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Western



WindEEE Research Institute
Engineering, Energy & Environment

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Preface

The WindEEE Research Institute has entered its early operational phase in October 2014. The WindEEE facility construction was completed in September 2013 and commissioning was finished at the end of September 2014. Full attention is now paid to the early operational phase, ensuring that both high caliber research and industry projects are secured. A Marketing Plan is under development in collaboration with the Ivey School of Business. The Marketing Plan will be followed by an in detail Business Plan to be developed in 2016-2017. Also, the Budgeting is in the process of being detailed.

Presently the WindEEE Research Institute has a healthy membership of more than 20 faculty members 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. Expansion of outside memberships is planned based on the participation of external researchers in national and international collaborations at the WindEEE Research Institute. Several research programs have been completed or are under development with partners from Europe (3), USA (2) and Asia (2) in which strong research groups and external researchers apply for funding in collaboration with the WindEEE RI.

WindEEE RI has been very successful in attracting a large base of research collaborations at the national level. Presently we continue our collaboration with the Wind Energy Institute of Canada (WEICan) where a very important field campaign, the Prince Edward Island Wind Energy Experiment (PEIWEE) has been conducted together with Cornell and York Universities. Research and Industrial projects are presently under development with UTIAS at University of Toronto and with UOIT. At the international level, WindEEE RI continues to develop MoU's with Institutes in Europe, the Americas and Asia. Three MoU's have been recently signed with Politecnico Milano, the University of Genova in Italy and the Construction University of Bucharest Romania. The Free Trade accord between Canada and the European Union correlated with the EU Horizon 2020 has been already explored with one EU proposal, "All under Control" lead by the Fraunhofer Institute that made it to the final stage. The participation of WindEEE RI in prestigious Asian projects such as Project 111 with China is also

regarded as an important source of research funding in the near future.

In April 2015 the G7 Group of Senior Officials provided a list of global research infrastructures (GRIs) seeking to increase their international collaboration. WindEEE RI was included among the Canadian facilities on this evergreen list: Ocean Networks Canada (ONC); the Wind Engineering Energy and Environment (WindEEE) Research Institute at Western University; SNOLAB; the Canadian High Arctic Research Station (CHARS); TRIUMF; and the Canadian Light Source (CLS). Presently collaborations and projects are fostered between these International Research Infrastructures.

During 2014-2015 alone, the WindEEE RI core group produced 36 International Journal Publications, 45 Conference proceeding publications and approx. \$1.75M in research funding out of which more than \$1.1M is non-IOF research funding. The vigorous Industry Collaborative Research at WindEEE RI continues. R&D contracts with the insurance industry are presently matched through NSERC CRD. Large collaborative grants have been obtained with transmission line operators and building manufacturers and matched with OCE and CRD grants. Additionally contracts with solar energy system manufacturers have been already successfully matched through NSERC and OCE grants. Several Engage Grants have been secured and several other are under development. International projects went up to the final application stage with EU partners (2 projects) and two projects are under development with the USA including one consortium application for NSF funding.

The WindEEE Research Institute is clearly establishing itself both at the national and international levels. WindEEE RI is directly contributing to make Western a top-five research-intensive university in Canada and to raise its international ranking.



Horia Hangan

London, December, 2015

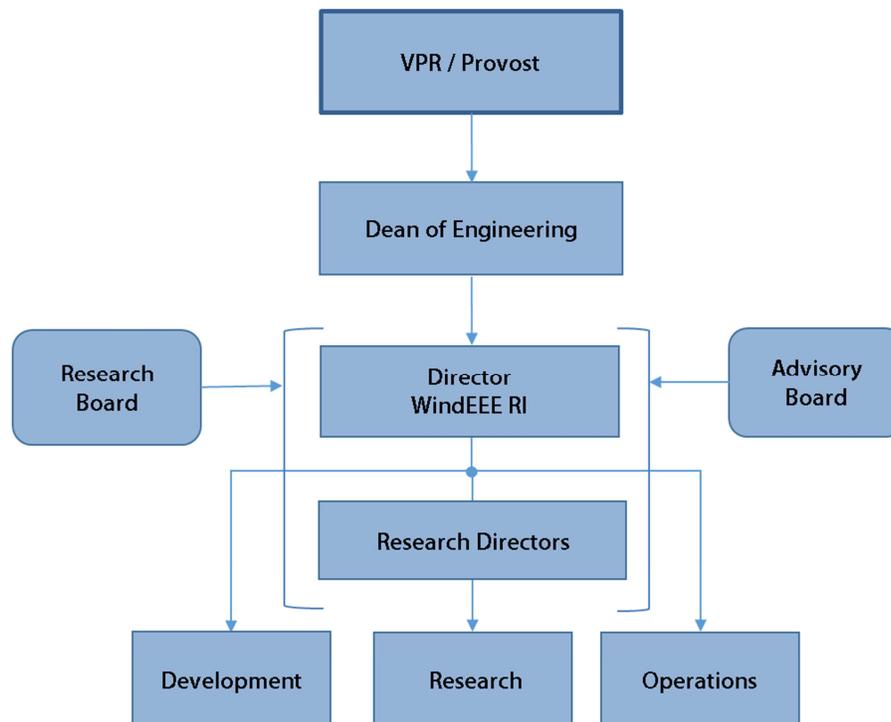
Governance Structure

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. The Director of the Institute reports to the Dean of Engineering. Two external Boards provide the necessary inputs to the Director of the Institute: the Advisory and the Scientific Boards.

As the status of Institutes at Western is presently under review, a **Governing Board (GB)** may be constituted at minimum by the VP Research and the Dean of Engineering. The Governing Board works together with the Director of the WindEEE RI to make the main decisions related the overall activity of the Institute including the Business Plan and the Annual Budget. The GB, in consultation with the Director, the Advisory Board and members of the Institute, is also responsible for constituting an External Review Board (ERB) at least every five years, and normally coincident with the final year of the Director's term. The GB will also receive an annual report from the Director on the status, progress and immediate future plans of the Institute. Such reports will be transmitted to the Vice-President (Research) for submission to Senate for information.

The **Advisory Board (AB)** advises the Director of the Institute on progress and advancement in areas related to WindEEE research and services. The board reports on Industry, International Institutes and Government with a global perspective along with providing advice on potential sources of funding in order to primarily address the non-IOF expenditures of the Institute and Facility. The Advisory Board will meet once a year starting 2014 and Members from Industry, Government and Academia are nominated for three (3) year terms. They are listed in WindEEE RI Advisory Board.

The **Research Board (RB)** 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 Research Board normally meets once a year and reviews the Research Proposals to qualify for WindEEE IOF funding. The Members of the Research Board of the WindEEE RI are nominated for three (3) year terms and have been now approved at the 2nd Annual Research Meeting in January 2014. They are listed in **WindEEE RI Research Board**.



People

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Wind Load Mitigation on Roof Top Solar Panel Arrays

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Atmospheric Boundary Layer Flow Commissioning at the WindEEE Research Facility

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Large scale testing for wind

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Wind Resource Assessment in Complex Urban Environments

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Downburst Characterization in the WindEEE Facility

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Wind Loading on Full Scale Solar Panels

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Near surface flow characterization over complex topographic terrain

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Effect of Topography on Tornado Response of Transmission Lines

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Testing and Behaviour of Transmission Lines Under High Intensity Wind



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Resilience and Sustainability of High Rise Buildings

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Behaviour of Reinforced Concrete Transmission Towers under High Intensity Wind

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Development of Design Procedure for Transmission Lines to Resist Downbursts

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Floor Vibration Studies

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Building enclosures with added sustainability functionality

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Sustainable building engineering: Effects of openings on buildings in ventilation, exfiltration and infiltration

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Aerodynamic and dynamic optimization of horizontal (bridge) structures

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Numerical modeling of tornadic flows

A. Gairoloa – MSc Student, supervisor: Dr. G. Bitsuamlak
Tornadic load on structures

Facilities

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

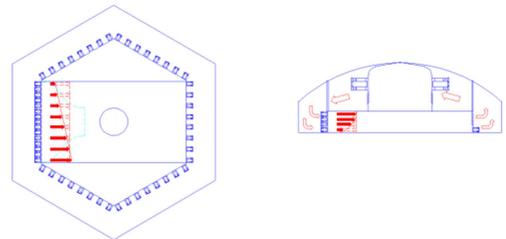


Figure 1 – Straight Flow Closed Loop

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

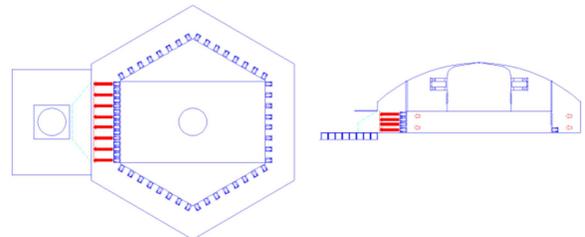


Figure 2 – Straight Flow Open Loop

Tornado

- Replication of EF0-EF3 tornados
- Properly scaled tornado flow-Refan et al. (2014)
- Geometric scale 1/100 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

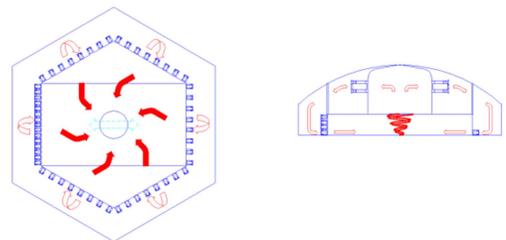


Figure 3 – Tornado

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

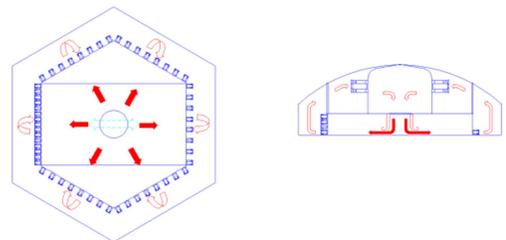


Figure 4 - Downburst

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



References

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

Refan, M.*, Hangan, H., Wurman, J., "Reproducing Tornadoes in Laboratory Using Proper Scaling", J. Wind Eng. And Ind. Aerodynamics, Vol. 135pp.

