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Western

WindEEE Research Institute
Engineering, Energy & Environment

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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. A vigorous team re-organization and growth has been complemented by increasing the efficiency of the administrative framework.

The Institute has been instrumental in helping the University efforts to hire a Western Research Chair in Urban Sustainability that would certainly add to its valuable directly affiliated faculty members. 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. The outside membership expanded with the participation of external researchers in activities at the WindEEE Research Institute through national and international collaborations.

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 and the National Institute for Standards and Technology (NIST- USA). Collaborative graduate programs are already in place with the Danish Technical University (DTU) and University of Genova, Italy and other such programs are currently under development with Tonji University and Chongqing University in China and the Polytechnic University of Bucharest, Romania. Based on WindEEE RI collaborations, top international researchers have been attracted to conduct research and teach summer courses, their presence enriching the activities at Western Engineering and at Western in general, complementing the new graduate program in Wind Engineering which is unique 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.

During 2016-2017 period alone, the WindEEE RI core faculty group solidified its research outcomes producing 53 international journal publications, 57 conference proceeding publications and approx. 2 M$ in research funding. The core group faculty members at WindEEE RI have collectively trained 47 High Quality Personnel (30 Ph.D; 12 M.Sc and 6 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 tackled. A new large contract work on wind development problems has been completed. Substantial research funding has been now granted by the National Institute of Standard and Technology (NIST) and by the European Research Council (ERC).

A Pan-Canadian Researchers meeting took place in June 2017 and approved the creation of the WindEEE Innovation Grant extending the Canadian participation in WindEEE RI research. The Research Board is presently restructured into an International Research Board to better reflect the international research collaborations at WindEEE RI. Additionally, the WindEEE Advisory Board has been re-structured to better reflect the industry collaborations and its 3rd meeting took place in October 2017.

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 2017 /London, Canada

Governance Structure

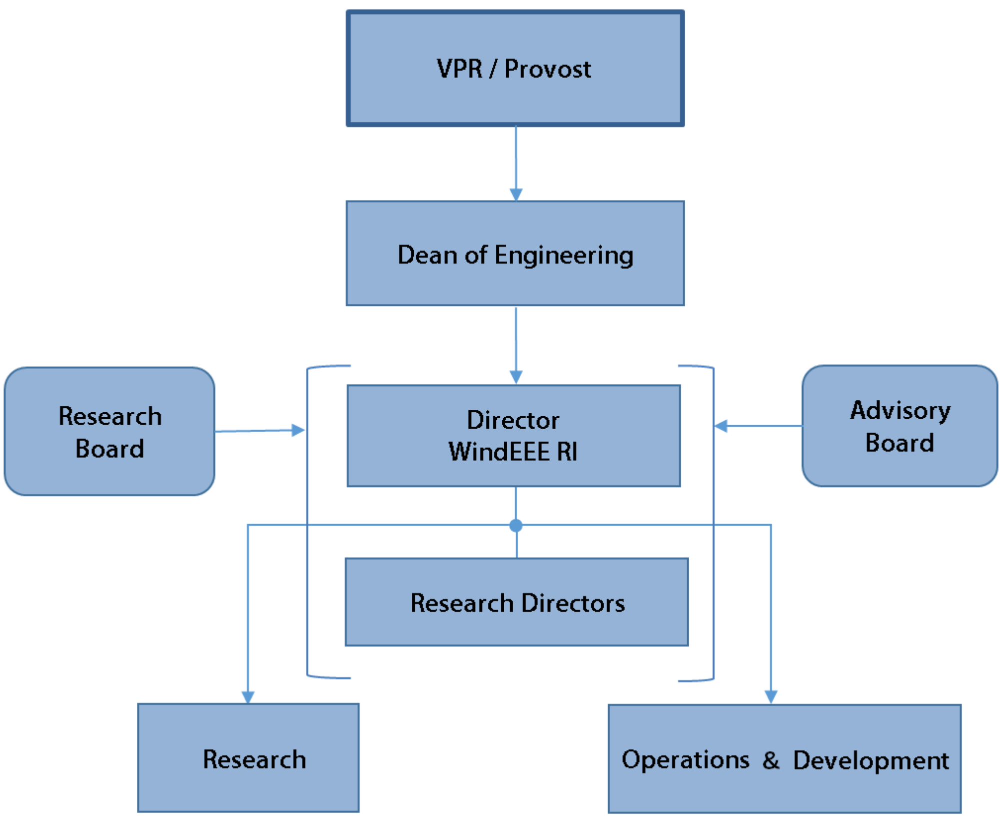
The **Governance Structure** provides both internal and external direction, innovative input and expert advice to the Institute in order to facilitate its development at Western and towards a National and International Institute, see Figure 1. The Director of the Institute reports to the Dean of Engineering.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

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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Dynamics of Thunderstorm Winds

M. Karami – PhD Student, supervisor: Dr. H. Hangan and Dr. K. Siddiqui
Extraction of Coherent Structures from Tornado-Like Vortices via POD Method

J. Chowdhury – MSc Student, supervisor: Dr. H. Hangan
Near surface investigation of Downburst flows

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Simultaneous Pressure and PIV Measurements on Low-Rise Buildings

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

A. Ashrafi – PhD Candidate, supervisor: Dr. H. Hangan

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K. Adamek – PhD Student, Supervisor: Dr. G.T. Bitsuamlak
Adaptive architectural forms and progressive aerodynamics

A. Melaku - PhD Student, Supervisor: Dr. G. T. Bitsuamlak
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B. Nighana – PhD Candidate, Supervisor: Dr. G. T. Bitsuamlak and Dr. F. Tariku
Optimal building envelope solar integrated thermal/PV systems

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Performance based wind design frame work for tall mass timber buildings

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Enhanced building energy performance evaluation

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Aerodynamic optimization of long span bridge sections

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Numerical and WindEEE modeling of tornado flow structure and its effect on communities

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Modeling non-linear aeroelasticity for high rise buildings

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Performance based design framework for tornado

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Hybrid numerical and experimental wind and earthquake modeling, Tongji University/UWO 2+2 Program

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Structural behavior of lightweight wood buildings under lateral loads

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F. Elezaby, Supervisor: Dr. A. El Damatty

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N. El Gharably– PhD Candidate, supervisor: Dr. A. El Damatty
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C. Santos – PhD Candidate, supervisor: Dr. A. El Damatty
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M. Hamada – PhD Candidate, supervisor: Dr. A. El Damatty
Transmission Lines Behaviour under Tornadoes Wind Loads

I. Ibrahim, supervisor: Dr. A. El Damatty
Downburst Mitigation Through CFD and Structural Analyses of Electrical Transmission Systems

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Multiple Span Aero-elastic Transmission Line Subjected to Downburst Wind

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Characterization of Three-Dimensional flow structure in Boundary Layers over a Flat Plate

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Investigation of Flow behavior in a PCM-Embedded Flow Channel

S.Jevnikar – M.E.Sc. Student, supervisor: Dr. K Siddiqui
Investigation of Flow Behavior in the Transient Liquid Phase of a PCM Thermal Storage

K.Teather – M.E.Sc. Student, supervisor: Dr. K. Siddiqui
Investigation of Pore-Scale Phase Change Process in PCM-Embedded Porous Media

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

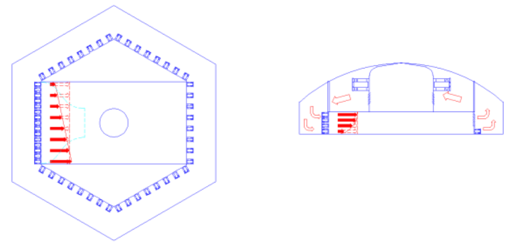


Figure 1 – Straight Flow Closed Loop

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

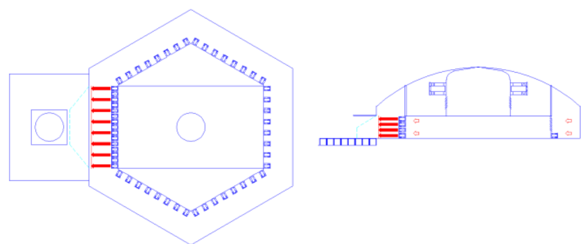


Figure 2 – Straight Flow Open Loop

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

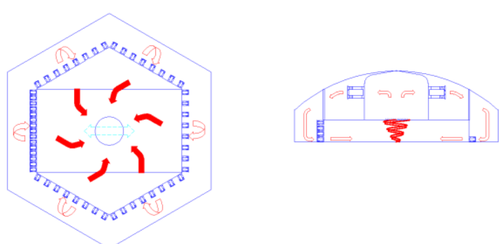


Figure 3 – Tornado

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

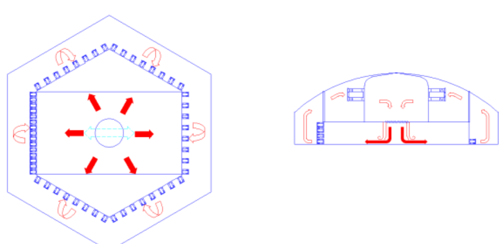
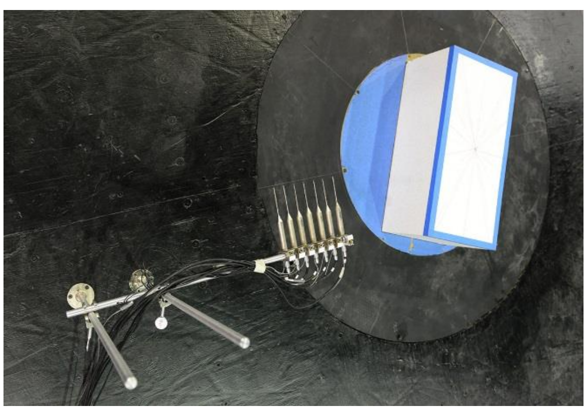


Figure 4 - Downburst

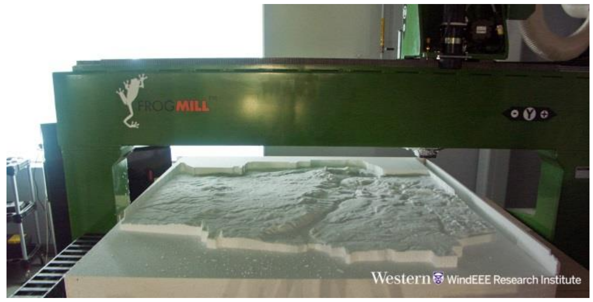
Example Uses

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.



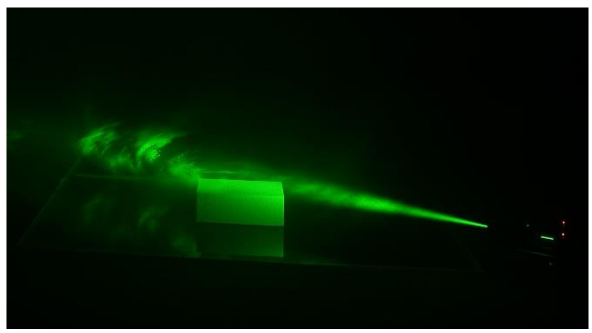
WindEEE can also be used to test large scale, prototype or full scale objects to a wide variety of wind fields. Applications range from testing of full scale solar panels and small wind turbines, large scale topographic and canopy models, large and full scale wind turbine components (blades, towers),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

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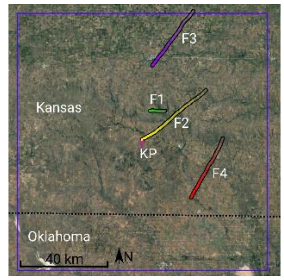
The Kansas Project—Surface Pressures due to Different Tornadic and Atmospheric Boundary Layer Flows

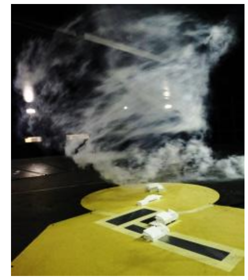
The Kansas Project (KP) will challenge the architectural status quo, which is to design to keep the elements at bay. The purpose of the project is to investigate the question: How can design foster a more symbiotic relationship between people and weather? In other words, the goal of the project will be to compel the dweller to see, hear, feel and experience the weather with clarity and intensity as they never have before. This project will include an exploration of ways we can harness the weather for its sustainable resources. And since the site just happens to be at the global epicenter of extreme weather, the KP will still take a good hard look at how we design to stay safe.

