, Toulouse, France
Horia Hangan

Short Course, Novel Techniques in Wind Engineering, University of Genova, Genova, Italy
Horia Hangan

Member, European Research Council International Advisory Board for Project THUNDERR
Horia Hangan

Invited Keynote Speaker, International Union of Theoretical and Applied Mechanics Symposium on Critical Flow Dynamics Involving Moving/Deformable Structures with Design Applications, Santorini, Greece
Horia Hangan

Keynote Panel Member, Inaugural Research Western Conference
Girma Bitsuamlak

NSERC Discovery Accelerator Award
Girma Bitsuamlak

Faculty Scholar, Western University
Girma Bitsuamlak

Associate Fellow, Ethiopian Academy of Science
Girma Bitsuamlak

Faculty Scholar, Western University
Girma Bitsuamlak

Ontario Professional Engineers Engineering Medal for Research and Development
Ashraf El Damatty

Invited Keynote Speaker, 8th International Conference on Environmental Effects on Buildings and People – Actions, Influences, Interactions, and Discomfort, Cracow, Poland
Ashraf El Damatty

Invited Keynote Speaker, 15th International Conference on Structural and Geotechnical Engineering, Ain Shams University, Egypt
Ashraf El Damatty

Invited Keynote Speaker, 14th Arab Structural Engineering Conference, Irbid, Jordan
Ashraf El Damatty

Events

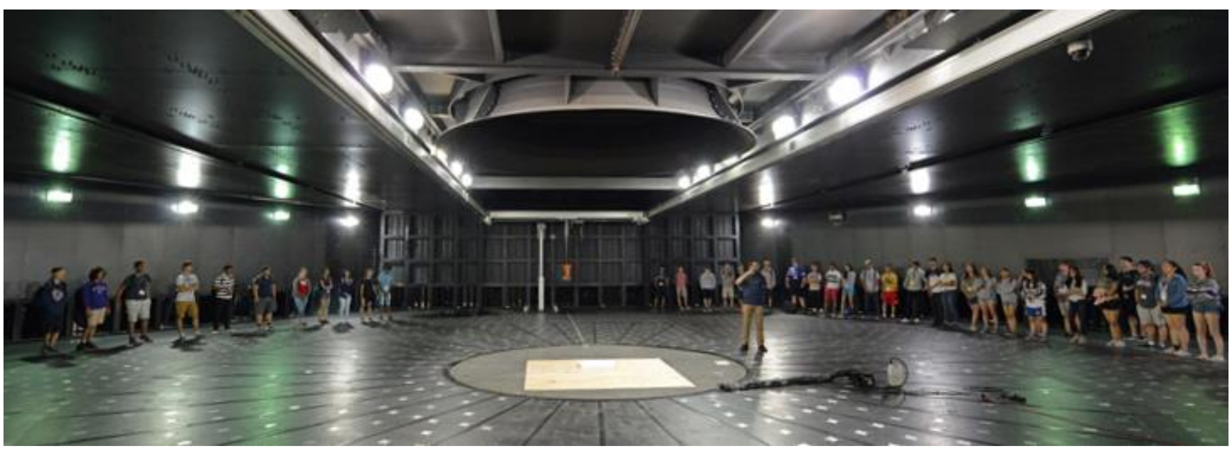
SHAD at WindEEE

Western University is the latest top university to join with SHAD, a prestigious program which brings the best and the brightest high school students to university campuses across the country every July for an intense program that helps them reach their full potential. SHAD, founded in 1980, has become known as an incubator for innovation and entrepreneurship among these students who specialize in STEM (Science, Technology, Engineering and Math). With an impressive list among its 15,000 alumni which includes 30 Rhodes Scholars, SHAD has seen a record number of applications for two years straight.

Western becomes the 12th host university campus around the country for the one-month residential program with places highly sought after by students who go through a rigorous competition and application process.

Each year, the program has a specific theme, built around a current economic and social problem. The students collaborate to develop a unique innovative product or service that addresses the issue. As part of this engineering and design challenge, teams are taught how to build a business and marketing plan, and design and build working prototypes. Winning projects advance to national judging and results are celebrated each fall.

A typical day at SHAD includes experiential learning, from class to labs and beyond. Students are inspired by university professors, business leaders, entrepreneurs and innovators, who help them set aspirational goals and envision their own extraordinary potential.



This summer, WindEEE Research Institute had the privilege to be one of Western's hosts for the SHAD group. The day at WindEEE started with a presentation about the Dome's capabilities, followed by facility tour and a tornado simulation.

A technical presentation on wind turbine designs and technologies introduced the students to the hands-on session. The students, divided in groups, designed and assembled small wind turbines to be tested inside the WindEEE test chamber. With plenty of construction materials at hand and keeping the rules of the game to a minimum, it did not take long until the innovative prototypes were ready to be tested. The competition was equally fun and exciting, bringing everything from entertaining failures to amazing performances.

Western Formula Racing Unveiling

Western Engineering students are among the most active students on campus when it comes to extracurricular activities, participating in faculty-based groups, clubs and teams. The Western Formula Racing (WRF) team is for students who are interesting in all things automotive and would like to become involved in the world of Formula SAE cars. Students use their engineering skills along with university and external resources available to them to fabricate and compete a formula-style race car in an annual competition with approximately 120 other vehicles from colleges and universities around the world.