Research

1. Wind Engineering

- Tornado wind loading on essential buildings
- Downburst effects on utility transmission lines
- Wind loading on full scale roof mounted solar panels
- Wind effects on ground mounted solar panels
- 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

Investigation of Flow Behaviour and Scaling Issues in Wind Tunnel Modeling for Wind Resource Assessment and Wind Farm Optimization

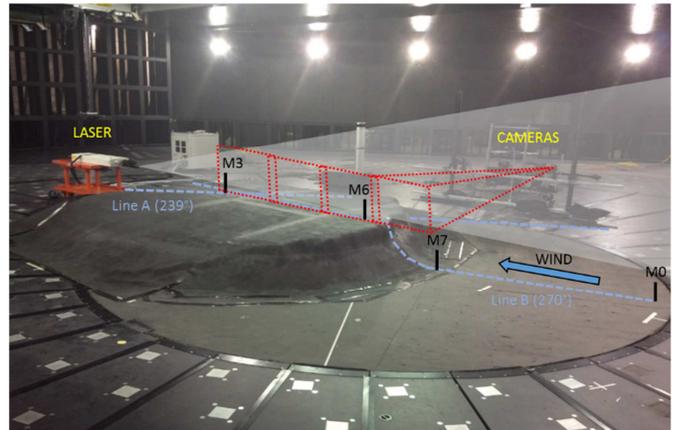
Wind turbines are increasingly being placed amidst complex terrain, such as hills, ridges, valleys and forest canopy. The complex topography significantly alters the flow dynamics in the lower Atmospheric Boundary Layer (ABL), and hence the inflow conditions for the wind turbine, influencing its performance.

Linearized models typically used for wind farm design, although well-suited for open, flat terrain, can produce inaccurate results when applied to design of wind farms in complex terrain. Hence, there is a need for detailed experimental characterization of the mean and turbulent flow fields in such geometries for the advancement of the scientific knowledge and better parameterization for improved model predictions, ultimately leading to improved wind farm optimization.

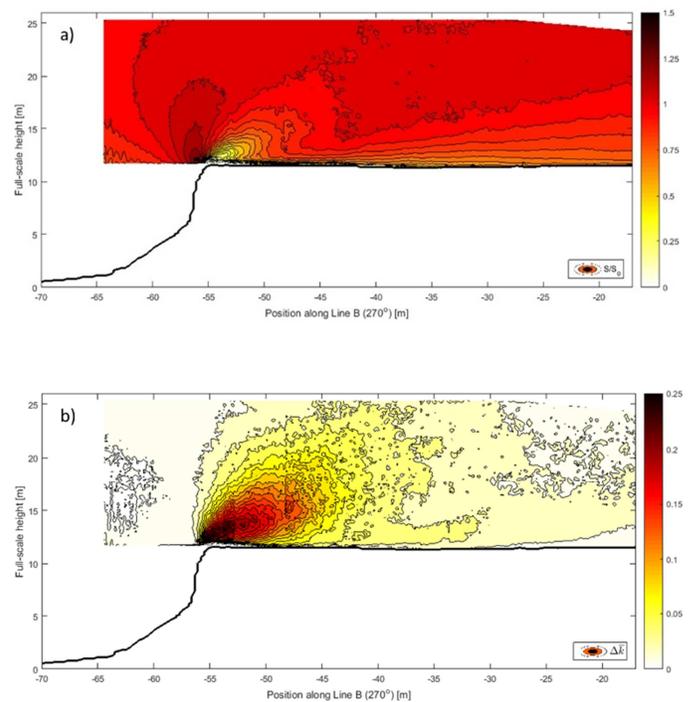
In addition, although wind tunnel investigation on scaled models is widely used to characterize and predict flow over topography, the question of whether scaled-model flow characterization accurately captures the underlying physics occurring at full-scale is not yet well understood.

The current study is focused on a systematic investigation of the mean and turbulent flow behaviours, as well as scaling effects in physical modelling of complex topographic terrains in wind tunnels. Bolund Hill, a 12 m high peninsula located near Roskilde, Denmark, which has become an important test case in the wind energy community, was selected as the physical model for the experiments. Bolund is characterized by a long upstream fetch, a steep escarpment and a long flat section on top of the island.

Two scale models of the island were used for testing: a 1:100 model tested at Western University's Boundary Layer Wind Tunnel Laboratory (BLWTL) Tunnel 1, and a 1:25 model tested at the WindEEE dome. Various Reynolds numbers were tested, and two flow directions were examined. Analysis is currently being performed to compare the scale model results to field measurements and to results obtained by other researchers, to gain insights into the flow behavior and the influence of various factors on the mean and turbulent flow.



WindEEE experimental setup (1:25 scale model shown)



Contour plots showing a) speed-up ratio and b) change in turbulent kinetic energy over Bolund model escarpment

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Aerodynamic Loading of a High-rise Building Subjected to Experimentally Simulated Tornado Winds

Tornado-induced damages to high-rise and low-rise buildings are quite different in nature. Tornado damages to high-rise buildings are generally associated with building envelope failures while tornado induced damages to low-rise residential buildings are usually associated with structural or large component failures such as complete collapses or roofs being torn-off. Surveys and available records on tornado-damage to high-rise buildings show that high-rise buildings survive the extreme wind load conditions with little or no structural damages. There has been no report of structural collapse of tall buildings due to tornadoes.

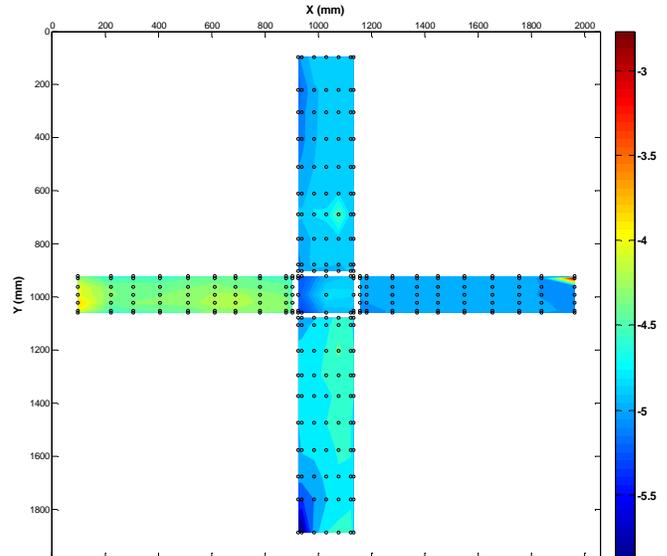
According to the damage survey performed on high-rise buildings hit by F2 tornado of Fort Worth on March 28 most of the building damages are associated with breaches of claddings and no apparent structural damages or failures were reported.

While studies of tornado-induced structural damages tend to focus mainly on low-rise residential buildings, transmission towers or nuclear power plants, the current rapid expansion of city centers and development of large scale building complexes increase the risk of tornadoes impacting tall buildings. It is therefore important to determine how tornado-induced load effects on tall buildings compare with those based on synoptic boundary layer winds. The present study applies an experimentally simulated F2-rated tornado wind field to the CAARC building (Commonwealth Advisory Aeronautical Council) and estimates its quasi-steady structural load effects.

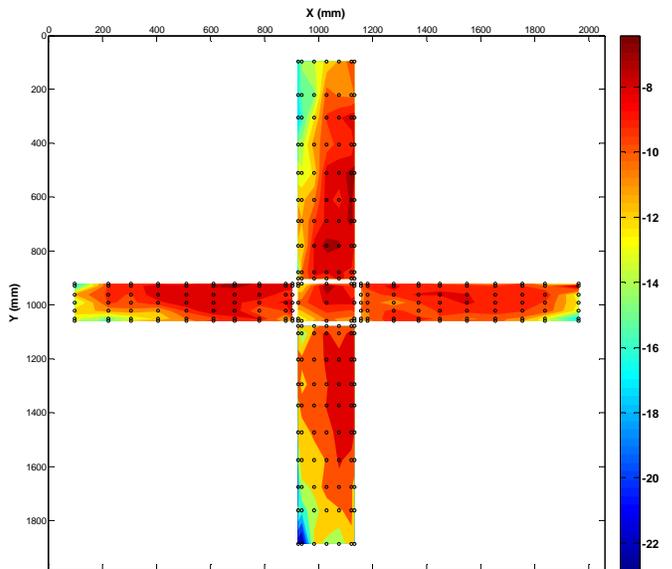
Simulations are performed at WindEEE Dome which is capable of creating an equivalent of EF0- to EF3-rated tornadoes using proper scaling. A 1:200 scaled model of the CAARC building ($W=30\text{m}$, $D=46\text{m}$, $H=183\text{m}$) was built and equipped with pressure taps. Surface static pressures were measured. The chamber static pressure and the maximum tangential velocity at the roof height were used as the reference and the dynamic pressure, respectively, for calculating pressure coefficients at each tap.

Mean and peak surface pressures are reported below over an exploded view of the building. The measured surface pressures are noticeable with the highest suction experienced by the lower floors.

In the next step, the surface pressure deficits will be compared with the ones reported for Atmospheric Boundary Layer flows in order to identify the differences in the wind load.



Mean hourly surface pressures - simulated EF2 rated tornado



Negative peak pressures – simulated EF2 rated tornado

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Large Scale Downburst Flow Field Measurements in the WindEEE Dome

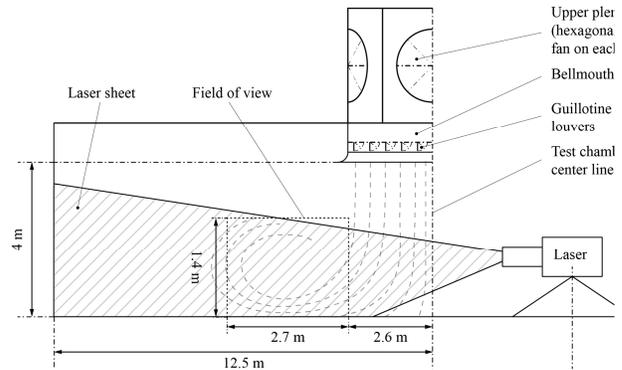
Downbursts are natural phenomena that can occur during thunderstorms. They are characterized by a strong downward air current that hits the ground below and convects radially, from the point of impact, generating high velocity ground level winds (Fujita, 1985). Wind profiles generated by such an event are greatly different from regular boundary layer winds. According to the analysis performed by Vickery and Twisdale (1995), 75% of the peak gust wind speeds occur during thunderstorms. From the civil engineering point of view, the extreme gust wind speeds are of great interest as they are used in structural engineering design codes and are largely caused by downbursts. Several parameters have been identified to have the largest influence on the downburst flow. Ground roughness (Vermeire et al., 2011a, Mason et al., 2010b, Li and Ou, 2012), the translation of the downburst-creating thunderstorm (Letchford and Chay, 2002, Holmes and Oliver, 2000, Chay et al., 2006, Mason et al., 2009) as well as the occurrence of multiple downburst events Vermeire et al. (2011b) need to be studied in further detail.

The main objective of research is to study and accurately characterize downburst flows in a laboratory setting and propose new scaling guidelines. Several contributing factors will be investigated in detail, such as the effects of modifying the downburst diameter to surface spacing (h/D), Reynolds dependency, influence of impingement surface roughness, downburst translation and multiple events. Flow characterization will be accomplished using single point as well as 2d- and 3d-field velocity measurements.