In this study, experimental methods are used to investigate resilience of various designs of the KP development to both atmospheric boundary layer (ABL) and tornadic flows. First, a generic building design submitted by the developer was exposed to WindEEE-generated ABL flows (open country exposure) and the external pressure distribution was quantitatively assessed. For this research, an in-house software package—Advanced Dynamic Response In situ ANalyzer - has been specifically developed in order to visualize the near real-time surface pressure distribution on the faces of investigated buildings. Next, the alternative building designs and a number of different building layouts were subjected to the WindEEE tornadoes equivalent to EF1, EF2, and EF3 rated twisters. Similarly to the ABL flow case, the external pressure distribution was quantitatively analyzed utilizing the in-house pressure visualization software.

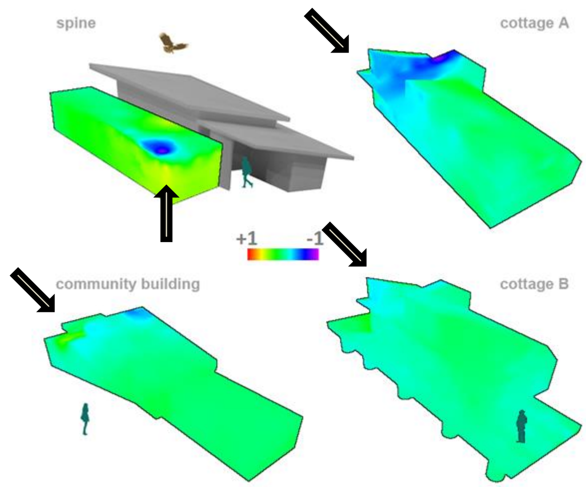
EF1 tornadoes produce more localized suctions when compared to EF2 and EF3 tornados. EF3 tornadoes result in suctions that typically encapsulate the whole building or sometimes even a couple of buildings. For instance, Cottage B is under the influence of EF3 tornadoes, but it is not affected by an EF1 tornado when both are centered above the Community Building.



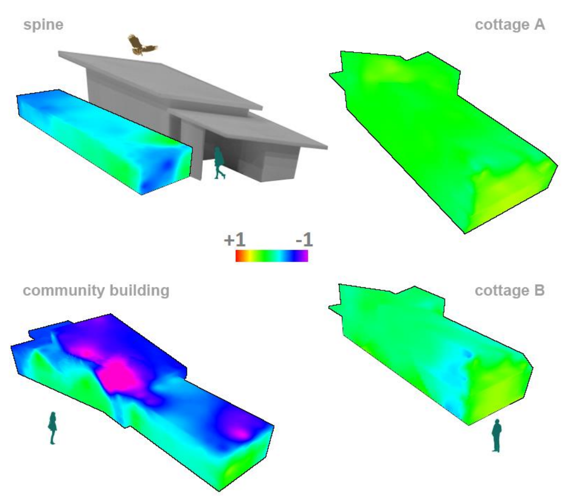
Most probable tornado tracks around the KP site



The KP buildings subjected to WindEEE tornado



Surface pressures due to the ABL winds



Surface pressures due to an EF3 rated tornado

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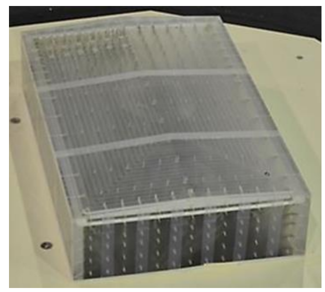
Simultaneous Surface Pressure, PIV, and Cobra Probe Measurements in Tornadic Flow

Every year, tornadoes cause massive destruction to life and property. Nearly 1000 tornadoes are reported annually in the US and Canada, and their annual damages can exceed over one billion dollars. The conventional low-rise timber buildings and light-frame constructions which account for majority of the residential buildings are considered the most severely affected structures.

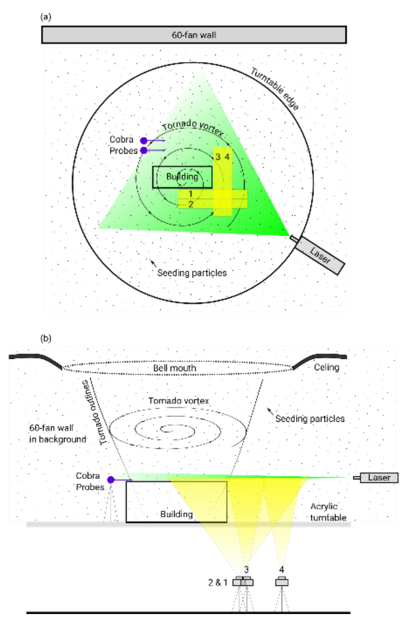
There is a limited number of studies that investigated the wind loads and flow structure around low-rise buildings for tornado-like vortices. For instance, Jischke and Light (1983) and Bienkiewicz and Dudhia (1993) studied wind loads and surface pressures on small building models in both tornado-like and atmospheric boundary layer (ABL) winds. Their studies showed that the tornadic winds were significantly stronger (3–5 times), and the surface pressures on the building models were also considerably different from the ABL winds. They concluded that the ABL approach utilized in the conventional straight flow wind tunnels is not sufficient for the estimate of tornadic wind loads. A new approach of measuring tornadic flows is needed.

In this study that is currently in progress, for the first time, simultaneous surface pressure, particle image velocimetry (PIV) and Cobra Probe measurements of the tornadic flow around a low-rise gable-roofed building model (i.e., NIST building) are conducted in the WindEEE Dome. The main goal of this research is to investigate the effects of stationary and translating EF-1 and EF-2 rated tornadoes on the NIST building with different heights, as well as to measure the velocity field around the building using PIV and Cobra Probe techniques.

A setup of four CCD cameras with a spatial resolution of 4096 × 728 pixels were used to capture images of the flow around the building in horizontal planes as shown in the figure on the right. The field of view of the camera was adjusted and pixel to meter conversion ratio was determined. The light sheet with uniform thickness of 2 mm was created using spherical and cylindrical lenses. The cameras were connected to a cluster of image acquisition systems. A four-channel digital pulse/delay generator was used to control the timing of the laser light pulses and to synchronize them with camera frames. For each experimental run, images were acquired at a rate of 200 Hz resulting in 100 vector maps per second. A stage smoke machine was used to fill the whole testing chamber with seeding particles. The cameras were located on a tripod underneath of the transparent acrylic turntable. This setup provided the unique opportunity to measure the horizontal velocity field of the tornado-like vortex with minimal flow alteration at a large field of view.



NIST building model



Experiment setup (a) top view and (b) side view

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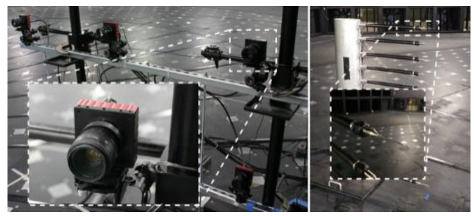
Simulation and Characterization of flow in Large-Scale Laboratory Produced Downbursts

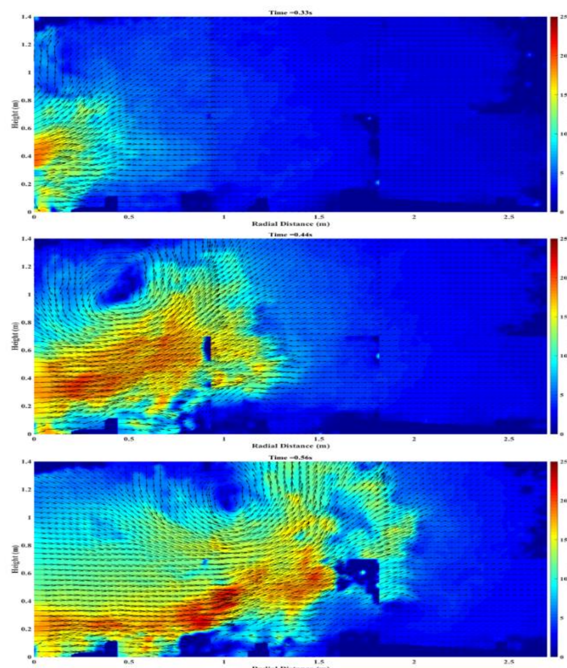
Downbursts are a natural event that occurs due to thunderstorms produced by a cumulonimbus cloud causing a strong downdraft which induces an outburst of damaging winds on or near the ground. This radially divergent wind with high wind velocity transpires when descending air hits the ground which can cause immense damage to the ground-mounted structures. As the strength of downbursts is measured by its wind speed both horizontal and vertical and the height above the ground at which the maximum horizontal wind speeds occur, it is of importance to evaluate these parameters. This current study employs Particle Image Velocimetry (PIV) technique in a large-scale laboratory produced downbursts in the WindEEE dome at Western University to understand the wind flow field near the ground. Effect of downbursts jet diameter (D) on the flow structures is investigated here in this study.

The experiment is conducted in Wind Engineering Energy and Environment (WindEEE) dome at Western University which has the capability of producing both synoptic and non-synoptic wind systems. The central chamber is 25 m diameter hexagonal with total 106 fans installed. Wind velocity in the downbursts is measured by the PIV (Particle Image Velocimetry). To capture the flow field over a large area, six 12 MP high-speed CMOS cameras are used that covered a region of 2.7m x 1.4m in a vertical plane which is placed at a distance of 3.5 m from the center of the downbursts. Three different fan speeds in the upper plenum are used to investigate the Reynolds number effect on the flow. Two different jet diameters (3.2 m and 5m) are employed to record wind speeds at high frequency in the downbursts flow. TFI cobra probes are also placed on a vertical mast as shown in figure 1 (right).

The main objective is to study and accurately characterize downburst flows in a laboratory setting and propose new scaling guidelines. Several cases will be studied to understand the effect of downburst diameter on surface spacing (h/d), Reynolds dependency, the influence of impingement surface roughness, downburst translation and multiple events. Vortex formation of a single event with H/D<1 and no roughness is shown in figure 02. Towards this goal new and existing measurement techniques for large-scale flows will be developed.



Array of 6 12 MP high speed CMOS cameras (left) and a mast is equipped with 12 equally spaced Cobra probes



Vortex formation of DB experiment, H/D<1 with no roughness

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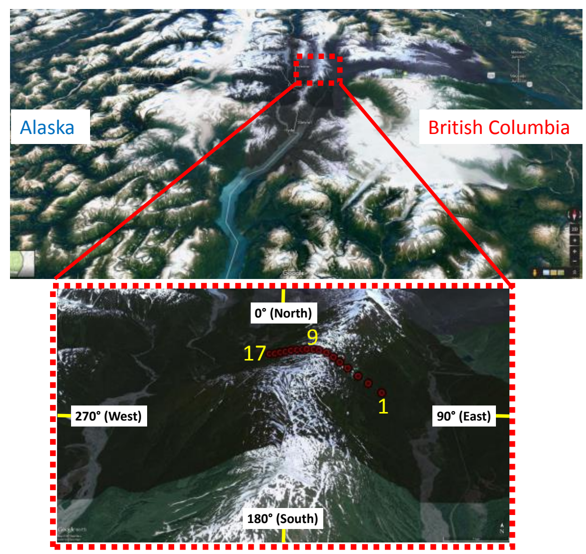
A Hybrid Approach for Evaluating Wind Flow over a Complex Terrain

Building codes provide guidelines to estimate wind speed over isolated hills, ridges and escarpments. In nature, an isolated hill in a large terrain with homogeneous roughness is a rare phenomenon and usually a hill is surrounded by other hills in the vicinity. Previous studies have reported that the building codes would lead to conservative results as the codes overpredict the wind speed-up over the hills.