WindEEE's involvement in the WRF this year was both in the areas of fabrication and presentation. In recent years, WindEEE has donated foam and services to fabricate cores to make wing elements for the car. This year was no exception as design became reality when the WindEEE team used its CNC hot wire foam cutter to make eight cores for wings on the ca.

Following the final assembly of the car, an amazing opportunity arose from the team's need to host an unveiling event worthy of all their hard work. The futuristic look and presentation capabilities of WindEEE, along with its uniquely large testing chamber, made it the perfect place to host roughly 90 attendees for the 30th anniversary of the WFR car unveiling. A day full of laughs, alumni presentations, cinematic experiences and testing out the team's driving simulator had everyone at the event excited for what next year would have in store.

Western Engineering Summer Academy

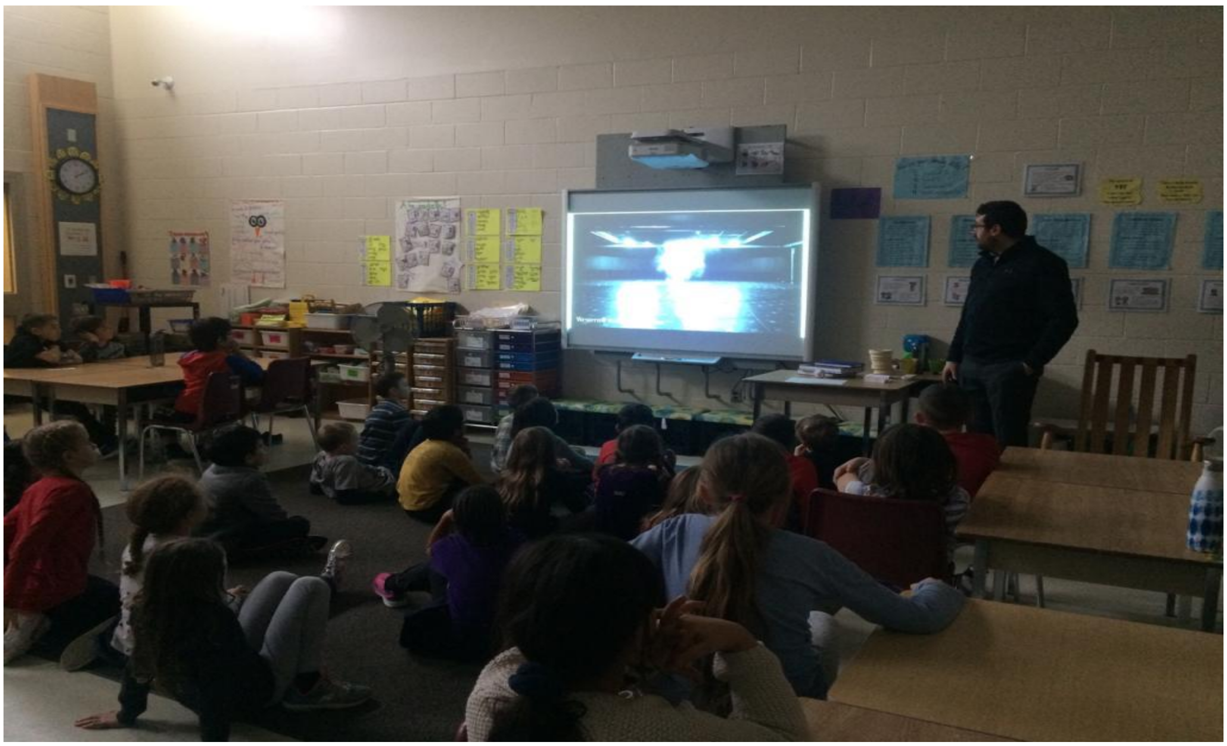
The Faculty of Engineering at the University of Western Ontario offers many programs for high school students to help them make informed choices about their post-secondary education. Among them is the Western Engineering Summer Academy (WESA) which offers students in grades 9 to 12 the opportunity to explore different disciplines of engineering, law and business. WindEEE, among other laboratories, opened their doors to students for hands-on experience in the area of civil engineering.

The day began at WindEEE with a lecture in the area of wind energy and wind turbine tower dynamics followed by a group activity directly linked the fresh, new material presented to them. Given all the materials and a small course on the instrumentation and software necessary for the activity, students designed and created wind turbine blades to be tested inside the WindEEE chamber, keeping in mind how the loading on the blades may induce dynamic loading on the tower. After assessing performance of the blades in a competitive fashion, experimental force data from each group was investigated and a discussion about the link between group's designs and experienced forces concluded the day.

Guest Teacher at Kensal Park French Immersion Public School

Within our community, WindEEE aims to be on the forefront of education in the areas of Science, Technology, Engineering and Mathematics (STEM) at both the high school and elementary school levels. As part of our mandate "to make global contributions in building resilience and sustainable communities through multi-disciplinary wind research, education and innovation", more of an emphasis has been placed on educating students within our community between grades 3-12 in aspects of wind engineering and wind energy.

This winter, WindEEE Research Institute was given the opportunity to apply aspects of our research and expertise to the science and technology Ontario Elementary Curriculum. Four grade 3 classes from Kensal Park French Immersion Public School in London, Ontario, Canada were taught about the role of engineers and facilities like WindEEE in making strong and stable structures that can withstand natural hazards like tornados and downbursts. Students participated in interactive presentations and engaging activities capped by the final challenge of constructing a paper tower that can resist strong winds while holding increasingly heavy loads. The day ended with a question and answer session which allowed them to ask questions about anything related to wind and engineering.



Notes

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