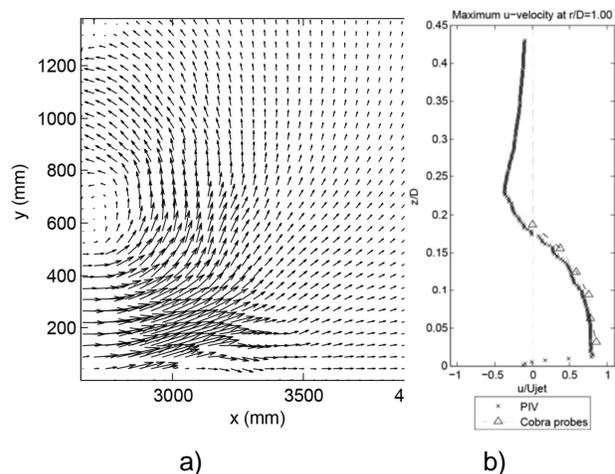
Towards this goal, new and existing measurement techniques for large scale flows will be developed, specifically for large scale experiments. Two methods represent the main focus of this research: a new, real-time method based on Particle Streak Velocimetry and an improved Particle Imaging Velocimetry approach. Secondary research topics include the expansion of the PSV method to 3D. Moreover, various data analysis techniques will be applied to these measurements.

The downburst experiment is set up in the WindEEE Dome. This facility essentially creates an impinging jet with the test chamber floor as the impingement surface. The forcing for this impinging jet model is driven by a constant velocity inlet, thus any results are

expected to be inlet velocity dependent within a certain Reynolds number range that needs to be determined.



Large scale PIV setup schematic



a) Vector map showing counter rotating vortex pair;
b) comparison between PIV and Cobra probe profile 3.2m from jet center.

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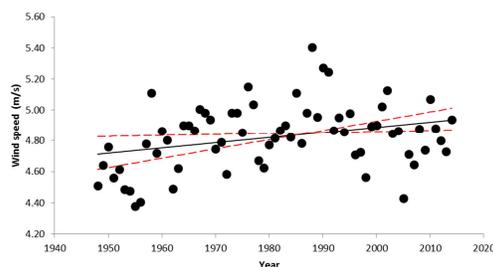
Wind Climatology of Toronto and its Potential Relation to Solar Activity

This study represents a comprehensive analysis of the wind climatology for the Toronto area based on the daily NCEP/NCAR reanalysis data extracted for the period 1948-2014. The research is focused on investigating wind speed and direction distributions, long-term wind trends and low-frequency wind spectrum.

The results are given at the sigma-995 level (approximately 35 m above ground). Westerlies are active in about 50 % of the time in year. The strongest winds are coming in from 240° direction. The windiest seasons are winter and fall, followed by spring.

A trend analysis of wind speed data shows that statistically significant and positive wind speed trends are present for both the omnidirectional mean annual wind speeds (figure below) and the major wind directions. Winter and fall winds had positive trends while negative wind speed trends in the summer and spring seasons are negligible.

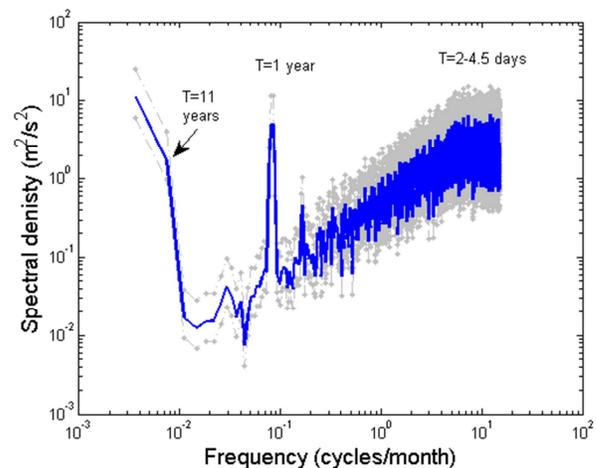
Temperature in all regions of Canada rose in the period from 1948 to 2014. This trend resulted in a temperature increase for the country as a whole by 1.6 K. The average annual temperature in the northern region of Ontario, however, has increased for 0.8 K in the analyzed 67-year period. In the same time period, the temperature rose for only 0.6 K in the most southeastern region of Ontario. These uneven temperature increases across Ontario might have resulted in an augmentation of the pressure gradients in the central Ontario, which in turn would result in the positive wind speed trends.



Mean annual wind speed at Toronto the period 1948 – 2014. The black line represents Sen's slope whereas the red (dashed) lines indicate slopes at the 95 % confidence intervals.

The spectral analysis shows three distinguished peaks (figure below). The first peak and the one with the highest frequency correspond to the passage of the low pressure systems (cyclones and depressions) with a period of 2 to 4.5 days. The second peak has a period of 1 year and corresponds to the annual cycle of seasons.

The low-frequency peak in the wind speed spectrum with corresponding period of 11 years is linked to the solar activity. The cross-correlation analysis confirms that there is a significant similarity between the mean annual wind speed at Toronto and solar activity. The highest correlation is observed at zero time lag and reaches 0.82.



Low-frequency wind speed spectrum (blue line) for Toronto based on the mean daily wind speed data in the period 1948 - 2014. The grey lines represent the spectral at the 95 % confidence intervals. The periods of pronounced peaks are denoted with a capital T.

It should be noted that our analysis between the mean annual wind speed and solar activity is purely statistical, without an attempt to develop an analytical theory of it. Comprehensive literature review, however, confirms that solar activity can have a profound influence on earth's climate; directly in the stratosphere and indirectly in the troposphere.

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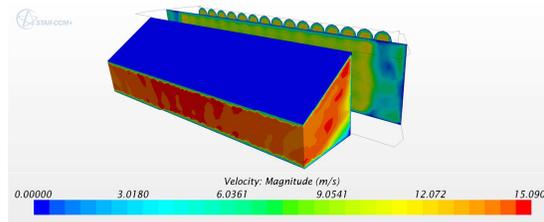
WindEEE Outside Flow Using a Contraction

WindEEE dome is a unique facility that has the ability to generate different types of atmospheric flows such as tornado, downburst and straight wind. All these flows are generated inside WindEEE's 3D hexagonal test chamber. Another capability of WindEEE is outside testing under straight flow conditions. This enables different types of testing such as destructive and wind-driven rain. During outside testing, both garage doors adjacent to walls 1 and 4 of the hexagonal chamber are opened to allow the air to flow in an open loop configuration and the fans on wall 1 are run in reverse.

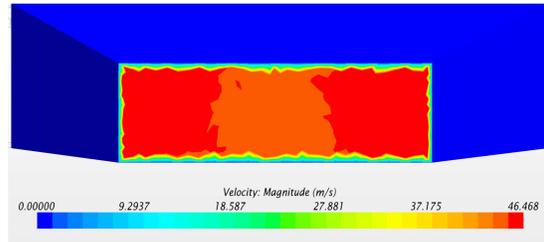
CFD simulations and experimental measurement are conducted to examine the outside flow characteristics. The simulations are done for two cases for the sake of comparison. The first case is for 60° open garage door with no contraction installed. The second case is for a straight contraction in place with 60° open garage door acting as the top wall. For both cases, maximum fan speed is used. The contraction exit dimensions are 6m width and 1.9m height.

The simulations show that for the first case, the mean wind speed magnitude at the door is around 15 m/s with uniformity as seen in the first figure. For the second case, the wind speed at the contraction outlet is enhanced due to the reduction in cross sectional area and reaches around 46 m/s with uniformity across the exit as seen in the second figure. The simulations clearly show qualitatively and quantitatively the outside flow' mean velocity for the two cases.

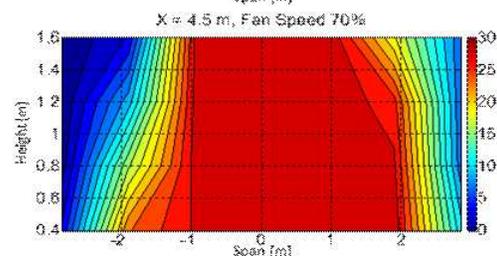
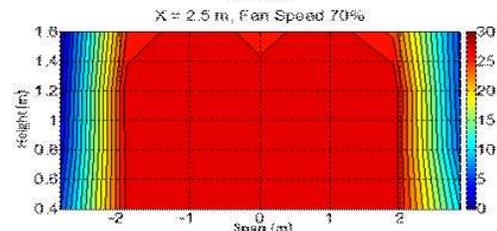
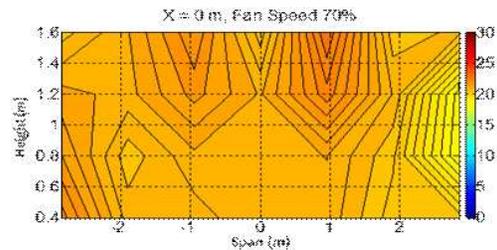
Flow measurements are conducted in the spanwise plane at different streamwise locations ($X=0, 2.5$ and 4.5 m) from the contraction opening using cobra probes. The maximum fan speed used is 70%. The mean velocity contour plots show flow uniformity across the measurement plane. The contours show that the flow maximum velocity is around 20 m/s at the contraction exit and 30 m/s at $X=2.5$ and 4.5 m downstream from the contraction exit. This is due to the generation of a boundary layer along both sides of the jet as seen in the contour plots. One can also see that along the streamwise direction, the area of maximum velocity is reduced due to the growth of the boundary layer.



Mean velocity contour at the door opening of 60° with no contraction installed



Mean velocity contour at contraction outlet



Mean velocity contour at different streamwise distances (X)

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Prince Edward Island Wind Energy Experiment (PEIWEE) Campaign

As wind energy is becoming more popular worldwide, Canada is making great strides in forwarding the wind energy sector. As of May 2015, Canada ranks seventh in the world in installed wind energy capacity with over 10,000 MW. This contributes to approximately four percent of Canada's total energy demand. Moving forward, new wind turbine installation capacity is expected to exceed the annual average of 24 percent [1]. Conventional sites for wind turbine placement are less available and it is becoming more common to install turbines in areas which have complex topographical features such as forests, hills and escarpments.

These features create complex phenomena such as wakes, flow separation and shear in the flow entering the turbines. There is a need to better understand the relationship between these flow characteristics and turbine power production and performance. In addition, wind farm simulation tools can under predict turbine inflow conditions near these complex terrains. This results in an over prediction of net power produced and has an impact on the payback period of the wind farm.