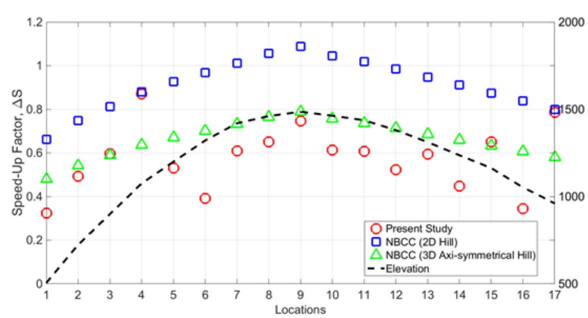
Both numerical and experimental approaches have been adopted to study the wind flow over complex terrains. Numerical simulations have the advantages of providing high resolution flow field information and performing parametric analysis at low cost. One of the major challenges in simulating wind flow numerically is to generate the time dependent inflow boundary conditions with the appropriate turbulence characteristics. In this regard, wind tunnel experiments are much more reliable compared to the numerical simulations. From the structural loading perspective, simulating the time dependent inflow condition is of utmost importance to estimate the peak wind loads.

In this study, a combination of numerical and experimental techniques have been used to estimate wind speeds over a complex topography. Three dimensional numerical simulations were performed to (i) identify the critical wind directions for some specific locations on the topography, (ii) analyze the wind flow structures around the same locations and (iii) get the appropriate boundary conditions at the leading edge of the experimental model. The boundary conditions obtained from the numerical simulations were then replicated in the WindEEE Dome at Western University in order to obtain realistic wind speeds over the topography. The speed-up factors calculated based on the present study are compared with the National Building Code of Canada.

From the numerical simulations, three critical wind directions were identified: 120°, 180° and 330° (where, North 0°). For 120° and 330° wind directions, the mean wind speeds on the windward side of the crest was much higher compared to the leeward side. However, for the 180° wind direction, where the ridgeline of the hill runs parallel to the wind directions, wind speed was overall uniform on either side of the crest. Contrary to the mean wind speed, 3-s gust wind speeds were much higher on the leeward side. In some cases, leeward locations produced as high wind gust as the location at the highest elevation. The speed-up factors for the maximum 3-s gust wind speeds at each of the location were compared with the National Building Code of Canada. Overall, the building code over-predicted the speed-up factors. Although over-predicted, the 3D axisymmetric hill assumption gave more accurate prediction of speed-up factors obtained from WindEEE testing compared to 2D hill.



Google Earth® view of the topography with the measurement locations (red circles)



Comparison of speed-up factors between present study and building code

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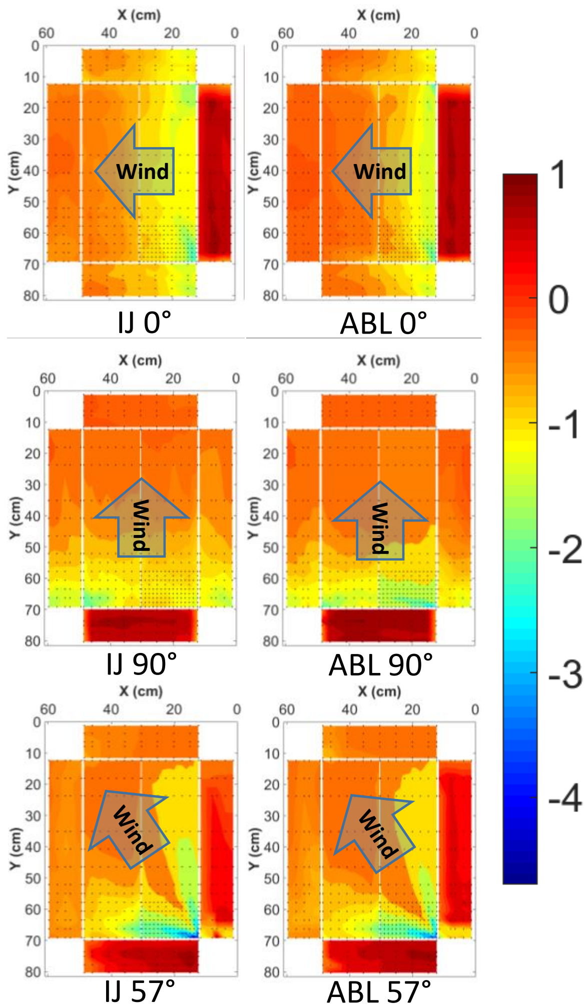
Aerodynamic loading of a typical low rise building for an experimental stationary and non-Gaussian impinging jet

Separation of thunderstorm from non-thunderstorm wind events is typically based on inspection of stationarity, Gaussianity, peak values, and gust factors from wind speed time seriea. For example, downbursts are strongly non-stationary and non-Gaussian wind events, whereas the standard synoptic winds are stationary and Gaussian. Interestingly, De Gaetano et al. [1] introduced a new class of wind events characterized by stationary, but non-Gaussian statistics. In addition, maximum wind speeds and gust factors associated with these intermediate events are fairly large, but not as large as for the downburst cases.

The main objective of this study is therefore to provide experimental aerodynamic loading data for stationary but non-Gaussian wind events. As demonstrated above, these wind records represent an important part of the real wind events in mixed climates. A new-generation wind facility—the Wind Engineering, Energy and Environment (WindEEE) Dome—at Western University in Canada has a unique capability of replicating stationary and Gaussian, as well as non-stationary and non-Gaussian flows. Present study demonstrates an additional capability of this facility to simulate stationary non-Gaussian winds as a special case of a stationary impinging jet (IJ) flow. Comparison of wind loads on the building between atmospheric boundary layer (ABL) flow and the IJ flow is also performed in this study.

The intermediate wind event created by the continuous radial IJ at WindEEE is stationary with statistical non-Gaussian properties similar to the event recorded at the Port of La Spezia in Italy. Skewness, kurtosis, peak wind speed, gust factor and turbulence intensity between the two records (WindEEE and full scale) are compared to characterize the IJ flow at WindEEE as well as to obtain scales. Corresponding scales between WindEEE and full scale event are; velocity 1:1.2, time 1:84 and length 1:101.

The mean pressure coefficient (C_P) distributions on the building surfaces are found to be similar between the IJ and the ABL cases, with mean roof suction higher on the roof close to the eave for ABL compared to IJ. However, when 3 s peak C_Ps are compared, the IJ produced localized higher roof suction than ABL especially for the corner angle case. When wind loads are compared with the ASCE standard, it is found that except for one zone on the roof (Zone F), the ASCE standard provides conservative design loads for the building orientations (0°, 57° and 90°) tested in this study.



Contours of 3 s peak C_Ps (Lieblein's BLUE Method)

[1] De Gaetano P, Repetto MP, Repetto T, Solari G. Separation and classification of extreme wind events from anemometric records. J Wind Eng Ind Aerodyn 2014;126:132–43. doi:10.1016/j.jweia.2014.01.006.

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Performance Testing of Industrial Wind Turbine

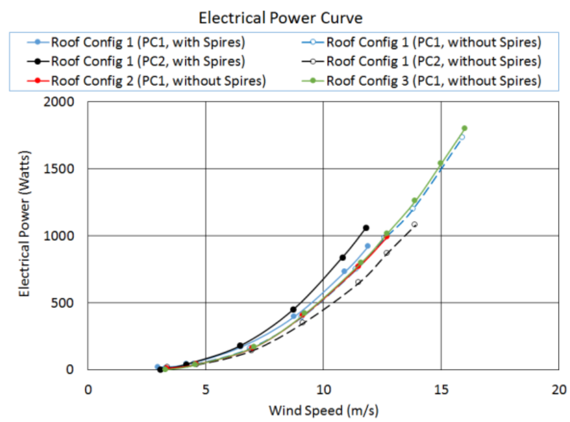
Tests have been conducted at the WindEEE Dome for a prototype wind turbine to investigate the performance of the turbine for various roof configurations and wind conditions. The turbine tested had five units and was mounted on a gable roof structure. Wind speeds were varied from 3 m/s (10.8 km/h) to 16 m/s (57.6 km/h). Turbulence intensity of wind was also varied between 4% and 23%. Higher turbulent flow (23% turbulence intensity) represented the similar turbulence that the turbine would encounter in a typical open country terrain. Other than the flow, the roof was also modified several times to boost the power output of the turbine.

CFD simulations were performed for two gable roof buildings with roof slope of 30° and 45°. The industrial wind turbine (RB2) was placed on the roof ridge. The principal objective of the simulations was to investigate the flow around the building and around the RB2 system. Therefore, the RB2 system was modeled as a rectangular block without the blades.

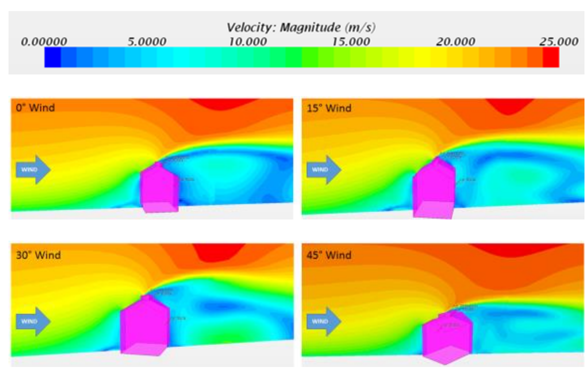
For this testing, 60 fans on one wall in the WindEEE Dome along with a 1:3 contraction were employed to generate the desired wind speeds. All 60 fans were run at a uniform RPM for a single wind flow case. From one wind flow case to another, RPM of the fans were varied from 10% to 70% of the fans' rated RPM. Testing was also conducted with and without spires in front of the 60 fan wall to see the effect of turbulence on the performance of the wind turbine. Spires are essentially a triangle shape structure which adds turbulence to flow without affecting the mean wind velocity significantly.

Different roof configurations did not improve the power output significantly. However, higher turbulence in the flow resulted in higher power output for the same configurations. Overall, efficiency of the electrical components was between 60 and 80% and power coefficient was in between 0.23 and 0.41.

The RB2 model on the roof in the WindEEE test chamber



Electrical power curve for different roof and flow conditions



Contours of velocity magnitude in a vertical plane for 30° roof slope

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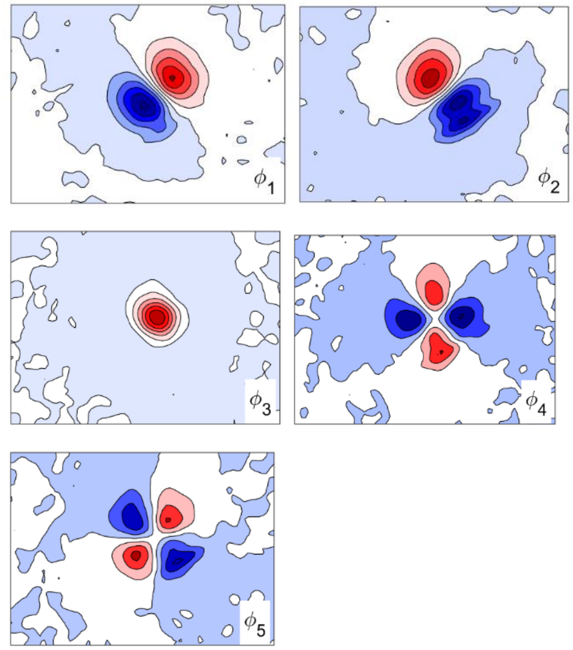
Extraction of Coherent Structures from Tornado-Like Vorticies

There have been few work on the study of interaction between tornado-like vortices and structures. Although these studies provide fairly some insights into pressure distribution in tornadic flows, they all lack clear properties of dominant patterns of pressure distribution that are responsible for large scale fluctuations. Moreover, it is important to identify the dynamic characteristics of tornado-like vortices that are believed to be important in structural damage. The main difficulty of this task is attributed to the highly unsteady and turbulent nature of the flow.