The PEIWEE campaign was a collaboration between the Wind Energy Institute of Canada (WEICan), Western, York, Cornell, and Denmark Technical University (DTU) that took place during the first three weeks of May 2015. The focus was to characterize the inflow and outflow conditions of WEICan's 80m wind turbines located in North Cape, P.E.I. The Wind Engineering, Energy and Environment (WindEEE) Research Institute was responsible for assessing three types of flow: boundary layer flow over a steep escarpment, flow over a forest canopy and wind turbine wakes. Full scale measurements were done using WindEEE RI's WindScanning Light Detecting and Ranging (LiDAR) instrument developed by DTU.

LiDARs emit a laser and sense the reflection in order to measure movement of aerosols in the atmosphere. The measurement technique uses the Doppler Effect to determine the speed of the aerosols, which represents the line of sight wind speed referred to as the radial wind velocity.

The WindEEE WindScanner is a short range (10-200m) LiDAR capable of scanning different patterns which reveal information about both wind speed and direction

The next steps are to analyze the acquired data from the LiDAR and use the results to simulate the same conditions within the WindEEE test chamber. This will allow model wind turbines to be tested in the realistic conditions.



The image above shows five 80m DeWind turbines located near WEICan's facility in North Cape, Prince Edward Island. The steep escarpment is located ahead of the upper turbines. Below is WindEEE's Wind Scanning LiDAR in use at the test site.



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[1] CANWEA : "National." Canadian Wind Energy Association. Web. 13 Nov. 2015.

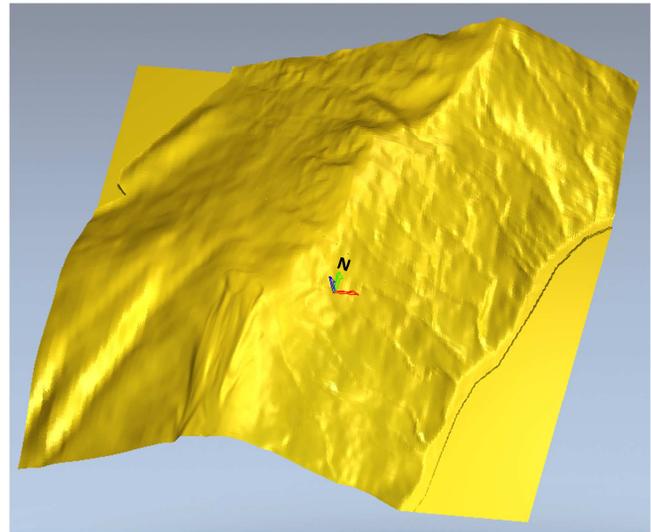
Large Scale Testing of Wind Flow Over Complex Topography

Atmospheric flow over mountainous terrain is very complex and highly turbulent due to flow acceleration-deceleration and separation-reattachment over the ridges and valleys. To estimate the design wind load on a structure in a complex topography, accurate prediction of wind speeds at the location of the structure is essential.

In an effort to evaluate wind speed over a complex topography, tests had been conducted at the Wind Engineering, Energy and Environment (WindEEE) research facility. The topography chosen for the experiment is located near Stewart, BC at the border of British Columbia and Alaska. A 1:1500 scaled model of topography was selected. The model dimension was 7m (length) \times 5 m (width) \times 1.3 m (height). The large test section of WindEEE test chamber (25 m by 3.8 m) had encouraged testing at this large scale. The test model was fabricated using an in-house CNC router.

In order to obtain the incoming flow conditions at the edge of the experimental model, CFD simulations had been performed for a much larger section of the topography compared to the experimental model (30 km fetch from the leading edge of the model). Wind flow profiles at the location of the leading edge of the experimental model were developed for two most dominant wind directions (0° - North and 210° - Southwest), which is obtained from the Canadian Wind Energy Atlas. Mean velocity and turbulence intensity profiles for two wind directions, obtained from CFD at the leading edge of the experimental model, were reproduced in the test chamber using the 60 fan wall at WindEEE.

Point measurements were performed at 72 locations over the topography for each wind direction using a TFI J-cobra probe mounted on a KUKA Robotic Arm. 5s gust wind speeds were calculated at the measured locations which could be employed to determine the design wind loads on structure in this complex topography.



CAD model of the topography



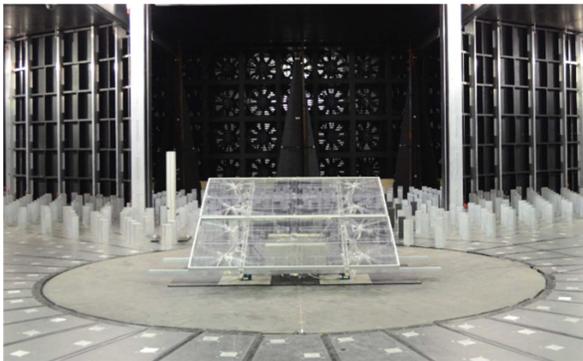
Model inside the test chamber at WindEEE

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Wind Loading on Full Scale Solar Panels

Solar energy is one of the important sources of available renewable energy which can be harnessed by solar panels for generating electricity. Usage of solar energy has surged approximately 20% a year over the past 15 years owing to encouraging Clean Energy policies. However, there are still some drawbacks which hinder the mass production of solar panels. One of the prominent factors is the cost of supporting structure of solar panels which is a significant portion of the total cost. Hence, optimization of this structure could be a key factor to extend utilization of solar panels.

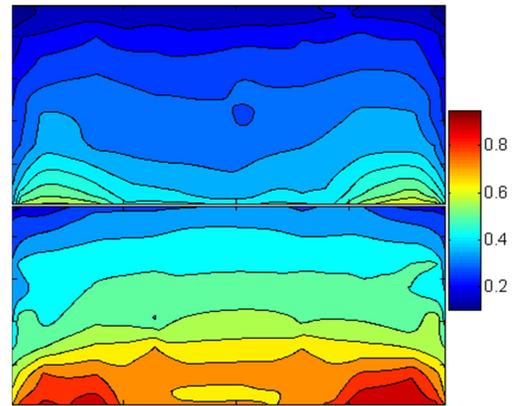


View of solar panel model and pressure taps consists of a double layer instrumented clear Polycarbonate sheets

In this research the main attempt was to accurately establish the pressure distribution on a ground-mounted solar panel while most of the applicable codes are silent in this regard. This was performed by applying a real wind pressure on full-scale solar panel model based on ESDU (Engineering Sciences Data Unit). The pressure distribution on both surfaces of the solar panel was then obtained using a high resolution pressure tap pattern.

The results of the wind tests were recorded for 21 wind angles from 0 to 180 degrees and pressures were sampled at the frequency of 625 Hz. The supporting structure of solar panel was also monitored using force balances and strain gauges installed on critical members to measure the reactions and member strains, respectively.

The experimental loading data was further used as an input load for Finite Element Analysis (FEA) of the supporting structure of solar panels.



Net pressure coefficient contour plot of solar panel under 0 degree wind direction

The critical loadings (0 and 180 degree wind direction) were employed for design optimization of supporting structure. Results revealed that the support reactions obtained from three different methods are in general agreement, as displayed in the table below.

	0 degree		180 degree	
	F _x	F _z	F _x	F _z
SAP (FE model)	218	544	292	730
Pressure taps	237	509	315	676
Force balances	279	653	324	865

Comparison of reactions obtained from FEA, pressure taps and force balances

In the next step, the results of experimental and numerical analysis will be used for design optimization of supporting structure of solar panels. This leads to saving in material and reducing the cost of solar panels manufacturing.

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Enhanced Building Energy Performance Simulation

Several researchers have indicated that there is significant amount of disparity between the predicted design stage energy performance of a building and the actual measure during use. One, among many, sources of this disparity is attributed to the thermos-fluid Building Energy Estimation/Simulation models used currently. The models use one dimensional heat transfer, first order differential treatments, and moreover patchy aggregation of components of different sources of heat and mass flux. The governing flow and energy model is complex and involves three dimensional heat and mass transfer considerations including moisture transport. The diurnal and seasonal transient loads of solar and ambient conditions besides the internal functional schedules remain the challenges to properly model energy performance needs. With this in mind, the current research aims to assess the possible improvement points in the energy modeling process and provide strategies for enhancement of the performance evaluation process.

Currently identified potential areas of improvement in modeling of building energy include: boundary conditions including heat transfer coefficient and pressure coefficient computation, one dimensional wall heat transfer, and patchy nature of the overall aggregation of fluxes. To this end this research attempts to numerically asses and find ways to find high resolution spatial and temporal information for heat transfer and pressure coefficient in the non-isolated building scenarios. Attempts will also be made to change the one-dimensional nature of wall heat transfer quantification. The patchy nature of superposing fluxes from different sources will also be tested in coupled Building Energy Simulation and Computational Fluid Dynamics platform. Tests will also be made at WINDEEE to validate some of the numerical results.

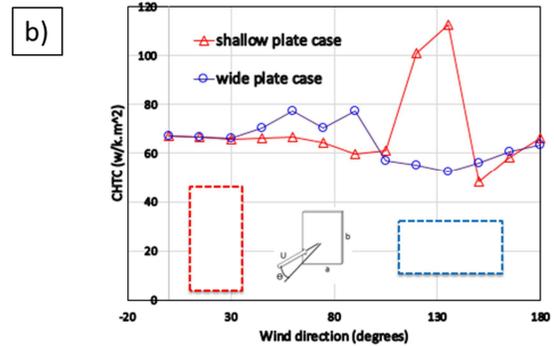
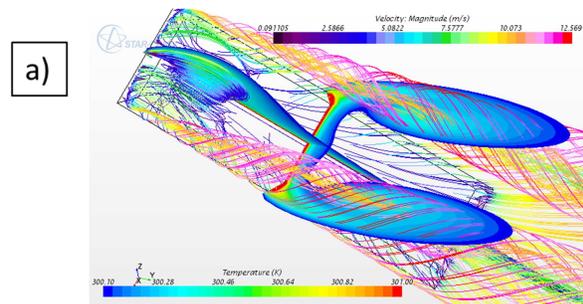


Fig. 1 a) Local heat and fluid flow phenomenon over an inclined surface b) CHTC plot of various aspect surfaces against wind angle of attack.

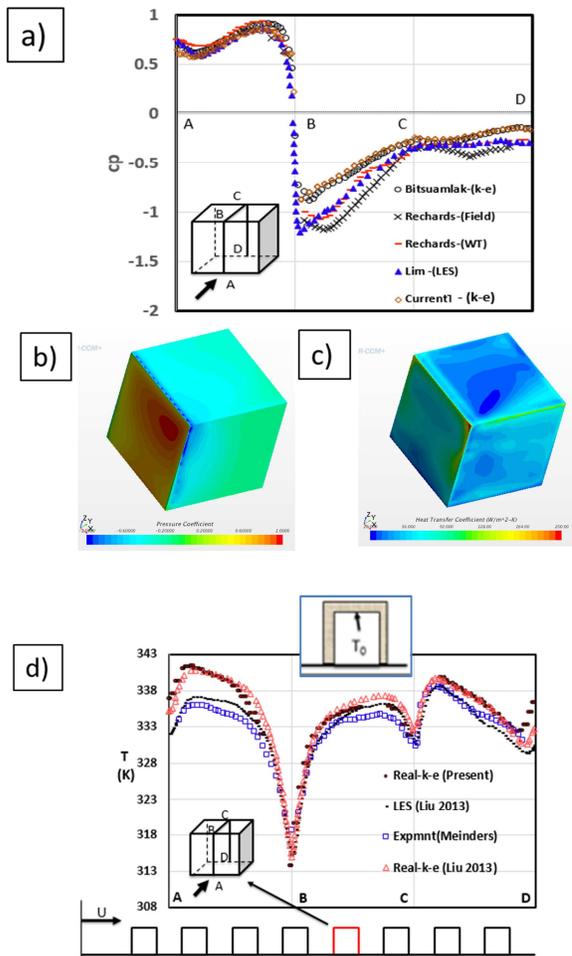


Fig.2 Flow around an isolated bluff body, a) pressure coefficient plot b, c) flow and heat transfer for flow approaching at angle d) the case of bluff body array

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Optimization of Fenestration Configuration in Buildings for Sustainable Thermal and Lighting Performance

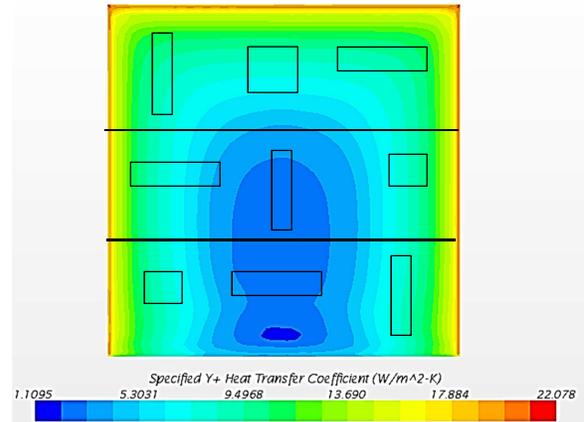
Buildings are designed to provide comfortable enclosures for occupants by separating the space between the surrounding environment and the occupied space along with HVAC systems as necessary. Buildings are also expected to be durable and energy-efficient. Most commercial high rise or institutional buildings uses glazed curtain walls from floor to ceiling; however, glazing has very little ability to control heat flow and solar radiation. The overall heat transfer coefficient (U-factor) of fenestrations is very high compared to other components of a building's enclosure such as walls, doors, roof, etc.

Thermal and lighting comfort inside a building is highly dependent on fenestration configuration. The selection of optimal fenestration configuration often involves many factors such as micro-climate conditions, building location, orientation, height and purpose of the room etc. However, fenestrations are mainly configured primarily based on their aesthetic value, with limited consideration to the thermal comfort and daylight distribution. Various studies have shown that 20% - 40% of the building's energy wasted through fenestrations (Lee et al., 2013). Further, there is lack of consistent, and building specific, evaluation of external convective heat transfer coefficient (CHTC) distribution on the enclosure.

It is also well understood that during fenestration configuration optimization, conflict will arise while attempting to enhance energy-efficiency, thermal and light performance simultaneously. Most often a small fenestration size is preferred to limit the heat loss during winter and limit solar heat gain during summer; in contrast a large fenestration size preferred for enhanced view of the outside environment, solar heat gain during winter and day lighting. Both sizes may be preferred choices simultaneously by the occupants; however, the designer will be challenged to optimize the fenestration size without having any specific guidelines or tools. In addition the effect of aerodynamics on fenestration configuration is not explored in detail. Wind flow varies with height and width of a building, which results in the CHTC variations on the surface of the building.

A novel fenestration configuration optimization frame is being developed that deploys a high resolution

computational fluid dynamics simulation integrated with Building Energy Simulation tool and an optimizer algorithm.



Fenestration configuration based on CHTC on surface of 10m height building at T_s 303K and T_{Ref} of 283k

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Application Guide for Wind Speed-up Factors for Transmission Line Towers

Electric transmission lines and towers crossing undulating landforms are subjected to an increased wind loading due to wind speed-up caused by abrupt topographic changes. Many national wind loading standards and codes of practice including the National Building Code of Canada, NBCC 2005, provide simplified empirical formulations in the form of speed-up factors for generic topographic shapes including isolated hills, ridges or escarpments. However, these standards do not include provisions for wind speed-ups and the associated turbulence characteristics in rapidly varying terrain, where the orographic characteristics change significantly over short distances, with scales of the order of overhead transmission line spans. More importantly, transmission line design standards, such as IEC 60826/CSA 22.3 for Canada, do not include any guidance on topographic effects. A detailed study has been carried out in collaboration with CEATI International Inc. to develop an application guideline for evaluating topographic-induced wind speed-up.

Semi-empirical models for calculating wind speed-up due to isolated topographic features (see Figure 1 (a)) have been reviewed and systematically outlined. A spreadsheet program was developed to implement the formulations and results for 10 generic and 3 natural topographic features were presented. For example, Figure 1 (b) shows the wind velocity pressure increment on a 60m tall transmission line tower located around the crest of a ridge ($H = 456\text{m}$, $L = 780\text{m}$, $x = 120\text{m}$) evaluated by using four international codes or standards: NBCC 2005; ASCE/SEI 7-10, AS/NZS 1170.2:2002; EN 1991-1-4:2005. The code predictions showed that the tower will experience wind load at least twice that which would be experienced if it was located on flat terrain for the same approaching wind speed.

For transmission lines crossing complex topography (see Figure 1 (c)), large scale wind tunnel testing using facilities such as the WindEEE Dome is recommended. In addition, the benefits of using Computational Fluid Dynamics (CFD) has been illustrated by simulating the wind flow over the Askervein hill (for validation of the proposed method) and over three terrain where wind induced failure of transmission line towers was previously reported. Figure 1 (c) shows a distribution of fractional speed-up ratio, FSUR (see Figure 1 (a) for FSUR definition) over a complex terrain simulated by using the CFD

approach. The FSUR plot demonstrates that transmission line towers constructed over ridges (hot spots indicated by red colour) would experience higher wind loading compared to those located off the ridge lines and those located in valleys may be subjected to high turbulence (not shown here). The application guideline was published by CEATI International Inc. for distribution to its member companies.

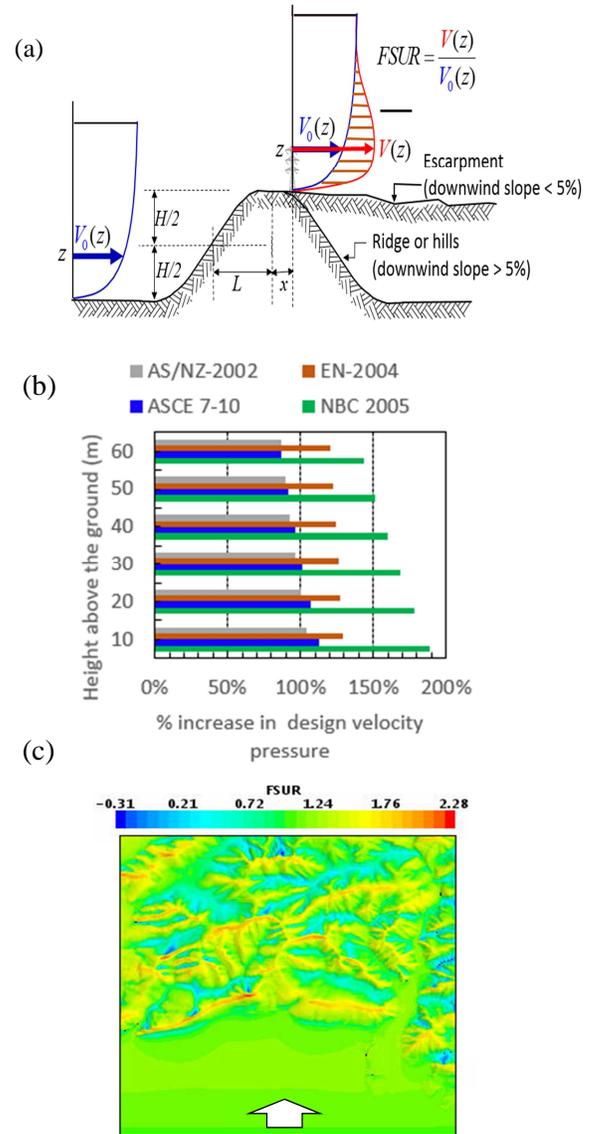


Figure 1: Topography induced wind speed-up: (a) definition of FSUR, (b) dynamic overpressure predicted by using provisions of international codes and (c) FSUR over a complex terrain predicted using CFD.

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Pressure Equalization on Roof Pavers

Concrete pavers are commonly used as surface finish to flat roofs of many high rise buildings. They are also used as additional landscaping elements, path ways on vegetated roofs (green roofs) and as mitigation element for preventing uplift of vegetative materials due to their relatively heavy dead-weight. Loose-laid roof pavers have demonstrated a propensity for failure when subjected to severe wind conditions. Pavers blown by extreme wind may also become airborne missiles which may cause successive failure to the surrounding building environment. For the above reasons, a number of studies have been devoted to the estimation of the uplifting forces on the pavers (Gerhardt et al. 1990; Bofah et al. 1996; Aly et al. 2011; Mooneghi et al. 2014) to enable solutions that are suitable to secure the roof pavers.

To prevent loose-laid pavers from being blown by extreme wind individually, interlocking system has been developed by WAUSAU Inc (Aly et al. 2011). In addition to the pressure equalization effects due to the permeability from edge-gap widths of roof pavers, the interlocking of paver units further promotes the reduction of net uplift through spatial correlation of fluctuating wind pressure. However, such wind load reductions are neither systematically presented in literature nor specified by wind loading standards such as ASCE/SEI 7-10 for practicing engineers to carry out wind resistant design of roof pavers. This study (i) identified geometric parameters of high importance for pressure equalization using CFD simulations, and (ii) evaluated the wind load reduction factors using large-scale testing at WindEEE for selected cases from (i). Pressure test experiments on a generic test building of a one-third scale ($B/h = 2$, $L/h = 2$, $h = 1.2\text{m}$, see Figure 1(a)) were conducted under open exposure wind field. The tests involve simultaneous pressure measurements from 450 pressure scanning tap points systematically placed on the upper and lower surfaces of the pavers mounted on the test building model. This enabled direct evaluation of pressure equalization on the pavers of 143 test configurations corresponding to various combinations of parameters including three edge-gap widths, G , between adjacent pavers, three cavity heights, H , between roof deck and pavers, four types of parapet walls, and six wind directions.