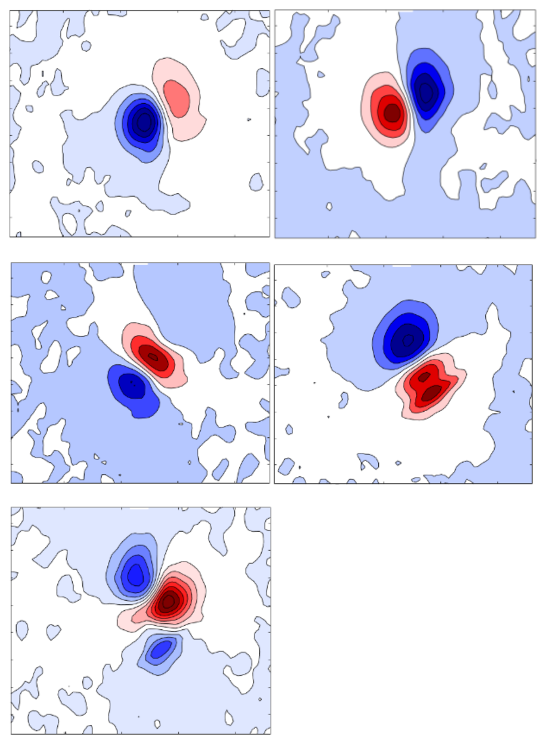
Coherent structures that provide a simplified but physical description of the flow are conventionally extracted by proper orthogonal decomposition (POD) method. However, this method sometimes fails to provide meaningful coherent structures. This is believed due to the non-justified orthogonality constraint imbedded in the POD. To mitigate this problem, we introduced independent component analysis (ICA) which does not have orthogonality restriction.

Here, we applied POD and ICA on the velocity field of tornado vortices. The experiment was done by PIV in a model of WindEEE Dome. Figure 1 shows the first five POD modes. Modes 1 and 2 represent two vortices. Mode 3 shows a single vortex and modes 4 and 5 present four small vortices. Figure 2 shows the ICA modes extracted from POD modes. Modes 1 to 4 represent two vortices and last mode shows three small vortices. When we compare ICA mode 5 with POD modes 4 and 5, we figure out the POD modes are non-physical. In fact, we only have three small vortices, but POD tends to make it symmetric and thus results in four vortices.

In the next step, we will apply Dynamic-POD which helps us to see how these modes change with time. In other words, we would be able to extract dynamic coherent structures.



The first five POD modes of the velocity fields at S=0.25.



The first five ICA modes extracted from the data space defined from POD modes.

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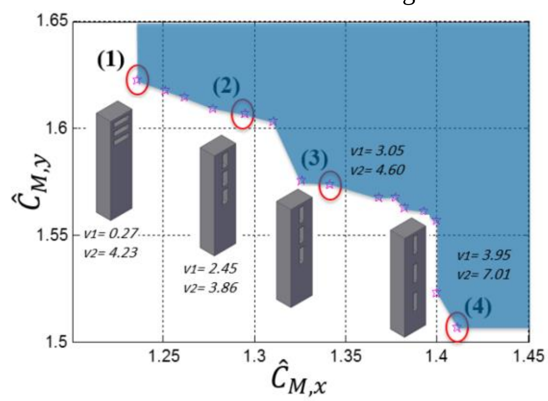
High Performance Computing for Assessing and Mitigating Extreme Wind Effects on Buildings and Cities

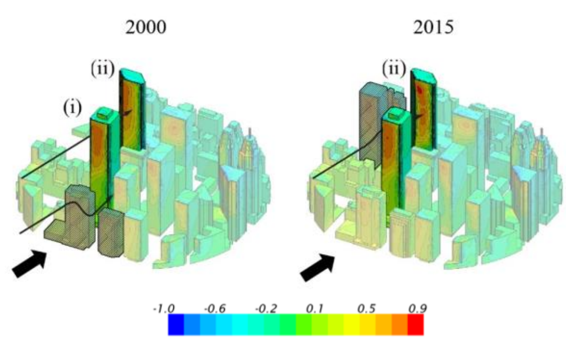
To maintain the prosperity of our communities, it is imperative that a comprehensive framework be developed to assess and optimize the impacts of extreme climate on cities. The current project aims to develop a multi-scale climate responsive design framework that accounts for the complex interaction between wind and buildings. This computational framework, at neighborhood scale, models urban micro-climate necessary to assess the impact of changing city topology on the pedestrian level wind, air quality and to generate boundary conditions for small-scale simulations. At building scale, it develops a full numerical aeroelastic model (e.g. building model that flex) immersed in turbulent city flows, for the first time. This frame work when integrated with artificial intelligence based optimization procedures, allow optimizing tall building aerodynamics (shape) and dynamics (structural systems) appropriate for current era of booming tall building construction. As a result, Canada will save materials and energy in one of the most resource intensive sector, while enhancing the safety during extreme climate.

For successful implementation of the framework, a high-performance computing environment and experimental validations are necessary, which are being enabled by two unique research facilities in Canada, BlueGene-Q/Sharcnet (high performance computing facilities) and WindEEE Dome (unique wind testing chamber capable of generating multiscale wind), respectively. The optimization process is carried out by introducing three openings at different heights of the building. The objective of the optimization process is to identify the optimal aspect ratio and distances between the openings that produce the best aerodynamic performance.

With regard to city scale, changes in aerodynamics due to the continuous urban development has been investigated. This need arises from changes in the flow field at a city scale, which leads to a significant variation in wind-induced loads on structural systems as well as non-structural components and cladding. With the change in urban topology, an individual building immersed in a complex surrounding can experience different flow mechanisms, such as wake effects, channeling and sheltering etc. These flow mechanisms depend on the shape, height and location of the surrounding structures, which alter in time with city development. We are currently working on investigating the risks associated with changing wind loads as urban surroundings develop.



Constrained opening optimization for tall buildings



Alteration of wind loads with city development

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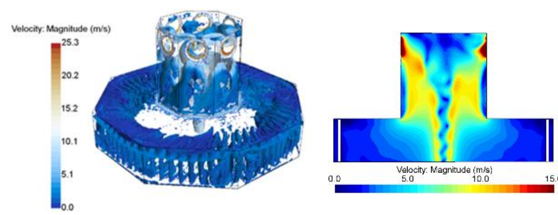
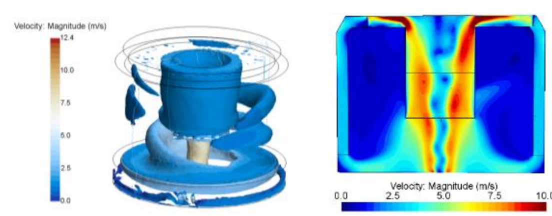
Numerical Tornado Model for Common Interpretation of Experimental Simulators

Numerical simulation of tornado-like vortices, like those produced in experimental facilities, poses many challenges. This is attributed to the complexity of the flow-field and the common practice of using the geometric dimensions and configuration of physical elements (like guide vane angle, ceiling height, etc.) of the experimental simulators to extract the parameters needed to characterize the generated vortices. The inherent differences in geometric dimensions and vortex generation mechanism of the existing experimental tornado simulators makes such vortex characterization very ad-hoc in nature and hinders direct comparison and validation of results. Therefore, to facilitate a universal interpretation of results, a simplified generic numerical tornado model, representing the three-major existing experimental tornado simulators, is developed in this study. The three experimental simulators in consideration are VorTECH at Texas Tech University, Tornado Simulator at Iowa State University and WindEEE Dome at Western University as representatives of “Ward” type, “top-down” type and “3-D wind chamber” type facilities, respectively.

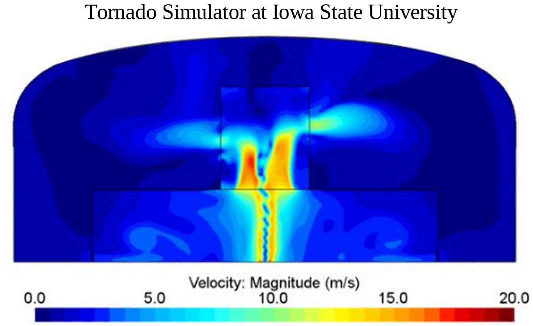
The simplification of experimental tornado simulators into one numerical model is based on identifying the flow characterizing parameters for various configurations of each experimental facility and then utilizing them for a generic model. These parameters like radius of updraft, inflow depth, etc., were strictly obtained from the flow-field inside the experimental simulators (generated numerically), as opposed to directly using the physical dimensions of the experimental facilities to obtain the same. First the geometric parameters of the flow field were identified, i.e. inflow depth ($\boldsymbol{h_0}$) and radius of updraft ($\boldsymbol{r_0}$). An important characteristic of the flow-field is that $\boldsymbol{v_z \approx 0}$ approximation should hold true (i.e. negligible updraft) up to the height of inflow at the radius of updraft location (no axial velocity within the inflow depth at the radius of updraft). Then, the geometric parameters of the physical simulator were identified, i.e. height of location of updraft hole (or bell mouth of the exhaust region) ($\boldsymbol{h_u}$), and the radius of the updraft of hole (or bell mouth) ($\boldsymbol{r_u}$). It was observed during this study that the effective radius of updraft hole may or may not be equal to the actual radius of the physical updraft hole in an experimental set-up, which had to be accounted for in the simplified model. Thus, the flow geometric parameters ($\boldsymbol{h_0}$ and $\boldsymbol{r_0}$) and simulator geometric parameters ($\boldsymbol{h_u}$ and $\boldsymbol{r_u}$) dictate the dimensions of the simplified computational domain, while the kinematic parameter (swirl ratio or ratio of $\boldsymbol{v_t}$ and $\boldsymbol{v_r}$ at inlet) governs the inflow boundary condition.



VorTECH at Texas Tech. University



Tornado Simulator at Iowa State University



WindEEE Dome at Western University

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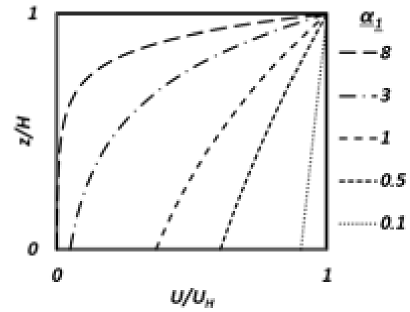
New Analytical Model for Air Flow in Canopies for Broader Range of Packing Densities

Reliable canopy layer velocity profile is one of the essential methods to characterize local transport around plant/building canopies and other obstacles. Moreover, such reliable models also help in estimation of proper canopy boundary drag contribution to the atmospheric scale analysis. However, existing transport models for canopy flows exhibit limitations especially in low and high packing density scenarios.

In the current approach, the canopy flow model is derived using consistent analytical procedure for obstacle canopy of defined morphological state. The derivation process involves the simplification of governing Navier-Stokes equation by employing relevant assumptions for flow past system of vegetative or urban roughness settings. First principles from turbulence mixing and eddy diffusivity are coupled with linearized frictional drag formulations to come up with a mathematical model for flow near obstacles of various packing densities.

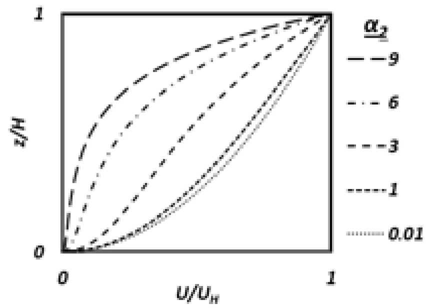
The recognition of relationship, from literature survey, between space averaged mean velocity and eddy velocity in fully developed, homogeneous turbulence, and steady flow in canopies is used to develop the new model. The eddy velocity is found to be predominantly proportional to the space averaged mean velocity the in canopies. This is in contrast to the conventionally widely considered case of constant mixing length (Inoue 1963, Cionco 1965) or constant eddy diffusivity (Cowan 1968).

Results indicate that the new canopy layer mean velocity profile displays superior traits in terms of the physical essence than conventional models found in literature. The present model satisfies vital conditions such as obeying no-slip condition near ground, matching the ABL (Atmospheric Boundary Layer) conditions under sparse packing scenarios and predicting counter flow behaviour under very dense plant or building arrangements. Experimental results from literature are then utilized to ascertain the consistency of the relation and hence determination of the model coefficients. The finding is an important step understanding and applications, such as heat and pollution transport among others.