Estimates of the combined gust-pressure coefficients from measurements of bare roof building models (see Figure 1(a)) are found consistent with ASCE/SEI 7-10 specification. Test results from paved roof models show that roof pavers having edge-gap width of 6mm

supported on pedestals with a clear cavity height ranging from 150mm to 450mm can reduce the net uplift wind load by a factor of about 3/5 (see Figure 1(b)).

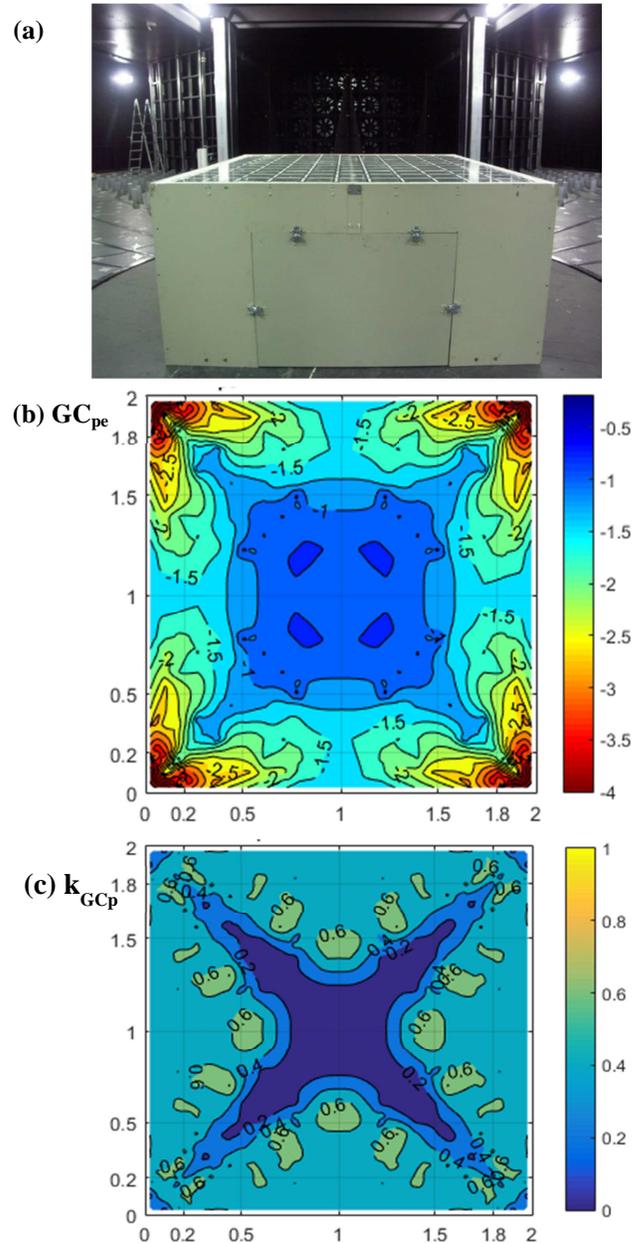


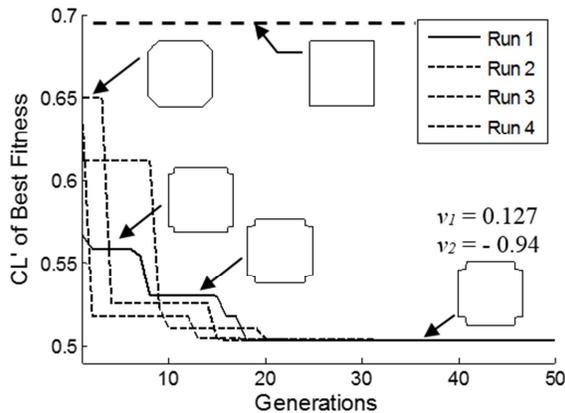
Figure 1: Contour maps showing envelopes of wind loading factors: (a) building model, (b) combined gust-pressure coefficient of bare flat roof, and (c) pressure equalization factor for paved flat roof estimated from test measurements

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Aerodynamic Optimization of Tall Buildings

With the development of new building materials and techniques, the new generation of buildings are becoming taller and lighter and a result more flexible and of lower damping. This is making super tall buildings more sensitive to the dynamic effects of wind. Aerodynamic mitigation through local or global shape modification is becoming an important aspect of the tall building design process. This can enable reductions in the lateral loads and limit the vibrations caused by the wind, consequently leading to a more economic and comfortable tall building.

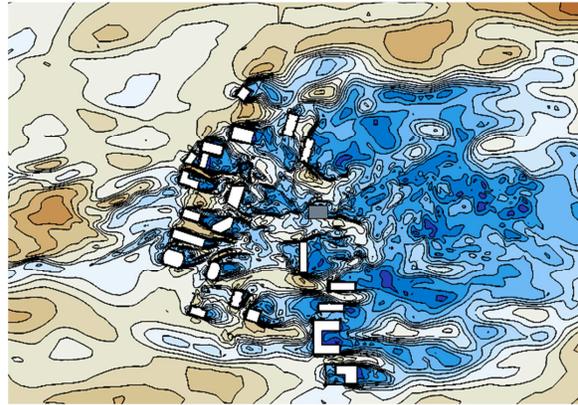
A new hybrid optimization framework is developed by coupling optimization algorithm, experimental or numerical results and a surrogate Neural Network (NN) model. The optimization algorithm is used to search for the optimal building aerodynamic performance by altering the geometric parameters controlling the building shape.



Improvement of aerodynamic properties using optimization technique

Limited number of CFD simulations are conducted for selected samples to train the NN for a database of shapes and aerodynamic properties within the target geometrical constraints identified by the designer. The surrogate NN model is used to estimate the objective functions during the optimization process.

For validation the final solutions, a more accurate Large Eddy simulation (LES) is carried out. The LES uses a newly developed turbulence flow generator named Consistent Discrete Random Flow Generator. This technique is tested for isolated and surrounded building cases. The developed optimization framework is being enabled for global modifications on 3D buildings using multi-objective optimization approaches.



Utilizing CDRFG technique for LES model of a building in a city center

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Numerical Modeling of Tornadoic Flow Interaction with Topography and Buildings

Tornado is one of the most devastating natural perils. More than 320 confirmed tornadoes were reported in North America in 2015. The total cost of damage was estimated to be around \$1 billion US during the same year in North America alone. Over the years, researchers and scientists have been developing various methods to analyze the flow structure of tornadoes. For example, several laboratory scale models have been used to analyze the flow structure of the tornadoic like vortices. More recently, WindEEE a unique state-of-the art tornado generation facility has been built at Western University. The long term objective of project aims at modeling tornado structure and its interaction with topography and buildings and validating it with WindEEE tests. The present study aims at numerically investigating the interaction of a tornado like with two different types of topographical changes i.e., steep and shallow hills, and a tall building. The adopted swirl ratio (0.4) is the representation of a one-celled tornado which resembles F2 scale tornado.

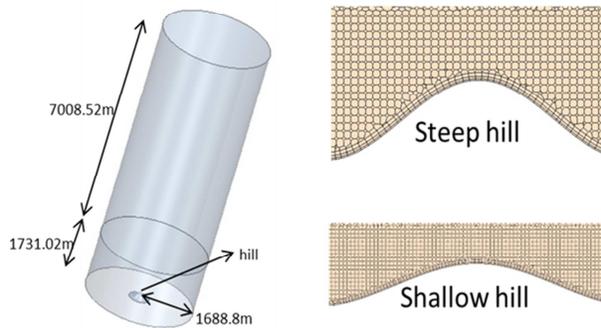


Figure 1: Computational domain and topographical changes

Pressure coefficients have been measured along the faces of the hills and along a particular circular section which have the radius of the hills or valley on the ground of the open domain. In this context pressure coefficient C_p was defined as,

$$C_p = \frac{P - P_0}{0.5\rho U_0^2}$$

where, P is the absolute pressure of the surface, P_0 is the atmospheric pressure, ρ is the density of air and U_0 is the reference velocity, which is maximum velocity at the hill height but in absence of the hill. For both cases, higher suction occurs at the core

center. Suction is higher for the steep hill case than the shallow hill.

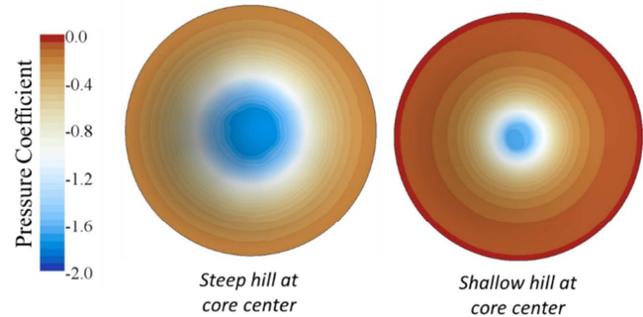


Figure 2: Pressure coefficient distribution at steep and shallow hill center

The other simulation pertains to tornado interaction with typical tall building. For this purpose a CAARC (Commonwealth Advisory Aeronautical Research Council) building was chosen as the model building.

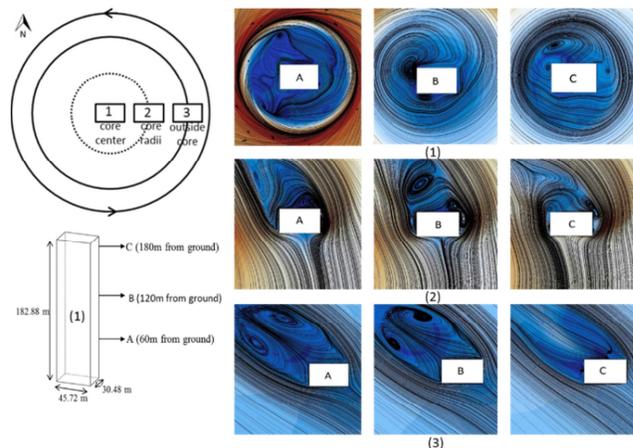


Figure 3: Flow structure for tall building at different locations from tornado core-center

The structure of the tornado flow interaction is shown in the above figures for a building location at the core center (location 1), core radii (location 2) and outside the core (location 3). The flow interaction at three different heights (height A, B and C at 60, 120 and 180 m from the ground) is also shown in Figure 1 for the three locations. More work is in progress to quantify the wind load and compare it with WindEEE experiments.

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CFD Based Aerodynamic Analysis – A Static Section Model of the First Tacoma Narrows Bridge.