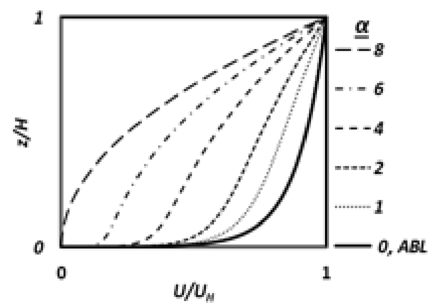
a) Inoue's model (1963)

$$U/U_H = \exp[\alpha_1(\zeta - 1)]$$



b) Cowan's model (1968)

$$U/U_H = \left[\frac{\sinh(\alpha_2 z/H)}{\sinh(\alpha_2)}\right]^{1/2}$$



c) Present model

$$U/U_H = (\alpha/8)\zeta^2 + (1-\alpha/8)\frac{\ln(\zeta/\zeta_0)}{\ln(1/\zeta_0)}$$

Canopy mean velocity profile (α_1, α_2, and α represent coefficients of the models, dependent on the density of the canopy)

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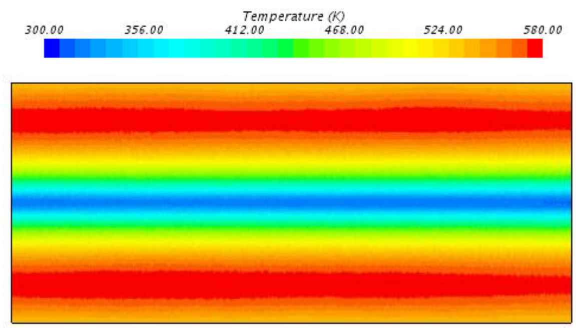
Advanced Building Envelope Systems: Thermodynamic Optimization of Building Integrated Photovoltaic/Thermal System (BIPV/T)

The building envelope is the part of the building that separates the interior from the exterior. It includes the walls, roofs, floors and openings. These enclosure components harmonize to maintain a safe and stable indoor environment by categorically providing the basic control, support, finish, and distribution functions. In view of sustainability, these functions can be extended to include energy generation and harnessing. Hence, sustainable development demands creation of advanced innovative building envelope systems which is the premise for design and adoption of BIPV/T systems for dual solar energy utilization in buildings.

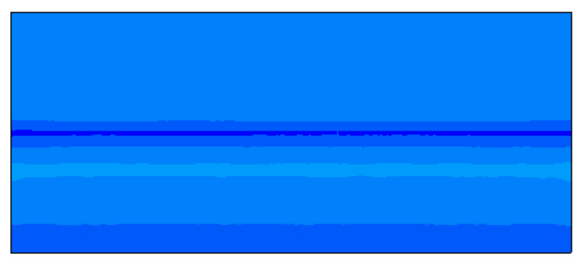
BIPV/T's are advanced building envelope systems that combine the functionalities of the building enclosure, solar cells and thermal collector in one product. BIPV/T systems are therefore complex systems in that the useful thermal and electrical energy output is dependent on a combination of climatic, envelope, insulation, covering, absorber configuration, and operational parameters. It is therefore necessary to determine the key parameters that impact the thermodynamic performance as well as develop a framework/procedure to systematically optimize the performance of BIPV/T systems. Further, research in BIPV/T is relatively new, hence, it is required to develop concepts that enhance energy extraction especially adoption of multiple fluids for a more efficient energy extraction.

To do this, an initial field experimental testing to generate data for validation of numerical simulation will be done using the whole building performance laboratory (WBPRL) at British Columbia Institute of Technology (BCIT). The sensitivity analysis to determine the key design and operational parameters that impact the thermodynamic performance of the BIPV/T system will be carried out. A numerical technique incorporating NSGA II and simplified thermal models, to optimize the key parameters to maximize the overall and exergy efficiency of the BIPV/T will be developed. Finally, the optimal solutions will be validated numerically (CFD) at SHARCNET and experimentally.

Preliminary results from CFD simulations show that the PV surface temperature is sufficiently reduced by passing a heat transfer medium. Further, the flow rates in the bi-fluid collector needs to be optimized to ensure a significant improvement in energy performance of the system.



No cooling: PV Surface temperature



Bi-fluid cooling: PV Surface Temperature

Effect of cooling on BIPV/T system efficiency

Heat Transfer Medium	T_{cell} (K)	$\eta_{electrical}$ (%)
None	513	0.61
Water, 0.03kg/s	507	0.72
Air, 0.14 kg/s	322	10.7
Air + Water, 0.14 kg/s + 0.03 kg/s	321	10.8

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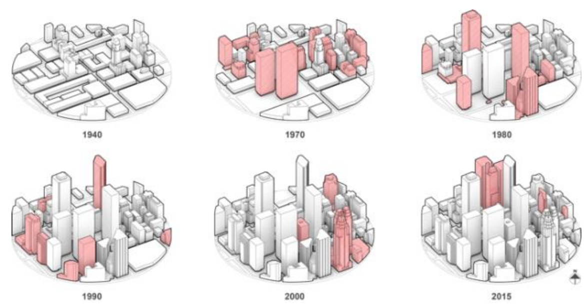
A framework for the multi-scale design of sustainable and resilient cities

With an increase in high-rise construction that is governed by wind, more frequent wind-related natural disaster destruction, and data that shows that buildings consume over 30% of the overall energy use contributing to global warming to heat and cool buildings, it has become apparent that a greater understanding and implementation of climate and climatic parameters, such as wind, within design are needed.

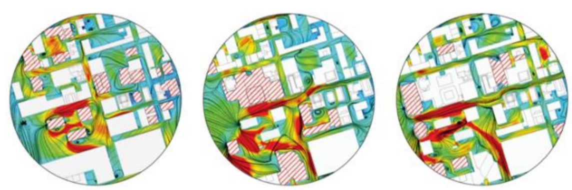
Researchers and consultants in the field of wind engineering have developed a deeper understanding of the relationship between wind and buildings of different shapes and how conditions change between existing, proposed, and future developments. However, these methods overlook the fact that once buildings become close in proximity, they no longer simply function individually; rather they become a single organism, where the decisions made by one design directly impact adjacent buildings. If this multi-scale interaction can be identified within a design framework, cities can be designed and/or retrofitted to reduce the amount of unexpected environmental consequences and failures.

Previously, a study showing the changing pedestrian level winds in the downtown core of Toronto Ontario over its 70-year development was conducted. Using computational fluid dynamics programs, this study showed how by the additional and removal of buildings close and even sometimes further away altered the flow of wind that would affect people walking on the street. Looking forward, the city growth affects ventilation efficiency, pressure distribution over all the buildings and changes with the ventilation systems within existing buildings when the flow changes. By creating a multi-scale framework that can determine the relationships of buildings in terms of ventilation, pedestrian level winds, loading and other factors the design of a city can be optimized and made sustainable and resilient.

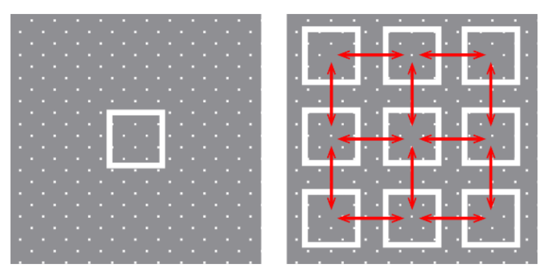
To create this framework, a combination of computational and physical testing methods will be utilized. The study will analyze the ventilation, loading, and pedestrian level winds on and around an isolated building, of different shapes with its interior functions laid out. The computationally results 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.



Toronto Development 1940-2015



Mean Velocity at Pedestrian Levels a)1970, b)1980, c)1990



City acts as an organism, all parts are dependent

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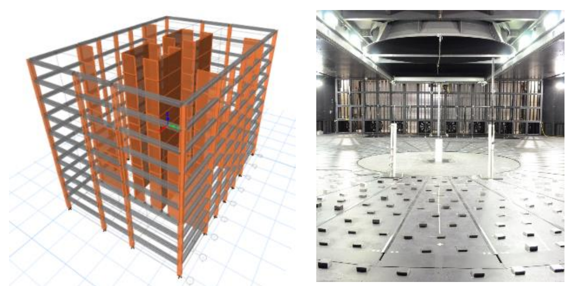
On the Lateral Stability of Multi-Story Mass-Timber Buildings Subjected to Tornado-Like Wind Field

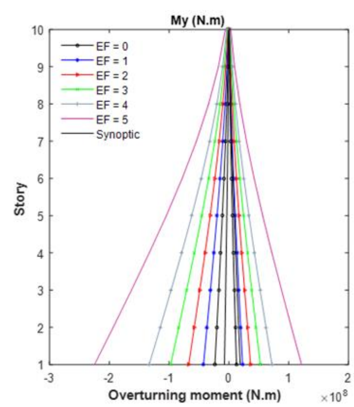
Mass-timber buildings utilize pre-engineered wood panels to form their main gravity and lateral load resisting systems. The lightweight nature of the wood makes these types of emerging buildings lighter and more flexible than buildings made from concrete, masonry or steel. In general, lateral instability can occur when the overturning forces due to wind loads exceed the weight of the structures. Therefore, the aim of this study is to evaluate the risk of lateral instability of multi-story mass-timber building subjected to extreme tornadic wind loads. As a case-study, a 10-story mass-timber building was designed for 1-in50 years wind speed of the city of Chicago, USA. The main lateral load resisting systems of this building are Cross Laminated Timber (CLT) shear and core walls (Figure 1a). Glulam columns, concrete spandrel beams and CLT floor systems form the gravity load resisting system.

Experimental tests were carried out at WindEEE Dome and Boundary Layer Wind Tunnel Laboratory (BLWTL) laboratories of Western University for non-synoptic and synoptic wind fields, respectively. High Frequency Pressure Integration (HFPI) tests were performed on reduced models at 1:200 geometric scale. Simultaneous time series of pressure fluctuations were measured and digitalized at the rate of 400-500 Hz. Figure 1b shows the testing chamber of WindEEE and test set up. Firstly, a tornado wind field with 1m diameter vortex core was simulated. The simulated vortex was a single celled structure with a swirl ratio of 0.5. For this experiment, a stationary vortex core was simulated, and the building was placed at a distance equal to the core radius (0.5 m) with respect to the geometric center of the simulator. Subsequently, another HFPI test was carried out at on the same building model at BLWTL using Atmospheric Boundary Layer (ABL) profile corresponding to open terrain exposure condition. Only the wind direction orthogonal to the wider face of the building model was considered in this study. Dynamic structural analysis was carried out by applying the wind force time series from both tornado and atmospheric boundary layer wind tests. For each analysis, by simplifying the case study building as uncoupled stick-mass model, full scale 10 minutes long wind force time series were applied at each floor in two sway and torsional directions. Linear-elastic responses were computed in time-domain by solving the equation of motion using Newmark-Beta numerical algorithm. The results in Figure 2 indicate that tornadic wind loads may pose lateral instability risk to mass-timber buildings designed for 1-in-50 wind speed. This preliminary study suggests additional design strategies for mass-timber buildings in tornado prone areas.



a) b)

a) Lateral load resisting system of the case study building and b) Testing Chamber of WindEEE



Floor level overturning moments

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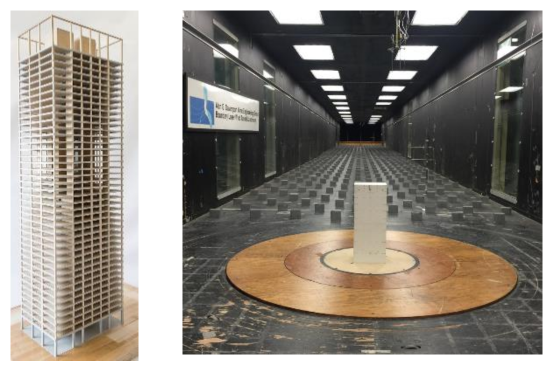
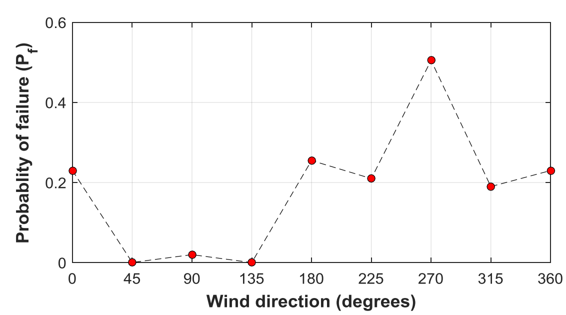
Probabilistic performance based assessment of tall mass-timber buildings subjected to stochastic wind loads

Tall mass-timber buildings utilize engineered massive wood products to form their main gravity and lateral load resisting systems, which makes them lighter and more flexible than buildings made from concrete, masonry or steel. As a result, frequent exposure to excessive wind induced vibrations can cause occupant discomfort and possible inhabitable buildings. Therefore, the objective of this research is to probabilistically assess the habitability performance of tall mass-timber buildings. For this purpose, the Alan G. Davenport wind loading chain is adapted as a probabilistic performance based wind engineering framework. The framework allows incorporation of uncertainties at each step of the wind load chain, i.e., local wind climate and exposure, aerodynamics, dynamic effects, and criteria. The habitability performance can be represented by the probability of exceeding the criteria in the wind loading chain. As a case-study, the framework was applied to quantify the habitability performance of a 102 meter tall mass-timber building. The concept design of this building was introduced by Skidmore, Owings and Merrill (SOM LLP). The gravity load resisting system consists of CLT floors supported by perimeter spandrel beams and glulam columns. Lateral loads are resisted by the coupled action of CLT shear and core walls using concrete link beams. The details of the structural system are depicted in Figure 1a.

Wind loads were quantified through aerodynamic wind tunnel tests at BLWTL of Western University (Figure 1b). A boundary layer flow corresponding to an open country exposure condition at 1:200 geometric scale was simulated. Simultaneous time series of pressure fluctuations were measured for different wind angles of attack and digitalized at the rate of 400 Hz. Wind forces were calculated by pressure integration over the surface the model. In wind engineering, stochastic nature of the wind field, wind tunnel tests, and structural properties are the main sources of uncertainties. In this research, 14 random variables were used to model these uncertainties. The resultant horizontal peak floor acceleration (PFA) response is considered as a performance parameter to evaluate the habitability of the case study building. Structural reliability analysis through sampling was used to propagate the uncertainties through the wind load chain to quantify the probability of exceeding the uncertain criteria. In the simulation, for random input parameters, the horizontal PFA in two sway and torsional modes were estimated using dynamic analysis in the frequency domain. Sector-by-sector independent reliability simulations were carried out for 36 wind directions to calculate the probability of exceedance/failure (P_f). Figure 2 depicts the probability of failure for different wind directions due to 1-in-10 year wind event. The figure shows the correlation between failure probability and wind direction. The results on Figure 2 provide additional information to the decision makers (owner, architect, and engineers) about the habitability performance of the building.



3D view of 30-storey mass timber building (left) and wind tunnel test setup at BLWTL



Variation of probability of failure with wind angle of attack

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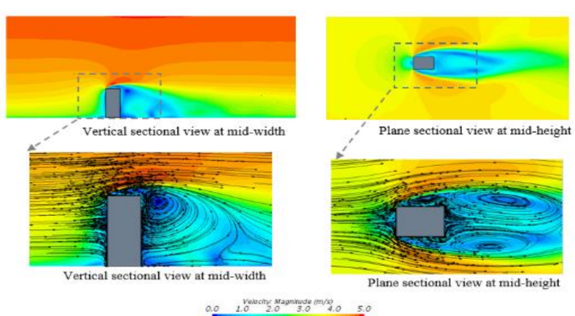
CFD Based Convective Heat Transfer Coefficient Analysis for Low and High Rise Building Facades

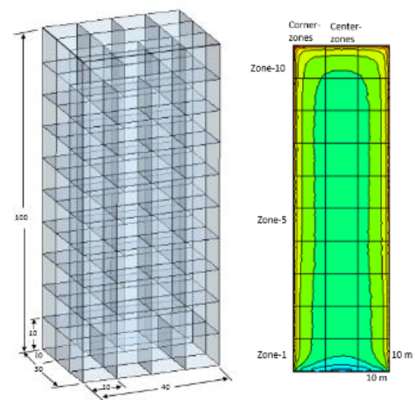
There is a trend towards the significant use of glazing in buildings where exteriors use glazing curtain walls that run from floor to ceiling. While glazing poorly controls the heat flow, it is important for viewing, daylighting, and solar design features. In order to evaluate building energy consumption accurately knowledge of convective heat transfer coefficient (*CHTC*) distributions over the façade of the building is important. In this research, high-resolution Computational Fluid Dynamics (*CFD*) simulations based on 3D steady Reynolds-Averaged Navier-Stokes (*RANS*) are performed and *CHTC* values at the windward facade of five buildings are presented.

Building energy simulators, use a single average-*CHTC* value to perform energy consumption analysis, regardless of the window position. However, this study revealed significant variations on the façade where the top-corner zone (zone-10) of the building about 24% more and the base-centre zone (zone-1) is low by 27% compared to the X), compared to entire windward façade average-*CHTC* value of 12.08 W/m^{2}K for a wind speed of U_{10} 1-5 m/s.

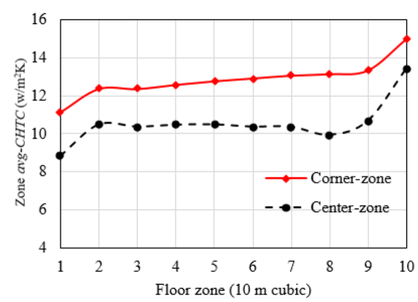
Therefore, the local- *CHTC* analysis shall be consistent with the *CHTC* distributions, to estimate energy consumptions accurately. Thus, contributing towards reducing the "sustainability performance gap" usually observed in sustainable buildings.



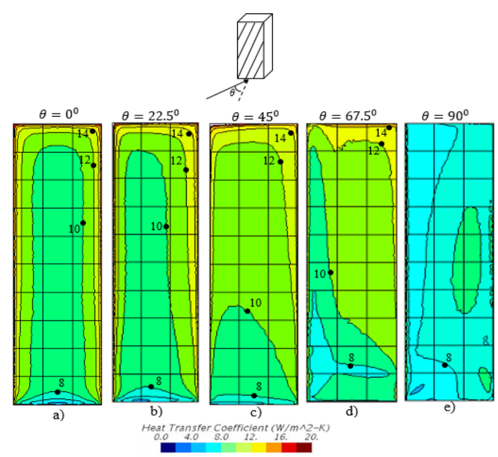
Wind velocity contours for the 100 m tall building (Ref. speed = 3 m/s at the inlet).



Zoning: A 100 m height of building divided into different thermal zones of 10 m cube.



Average-*CHTC* distribution on different zones of 100 m height building for windward a wind speed of U_{10} = 1-5 m/s, and wind direction of 0^0.



CHTC distribution across windward façade, for U_{10} of 3 m/s and for wind direction of: a) 0^0 b) 22.5^0 c) 45^0 d) 67.5^0 and e) 90^0

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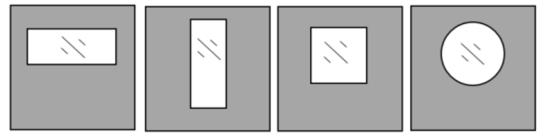
Numerical study of the effect of window configuration on the convective heat transfer rate of a window

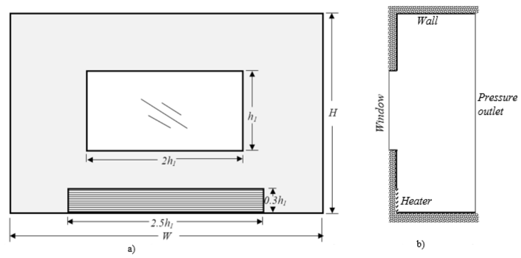
In a cold winter, outdoor environmental conditions primarily influence the indoor surface temperature of building windows. This leads to a temperature gradient in the indoor environment which induces a downdraft affecting the thermal comfort of occupants. This phenomenon is sensitive to the configuration and location of windows. In this study, the influence of window configuration on the convective heat transfer rate of a window is investigated numerically at different Rayleigh numbers of 1.7×10^6 to 1.7×10^{11}. Convective heat transfer rate of a model window is evaluated using high-resolution 3-D steady Reynolds-Averaged Navier-Stokes (RANS) CFD simulations

ASHRAE standard 90.1 (2010) provides a guideline on the Window-to-Wall Ratio (WWR) stating that: *"the total vertical window area shall be less than 40% of the gross wall area"*. Although this is useful information, it does not account for differences in window configurations as well as the thermal and lighting performance for the same WWR. For example, consider the four window configurations illustrated in below Figure 1 that have the same area of 20% WWR. It is important for, the guideline to accommodate as the question of which of the four window configurations is more energy efficient and thermally comfortable?

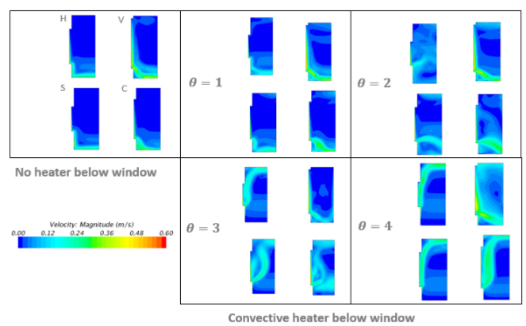
The simulation results show that, variations in convective heat transfer rate are independent of the window configuration and the dimensionless heater temperature (θ) while considering the window average-Nusselt number ($\overline{Nu}$) at the lower values of Rayleigh numbers (Ra). This is because the flow is mainly laminar. However, at the higher values of the Rayleigh number, variations are dependent on the window configuration and the dimensionless heater temperature. The horizontal rectangular window configuration shows the least convective heat transfer rate value (Nusselt number) whereas the vertical rectangular configuration shows the largest convective heat transfer rate value.



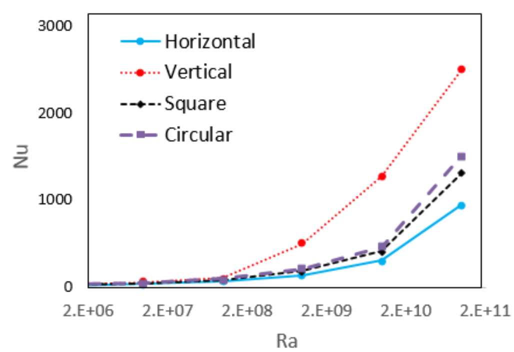
Window configurations with 20% Window-to-Wall Ratio (WWR) that represent a) horizontal rectangular b) vertical rectangular c) square d) circular



Model window configuration used for parametric study



Variation of window mean Nusselt number with Rayleigh number averaged for a dimensionless heater temperature of θ =1, 2, 3, and 4.



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Predicting aeroelastic response of felexible structures using high fedelity fluid-structure interaction

New technologies in material science and design method are fueling the need to build light-weight and flexible civil-structures like tall buildings, long span bridges, and large span roofs, etc. (see top figures). Due to the reduced mass and stiffness, these structures are highly vulnerable to wind induced effects. In the current study, high fidelity transient strongly coupled fluid-structure interactions framework is developed to predict the aeroelastic response of flexible structures in general, and high-rise buildings in particular.

Prior CFD based numerical load evaluation studies on higher-rise buildings are largely devoted to studying the aerodynamic loading assuming rigid configuration of the structure. However, for tall and flexible buildings experiencing substantial wind induced deformation, the structural displacements of the building must be considered in the modeling. To address this, a partitioned fluid-structure interaction solver is utilized for examining the aeroelastic behavior of the buildings as well as the wind induced stress on their components (bottom figure).

For the wind flow simulation, the well-known Navier-Stokes equations are modeled on Arbitrary Lagrangian-Eulerian (ALE) formulation using Finite Volume Method (FVM). Whereas, for the structural part, large deformation geometrically nonlinear formulation is adopted. The wind flow simulation is advanced on a moving mesh that will accommodate the deformation of the structure at fluid-solid interface. The coupling between the fluid and structure is performed by transferring force and displacement back and forth iteratively until convergence is established in both fluid and solid domain. This study will provide a groundwork for better understanding of the computational aeroelastic modeling and the associated challenges. After thorough validation using wind tunnel aeroelastic experiment, the developed framework can also be used as a reliable tool for structural optimization of high rise structures for aeroelastic performance.