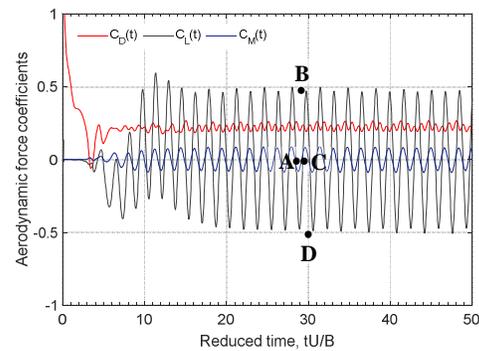
From economy and aesthetic perspective, plate girder decks have been preferably used in construction of long span bridges. However the sharp edged bluntness of such decks makes them vulnerable for wind action. Typical examples include, but are not limited to, strong oscillations sustained by White Bronx Bridge in USA (King 2003) and Long Creek Bridge in Canada (Wardlaw 1994), and to a total collapse of the first Tacoma Narrows Bridge. Following those experiences, aerodynamic mitigation measures have been devised through the use of wind tunnel iterative experiments.

The advancement in computational power has enabled simulation of such interactions and to propose aerodynamic measures through automated procedure. This involves the use of CFD for aerodynamic analysis and numerical optimization tools for iterative selection of mitigation measures. The method is well practiced in aeronautical and automobile industries. However a framework for applying such tools for long-span bridges needs to be developed and to be tested for practical implementation.

We have proposed a framework; implementation and testing of various subroutines of the framework is under progress. The case studies include identification and performance evaluation of mitigation measures for plate girder bridge decks. Illustrative results from the core routine of the framework, the CFD module, are presented in Figure 1. The Figure presents plots of unsteady aerodynamic forces and corresponding excitation mechanisms around an H-shaped deck for zero angle of attack. The simulation was carried out using unsteady SST κ - ω turbulence model for the flow domain and a static section model of a generic plate girder deck that mimics the shape of the first Tacoma Narrows Bridge deck having breadth-to-depth ratio of 5.

The time history plot (a) shows the quasi-steady drag, and highly fluctuating lift and torque with zero mean; all being normalized with oncoming dynamic pressure. The fluctuations are mainly attributed to temporal evolution of the pressure field around the deck as shown in the second column plots of (b, c, d, & e). This in turn caused by dynamics of shear layers separating from leading edges, rolling of vortices on the horizontal surfaces and shedding of vortices from the trailing edges of the deck as shown in the first

column plots of (b, c, d & e). Instants of net zero lift (instant A & C) correspond with quasi-symmetric pressure on the lower and upper surface of the deck occurring before moments of full dislocation of vortices from the trailing edges. The maximum peak lift (instant A) occurs with development of strong suction on top deck surface due to roiling of a strong coherent vortex and positive pressure recovery on bottom surface linked with shedding of a vortex from the lower trailing edge. The mirror image of this mechanism induces the minimum peak lift (instant D).



a) Time traces of aerodynamic force coefficients

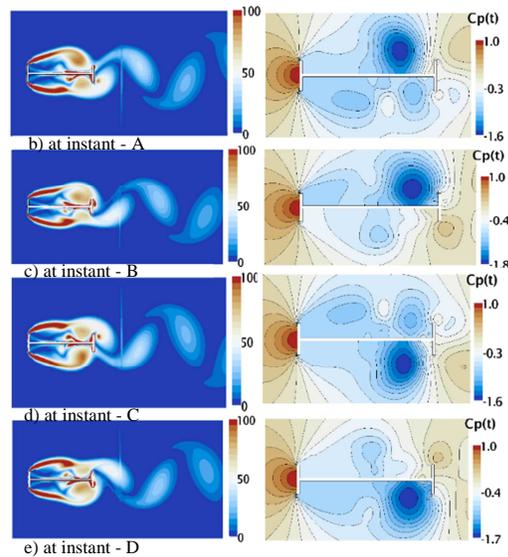


Figure 1: unsteady aerodynamic force coefficients for a static section model of plate girder bridge deck, and vorticity and pressure fields around the deck at instants of null (A & C), maximum peak (B) and minimum peak (D) lift force.

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Destructive Testing of a 1:3 Scale Model House

Load paths in light-frame wood structures are typically adept at transferring gravity loads to the foundation, often using nailed connections between the sheathing and rafters, and toenail connections between the rafters and stud walls. However, these connections have poor uplift resistance, as occurs in high wind speed events, causing sheathing or roof-to-wall connection failures.

Approximately 95% of the \$20-25 billion USD in economic losses from the 1992 landfall of Hurricane Andrew were caused by failure of part or all of the roofing system in residential light-frame wood structures. Improvements were made to building codes after this event, which saw enhanced performance of new or retrofitted structures in Hurricane Katrina. However, the economic losses caused by Katrina pointed to a lack of adequate load paths from roof to foundation in older structures.

Dr. El Damatty in collaboration with M.A. Steelcon, a structural engineering firm based in St. Catharines Ontario, have developed a temporary cable netting as an alternative to relatively expensive and invasive retrofitting option. This net is anchored to concrete piles outside the structure and can be applied prior to a high wind speed event to provide an uplift resistant load path.

This study plans to compare the performance of a model house with and without the cable netting applied. To do this, a 1:3 length scaled model house with no eaves and a 3:12 roof pitch is being tested until failure under real wind loading by exhausting wind outside through a contraction to the model platform. Then, an identical model will be tested with the cable netting system applied to assess its performance.

To achieve realistic failure, the roof truss member cross-sections and sheathing thickness are selected to reach stresses at failure similar to the corresponding components of a full scale structure at failure. Further, 2D common nails are used as toenails in the roof to wall connections to simulate a scaled-down withdrawal capacity while retaining the nonlinear behavior of the full scale toenail connection. This size of nail was selected after testing conducted at the Insurance Research Lab for Better Homes determined that their withdrawal capacity was appropriate to produce failure under the wind speeds available.

Recently, an initial concept model has been tested to assess the pressure profile of the roof, load-sharing

properties of the roof-truss system, and improvement areas for generating roof failure with the available wind speed.

The next stage of this project is to build another two models, incorporating changes made from analysis of the test data recently collected. These models will then be comparatively tested with and without the retrofit system.



10' x 10' x 4' model being tested 4.5m away from the aperture of the contraction



Strain gauge and pressure tap setup

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Behaviour of Pre-stressed Concrete Poles Under High Intensity Wind

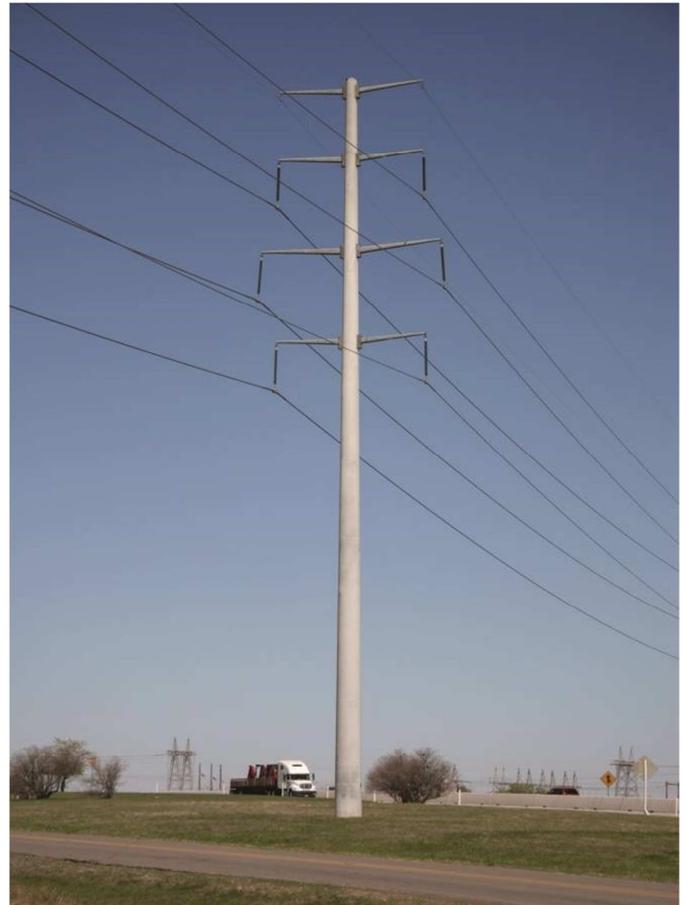
Transmission line structures play a great role in electrical energy transmission. The major components of a transmission line are conductors, ground wires, insulator strings and supporting towers. Pre-stressed concrete transmission poles are becoming widely used due to low installation and maintenance costs, appropriate delivery time and corrosion resistivity. The pre-stressed concrete poles are mainly subjected to dynamic normal (synoptic) and high intensity wind loading (downbursts and tornadoes), ice loads and maintenance loads. The behaviour of this type of poles under local high intensity wind, such as tornadoes and downbursts, has not been studied before despite the fact that significant failures have occurred during these conditions. This research is considered as part of a large scale research program that has been conducted by a number of investigators at Western University during the last decade.

A numerical technique which accounts for material and geometrical nonlinear behaviour due to the stress strain relationship of reinforced concrete, pre-stressing strands and time dependent changes that occur in the pre-stressed concrete, such as: shrinkage, creep and relaxation of strands, is developed and validated. The non-linear behaviour of the conductors under high intensity wind loading is included in this simulation using a closed form technique previously developed at Western University. The high intensity wind forces induced from the tornado and downburst events acting on the concrete poles and the conductors are calculated based on previously conducted computation fluid dynamics.

The behaviour of the poles under the effect of various probable tornado and downburst events is examined using the developed numerical model. The tornado and downburst locations and configurations leading to maximum straining actions and deformations in the poles are identified through an extensive parametric study. Provisions for the design of concrete poles always recommend that the poles remain un-cracked throughout under synoptic wind loading. However, existing poles are found to be subjected to plastic deformations, cracks and even failures when subjected to the critical tornado and downburst configurations.

It is concluded that the existing design procedures and practices for the pre-stressed concrete poles are inadequate to keep the pre-stressed concrete

transmission pole structures un-cracked while being subjected to those local high intensity wind events.



Pre-stressed Concrete Transmission pole

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Multiple Span Aeroelastic Transmission Line Subjected to Downburst Wind

High Intensity Wind (HIW) events (downbursts and tornadoes) are believed to be responsible for more than 80% of all weather-related transmission line failures worldwide. This study focuses on evaluating the critical response of transmission lines subjected to downburst loads. The main challenge of analyzing a transmission line under those events is the localized nature of the wind fields. This means a huge number of load configurations should be taken into consideration in order to evaluate the critical response of a transmission line subjected to downbursts. In addition, codes of practice provide very limited information regarding the loading profiles of downburst events affecting a transmission line, which makes the problem more challenging. Therefore, there is a pressing need to conduct advanced investigations such as wind tunnel testing to assess and evaluate the response of transmission line structures subjected to downbursts. A multi-spanned aeroelastic test of a transmission line system has been conducted at the WindEEE facility as shown in Figure 1. The test simulates a line consisting of V-shaped guyed towers similar to those that failed in August 2006 near the Township of Waubaushe as reported by Hydro One, Ontario. The aeroelastic model consists of seven towers and five spans of conductors. The model is built using a 1:50 length scale of the prototype. The downburst diameter simulated at WindEEE will be 3.2m, which represents a real downburst diameter of 160m.