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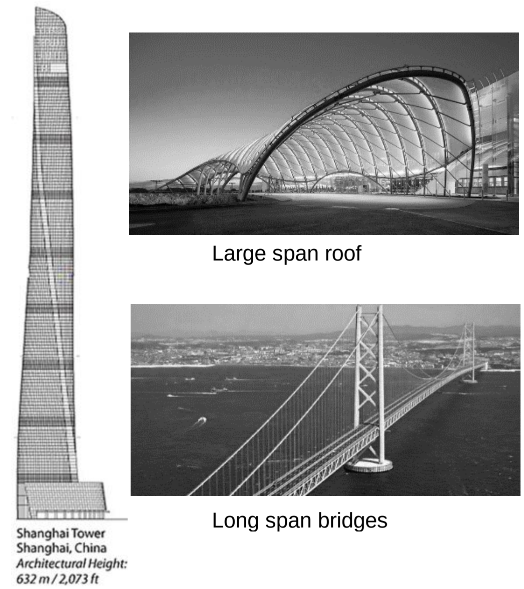


Figure 1. Examples of flexible structures prone to wind

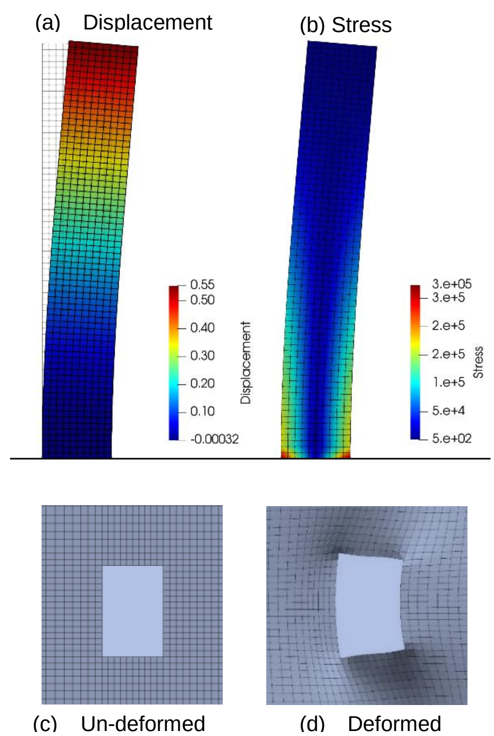


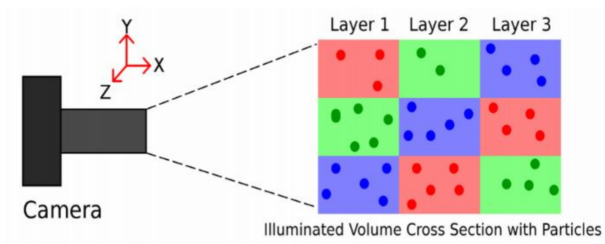
Figure 2. Result of fluid-structure interaction for CAARC model under wind load: structural response (a), stress (b), un-deformed mesh (c) and deformed mesh (d)

A Multi-Color Technique for Volumetric Flow Measurements

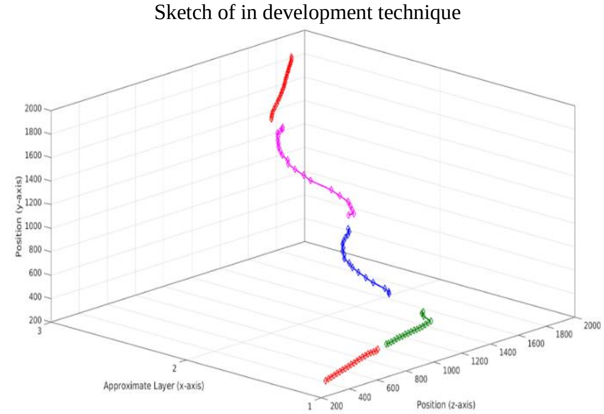
Turbulent flows are three dimensional in nature. Fluid motion in these flows occurs over a wide range of length and time scales. The dynamics of turbulent flows are governed by non-linear dissipative processes. Due to their complexity, performing investigations that are numerical in nature is highly resource intensive. This makes experimental research the primary means of studying turbulent flows. In order to characterize turbulent flows, measurements of all three velocity components must be taken simultaneously to determine key quantities such as the turbulent kinetic energy (TKE). Hence, there is a need for the development of three-dimensional flow measurement techniques. Current three-dimensional techniques are often either limited to single point measurements or resource intense to implement. The objective of this study is to develop a 3D flow measurement technique that utilizes color to indicate three-dimensional motion.

The new technique divides a measurement volume into several color coded volumes using a grid pattern. This pattern causes color variations in two planes relative to the camera field of view. The pattern can be extended with color permutations to enable measurements from a larger volume. A LCD projector is used to enable precise control over the distribution of colors and size of the illuminated volume. Experiments were performed underwater in a 30 cm by 30 cm by 25 cm high water tank. Three-dimensional fluid motion was produced by hand mixing. A high resolution color camera was used to capture images of color streaks formed by seed particles. Captured color streak images were processed using a program written in MATLAB to capture the streak shape and color. Using a 3 x 3 color grid pattern, three-dimensional motion was successfully captured. Tests with a finer 6 x 6 grid showed an increase in spatial resolution while also identifying some limitations of the technique

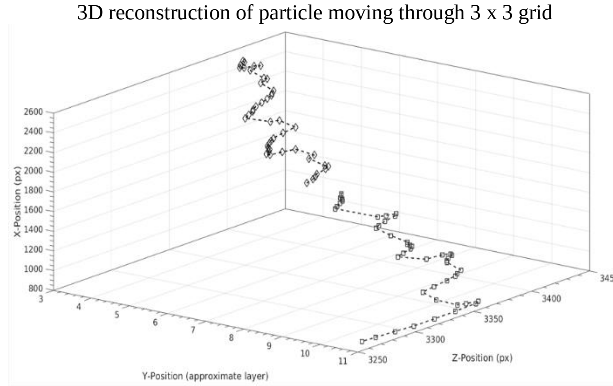
Current research is working on addressing these limitations with improvements to the measurement technique. Color permutations is one improvement where the spatial resolution of the volume can be greatly increased without additional colors. This is made possible by ensuring each color appears adjacent to every other color exactly one time. Hence, a streak that transitions between colors is correlated to motion between two adjacent volumes. For example, using 5 colors it is possible to produce a measurement region with 11 volumes. Similarly, 7 colors can produce 21 volumes. Early results from experiments with an 11 volume measurement region show a clear increase in out-of-plane spatial resolution, showing promise for further increasing the number of volumes through permutations.



Sketch of in development technique



3D reconstruction of particle moving through 3 x 3 grid



3D reconstruction of particle moving through 11 volume pattern

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Thermal Regulation of Biofuel Producing Microalgae using Phase Change Materials

The global reliance on fossil fuels accounts for almost 70 % of human greenhouse gas contributions (IEA, 2016). Biofuels have the potential to be a sustainable alternative as a clean, carbon neutral fuel. A current limitation to the widespread production of biofuels is competition of biofuel crop plants with food crops for farmland. An innovative technology has been proposed that integrates an incubator for the growth of microalgae with the building façade, eliminating the need for arable land. The microalgae use solar energy and CO2 to create biomass which can be used to produce biofuels and other useful by-products.

My research intends to address a design challenge in the development of the incubator using phase change materials (PCM) which that make use of the high specific heat capacity of phase change to store and release heat at a near constant temperature.

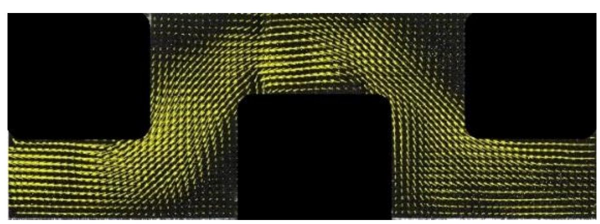
The design challenge arises from the temperature sensitivity of the microalgae, where productivity is temperature dependent, and death occurs when they are exposed to high temperatures. As the incubator is exposed to daily temperature fluctuations and solar radiation that could cause temperatures to exceed the optimal range for microalgal function. In my project I propose thermal storage in the form of PCM. The PCM will absorb solar radiation, and store it as latent instead of sensible heat, thereby preventing the incubator from overheating. Overnight, as temperatures cool the PCM will solidify, releasing the energy stored during the day.

The first phase of this project is to determine the effects of insert geometry and orientation on the fluid flow through the volume. For this, circular and square cylinder inserts are being tested, with 2 spacing configurations. Particle image velocimetry (PIV) is being employed to resolve the velocity field at mid-height in the flow.

Once the flow characterization is complete, the inserts will be filled with PCM, and the surrounding fluid heated above the melting temperature of the PCM. Changes to the flow and the melting efficiency of the PCM will be investigated to determine which set up is the most effective at modulating the temperature of the microalgae and their nutrient broth. Tests will be first be performed here with water, and later through collaboration with the University of Paris Diderot with the microalgae and their nutrient broth to observe the effect of the geometry, wall temperature and flow patterns on the algae. Temperature.

Successful implementation of this project will provide a space efficient, CO2 capturing method for producing biofuels which will reduce global reliance on fossil fuels, and lead to a decrease in greenhouse gas emissions.

Proposed building design[1]



PIV of flow over a set of square cylinder inserts in a channel

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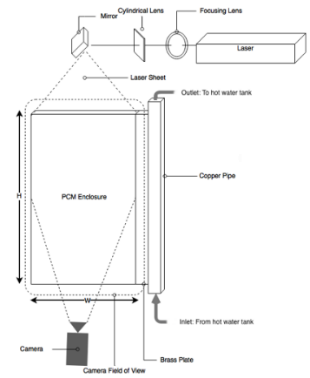
Investigation of the flow behavior in a PCM-based energy storage using Particle Image Velocimetry

Global demand for energy consumption has shown a rapid and accelerating growth in recent years. It has been predicted that fossil fuels will continue to be used as primary energy sources to meet this energy demand, leading to a detrimental impact on the climate and environment. Hence, there is an urgent need to conserve energy as well as to integrate more renewable resources. Thermal energy storage (TES) is one of the potential options to conserve energy and increase consistency and reliability of solar thermal energy. TES systems utilizing phase-change materials (PCMs) have very high energy storage density due to the exploitation of the enthalpy of phase change making them a suitable option in many applications. PCMs undergo a transition between solid and liquid phases during the heat absorption or rejection. However, due to the complicated nature of the natural convective heat transfer in the liquid phase where buoyancy effects are dominant, the phase transition and associated heat transfer process in a PCM-based thermal storage is not well understood**.** A better understanding of these behaviours will enable efficient design for PCM-based TES.

The present study is focused on characterizing the flow in the liquid PCM domain during the melting process initiated by a vertical heat source. Particle image velocimetry (PIV) was used to obtain two-dimensional velocity fields within the liquid domain of the PCM enclosed in a thin rectangular chamber.

Results show the presence of a dominant recirculation zone in the upper region of the enclosure. A prominent vortex was also observed that was located near the bottom of the recirculation zone, which played a major role in sustaining the fluid recirculation and locally intensifying the melting rate. Results also show that the flow primarily circulates along the boundaries of the liquid PCM domain while the bulk fluid remains almost stagnant. This work was recently presented at the Energy and Natural Resources Conference in Windsor, Ontario.



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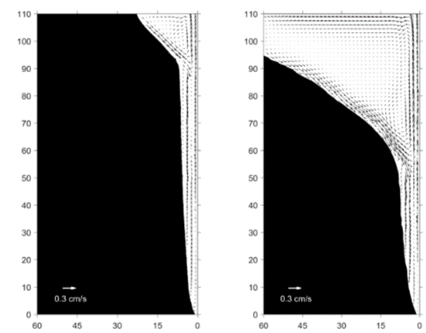
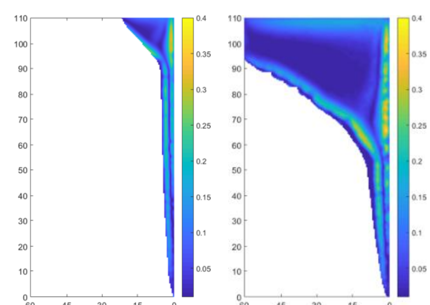
Schematic of experimental setup – PCM enclosure



Flow velocity field in the liquid PCM domain at different time instances after the beginning of the melting process, (left - 40 min, right - 240 min). The black region corresponds to the solid PCM domain. The x and y axes present the distance in



Colourmaps of the resultant fluid velocity in the liquid PCM domain at different time instances after the beginning of the melting process, (left - 40 min, right - 240 min). The white region corresponds to the solid PCM domain. The bar scale is in cm/s.