The test plan has been designed to accommodate 180 test setups by varying the following: line's span, line's in-plane angle, conductor's properties, downburst velocity, and terrain exposure.

The main findings of this test will help in the following:

- Validate the built in-house numerical model that has been used in the numerical part of this research project. Sample of the results is shown in Figure 2.
- Investigate the critical load cases of downbursts on transmission line structures.
- Assess the aerodynamic damping of conductors under downburst wind load.

- Assess the effect of transmission line angle on its response under downbursts.
- Assess the dynamic behavior of the tower and its attached lines under downbursts.



Figure 1 Multi-spanned aeroelastic model of a transmission line structure

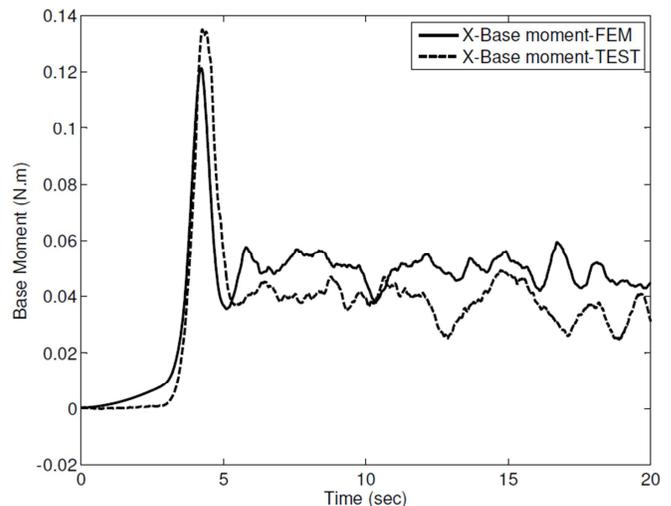


Figure 2 Built in-house Finite Element Model validation using the test results

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Ashraf El Damatty / damatty@uwo.ca

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Grants

NSERC / \$ 110,000 / 2012-2017

Investigation of complex shear and vortex flows with applications to wind engineering, energy and environment
Hangan

Western Strategic Support for Research Accelerator / \$ 40,000 / 2015-2016

Wind Sustainability and Resilience Index
Hangan

NSERC / \$ 540,000 / 2015-2018

Determination of load differences between straight winds and tornadoes in the WindEEE Dome
Hangan

Joint Usage Center for Wind Engineering Grant, Tokyo Poli / \$ 7,140 / 2014-2015

Comparison of tornado simulators
Hangan

Joint Usage Center for Wind Engineering Grant, Tokyo Poli / \$ 3,927 / 2015-2016

Calibration of Tornado simulators
Hangan

NSERC / \$ 25,000 / 2015

Investigation of wake and topographic effects on a wind farm performance
Siddiqui & Hangan

CFI / \$ 5,491,391 / 2015

Enhancing the resilience and sustainability of critical Geotechnical infrastructure
Newson, Hangan & others

SBM Engineering / \$ 66,000 / 2015-2016

Development of software for analysis of multi-storey wood buildings
El Damatty

NSERC / \$ 180,000 / 2015-2017

Numerical and Experimental Study of a New System for Retrofitting Roofs Subjected to Extreme Wind Loading
El Damatty & Bitsuamlak

Hassco Industries Inc./ \$ 75,000 / 2015-2016

Efficient alternative for material handling in rice straw power generating prototype
El Damatty & Gomaa

NSERC / \$ 25,000 / 2015-2016

Finite Element Modelling aspects of Mid-Rise Light Frame Wood Buildings
El Damatty

Connect Canada / \$ 50,000 / 2015

Comprehensive software for analysis of transmission line structures under high intensity wind
El Damatty

Hassco Industries Inc. / OCE / Connect Canada / \$ 50,000 / 2014-2015

Biomass processing technology for production of green power and value-added products
El Damatty & Gomaa

NSERC / \$ 25,000 / 2015

Investigation of wake and topography effects on a wind farm performance

Siddiqui

NSERC / \$ 25,000 / 2015

Thermal characterization of polyurethane-cement composites

Siddiqui

MITACS / \$ 13,333 / 2015

Accelerate development of new technologies and applications for advanced water treatment

Siddiqui

Events

Prime Minister Stephen Harper visit

On November 24, 2014 The Right Honourable Stephen Harper, accompanied by London West MP Ed Holder and London North Centre MP Susan Truppe visited WindEEE. Western was represented by Western President Amit Chakma and WindEEE Founding Director Dr. Horia Hangan, who toured the Prime Minister through WindEEE and provided a demonstration of the facility's capabilities. A lot of work goes into preparing for an event of this magnitude and the entire WindEEE team contributed to making it a complete success.



WindEEE in the Community

The Governor General's Canadian Leadership Conference

On May 29th 2015, WindEEE hosted a group from The Governor General's Canadian Leadership Conference. The Governor General's Canadian Leadership Conference is a two-week long event that brings together 250 of Canada's top emerging leaders to develop the next generation of leaders and discuss key issues that affect Canada. Competition to participate in this conference is fierce with over 1500 applicants for the 2015 event. Conference attendees are selected from business, labour, government, NGO, education and cultural sectors to provide a diverse range of expertise and ideas. This tour provided the opportunity to discuss a very broad range of topics, from general questions around green energy and severe weather, to more specific questions such as the effect of downbursts on airplanes at the Charlottetown PEI airport and the topography challenges faced by communities in Nunavut.

Canadian Association for Girls in Science

On April 8, 2015, WindEEE hosted a community outreach event for the Canadian Association for Girls in Science (CAGIS). CAGIS promotes, educates and supports girls aged 7-16 in pursuing careers within science, technology, engineering and mathematics. The WindEEE outreach event focused on providing education relating to Wind Energy and various weather phenomenon. The group had an opportunity to tour the WindEEE facility and build and test their own wind turbines.

TD Friends of the Environment

For 2014-2015 WindEEE continued their partnership with TD Friends of the Environment to provide seminars for grade 6-8 students educating them about Wind Energy. To date roughly 150 students have come through the program which provides the opportunity to participate in an interactive tour of the facility and complete a hands-on workshop. These tours provide students with an appreciation for the types of activities that take place at a university research facility, introduce them to a variety of wind and weather concepts and highlight engineering as a potential career option, at a critical age before selecting pre-requisite high school courses.



Chronicle



2014.09

First Tornado PIV tests

Laser Permit Issued

Filming for Missing Evidence TV Show

Downburst profiling complete

2014.10

WindEEE declared Research Ready

CEATI International tour and demonstration

1:300 Atmospheric Boundary Layer system developed



2014.11

Prime Minister Stephen Harper visits WindEEE

High Performance Computer comes online with SharkNet

DTU visits WindEEE for LIDAR training

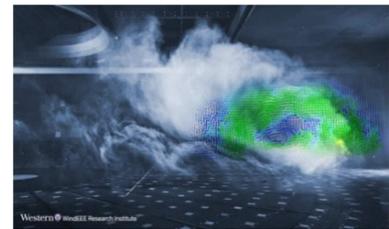
2014.12

First Downburst PIV

Pressure scanning system tubing system development

Donor signs installed at WindEEE

First 3D printed model at WindEEE



2015.01

WindEEE welcomes Technical Specialist (Gerry Dafoe)

Dr. El Damatty receives E. Whitman Wright Award

Southern Ontario Glider Group Tour

Dr. Hangan receives ENR Top 25 Newsmaker award

2015.02

FM Global tornado tests

DFATF, Industry Canada, MEDEI visit

WindEEE achieves LEEDs Silver accreditation

IBM tour

**2015.03**

CBC Nature of Things filming

Oxford University Material Science Engineering visit

GE Canada tour

2015.04

Transmission tower downburst testing

Hydro One, NSERC, OCE visit and demonstration

First UAV flight at WindEEE

Topographical model of London, ON fabricated

Dr. Siddiqui elected as Fellow of ASME

**2015.05**

Full scale solar panel pressure tests

CANCAM Conference presentations

PEIWEE study field tests

Governor General's Canadian Leadership Conference

2015.06

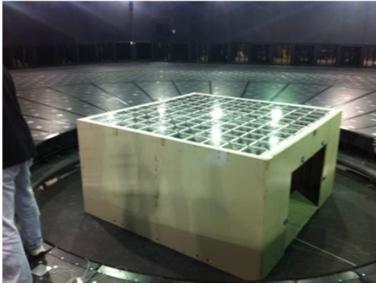
ICWE Brazil Conference

Bolund PIV experiments

Korean Institute of Land and Housing tour

Long Lake topographic study





2015.07

Dr. Bitsuamlak revives tenure

Israeli Ambassador to Canada visit

Wausau roof paver pressure tests

Singapore Power tour

2015.08

WindEEE Annual Summer Party

Turntable acrylic floor received



Media

ME1 Productions Inc. / Smithsonian Channel – The Missing Evidence: The Nevada Triangle

<http://www.smithsonianchannel.com/shows/the-missing-evidence/the-nevada-triangle/1003747/3418206>

New Scientist Magazine Feb 14 2015 (magazine and online)

<https://www.newscientist.com/article/mg22530082-600-bad-air-day-see-my-tornado-in-a-bottle/>

Engineering News Record Jan 21 2015 (magazine and online)

<http://www.enr.com/articles/7413-bottling-tornadoes-to-inform-structural-design?v=preview>

Windpower Engineering & Development – World’s first and in Canada: A ‘tornado-creating’ wind dome deploys an advanced 3D scanner

<http://www.windpowerengineering.com/construction/simulation/worlds-first-canada-tornado-creating-wind-dome-deploys-advanced-3d-scanner/>

Renewable Energy Magazine – Canadian researchers create ‘tornado-creating’ wind dome with wind scanner

<http://www.renewableenergymagazine.com/article/canadian-researchers-create-worlds-first-a-20141218>

ZephIR Lidar - World first as Canadian WindEEE wind dome deploys DTU / ZephIR WindScanner

<http://www.zephirlidar.com/world-first-canadian-windeee-wind-dome-deploys-dtu-zephir-windscanner/>

Wired - These DIY tornadoes are designed to improve the stability of buildings

<http://www.wired.co.uk/magazine/archive/2015/07/start/diy-tornadoes>

Maclean’s Canada’s Best Schools – Special 25th Anniversary Issue (2016 University Rankings)

Western Engineering News – Climate study offers insight into ‘skin’ of buildings

http://www.eng.uwo.ca/news/2014/climate_study_offers_insight_into_skin_of_buildings.htm

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