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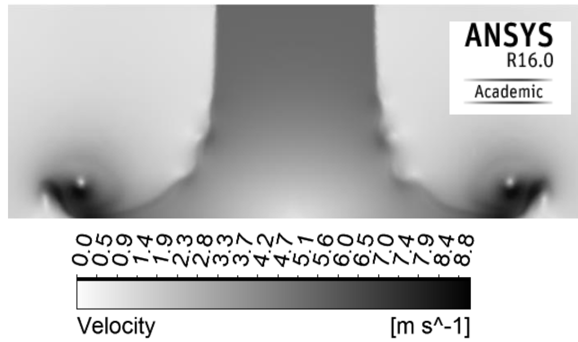
Assesment of Dynamic Effect of Transmission Line Conductor Longitudinal Reaction Due to Downburst loading



Snapshot of simulated downburst velocity field

Due to the locality and non-stationary nature of downburst wind loading events, their effect on the structural response of transmission line structures is of special nature that differs from conventional atmospheric boundary layer wind loading.

Acknowledging such difference, the current study aims to quantify the dynamic effect associated with downburst loading on transmission line systems. To achieve that, several steps had to be realized. One of the most important steps was the verification of the structural numerical model using reduced-scale experiments conducted at WindEEE.

Utilizing the newly availed privilege of wind-tunnel-scale testing for downburst wind fields, the experimental results were used to verify the structural numerical model. This also included developing a computational fluid dynamics (CFD) model, to capture the detailed wind field with its spatial and temporal characteristics, before applying it on the structural numerical model

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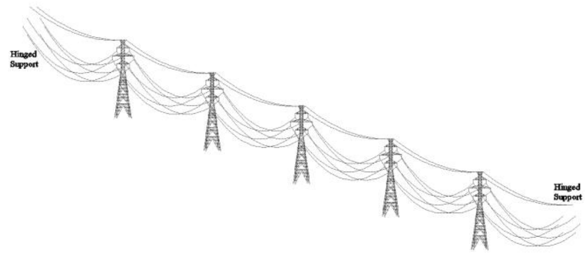
Angle and End Transmission Line Tower Behavior under Tornado Wind Loads



Schematic layout of the transmission line system model.

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 tornado 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. The forces acting on the structure depend on the location of the storm relative to the structure. Therefore, it is important to identify the tornado locations that lead to the maximum structural responses. This is challenging for transmission lines, where the wind forces resulting from tornadoes vary along the span of the lengthy conductors and along the height of the towers. Thus the behavior of angle and end lattice transmission towers will be assessed under tornado wind loads. The research proposed in this study will build on the findings, developments and experience gained during the previous research program. The objective is to develop guidelines for designing transmission line structures to resist tornado events and to use these findings in codes of practice.

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Progressive collapse of transmission towers along a line subjected to downbursts

Most of transmission line structures failures during natural disaster events are due to localized high intensity wind (HIW) loads associated with downbursts. Research related to high intensity wind loads and their effects on structures in general is very limited and on transmission line structures in particular is rare. Previous failure investigations were limited to individual towers and on stationary HIW.

However, an incremental progressive failure analysis must be considered since failures of transmission lines occur in the form of a cascade failure progressing from one tower to another. Therefore, there is a pressing need to develop a nonlinear finite element model for predicting the progressive failures of transmission towers along a line subjected to downbursts.

Some of the key features in the model:

- Incorporating the downbursts translation motion and modifying the load instantly on different towers depending on their locations to the downburst center.
- Predicting nonlinear effects resulting from steel yielding, buckling as well as connection failures.
- Conductor's behavior during the initiation of a tower's collapse and the effects on the adjacent towers.

In the next step, a unique model will be tested at WindEEE for the validation of the progressive failure model in order to understand the failure mechanism of the entire line.

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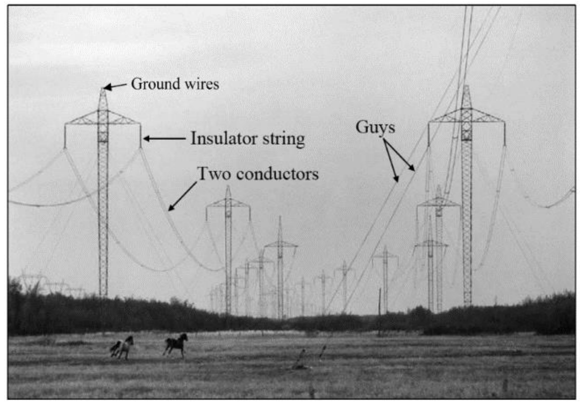
Progressive failure of Transmission lines occurred in South Australia during Sept 2016 Thunderstorms.

Behavior of Transmission Line Structures under Full-Scale Flow Fields Obtained from Numerical Simulation of Various Mid-Range Tornadoes



Tornadoes cause many transmission line system failures at numerous locations worldwide. Structural response of multi-span self-supported and guyed transmission line systems under various mid-range tornadoes is 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 guidelines, which up-to-current do not account for tornado-induced loads

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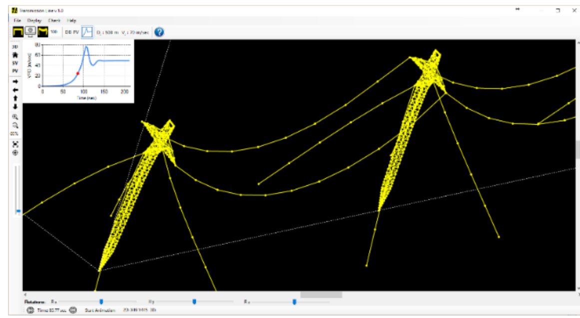
Graphical User-Interface Software for Transmission lines Subjected to High Intensity Wind

High Intensity Wind (HIW), such as downbursts or tornadoes, are responsible of the majority of transmission line failures in many regions all over the world. A software was previously developed at *The University of Western Ontario* to analyze transmission lines under HIW events. This software is extended in the current study by incorporating a graphical user-interface tool to plot multiple tower transmission lines in the 3D space.

The extended software has many features such as zooming and free rotations in the 3D space. The software shows the configurations of the downburst and tornado critical cases. The extended software has the ability to plot the undeformed shape of towers as well as the deformed shape at each time within the downburst or tornado time history. The software's graphical interface visualizes the progressive failure of a transmission line such that the order of the towers' failures is detected. The axial forces, axial capacities, force/capacity ratios at each time during the time history are presented using either numerical or color scales.



Example of transmission towers being examined the user interface

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Development of Tools for Analysis and Design of Multi-Story Wood Buildings under Wind and Seismic Loads

Wood buildings have been standing for hundreds, maybe thousands, of years. New research shows that wood can be used for buildings much taller than normal single-family houses and low-rise buildings.

The recent changes to the building codes in Canada and worldwide encouraged the enormous growth in the number of mid-rise Light Framed Wood Buildings (LFWBs). Recently, a full three-dimensional nonlinear finite element modelling and design rises to prominence of picturing rather than using the traditional element-by-element analysis and design. The main objective of the current study is to develop an advanced nonlinear three-dimensional finite element analysis technique to predict the accurate behavior of (LFWBs) when subjected to lateral loads.

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

Multi-story wood framed building

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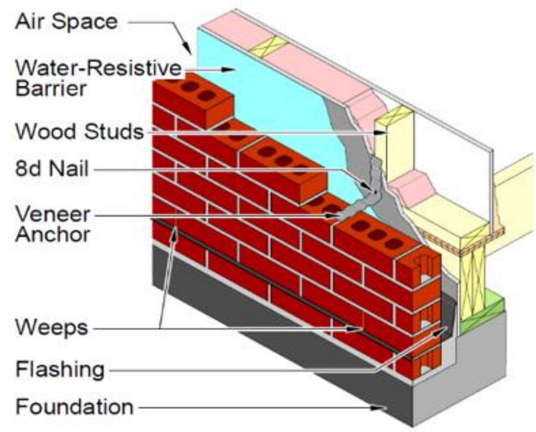
Performance of Low-rise Brick Masonry Veneer/Wood Stud Buildings under Multi-Hazard Effects of High Speed Wind

Brick veneer is a commonly used cladding for residential and commercial building construction in North America. Structurally, the masonry veneer must be able to carry its own weight and transfer out-of-plane loads, resulting from wind or earthquakes, through steel ties connected to a backup wall. Design of this system have been based on code prescriptive requirements.

Little testing had been carried out to investigate this system's performance despite of the fact that numerous failures were reported in strong wind events. In this research program, numerical and experimental investigations of brick veneer/wood stud wall system under high-speed wind will be conducted. Full-scale testing on brick veneer systems will be performed to measure the wind loads corresponding to different failure scenarios. In addition, a parametric study, using a three dimensional finite element models, will be performed and validated using the results from the experiments. By employing the findings from the parametric study, a simplified approach for designing the brick veneer systems will be proposed.



Common composition of residential wall n in North America

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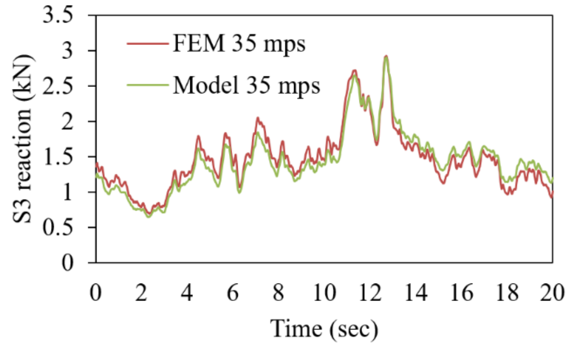
Closed-Form Solution for Light-Frame houses under Uplift Wind Loads

Observations of post-hurricane events indicate that light-frame wood houses could fail due to the inability of wood house connections to provide sufficient transfer of uplift wind loads from the roof to the foundation.

This research introduces the analysis of these connections by the use of 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 through the use of statically indeterminate slope deflection equations that include shear deformation. This figure illustrates the reaction values for one of the critical connections through the time history associated with pressure of wind velocity 35 m/sec. As shown in Figure, good agreement is indicated between the three-dimensional finite element model and the solution model reactions with respect to the magnitude and shape of the curves.



Comparison between Finite Element Model (FEM) and closed form solution model

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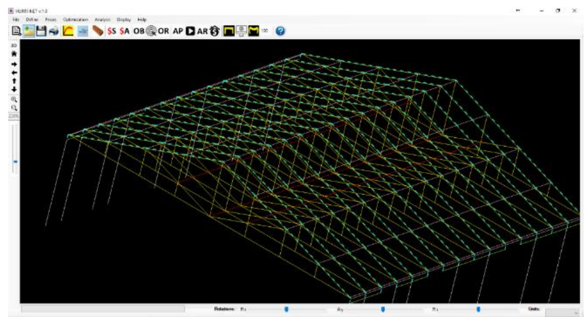
Optimization of Retrofit System for Light-Framed Wood Houses Under Wind Loadings

Light-framed Wood Houses (LWH) are commonly used in North America due to the availability of materials as well as ease of construction. Previous wind events caused catastrophic human and economic losses.

A retrofit system can be used to increase the uplift capacity of LWH under wind loadings. The system consists of a set of bearing and external cables as well as rigid bars. A software is developed to optimize the retrofit system for a general LWH under wind loadings. In the software, the wooden roof and retrofit system with different dimensions are modelled using 3D frame elements. The flexibility of the roof-to-wall connections, based on experimental results, are considered. Prices of cables and rigid bars available in the market are specified as input to the software. Three dimensional presentational of the house and retrofit system is also provided by the software.



Representation of the optimized retrofit system shown by the software

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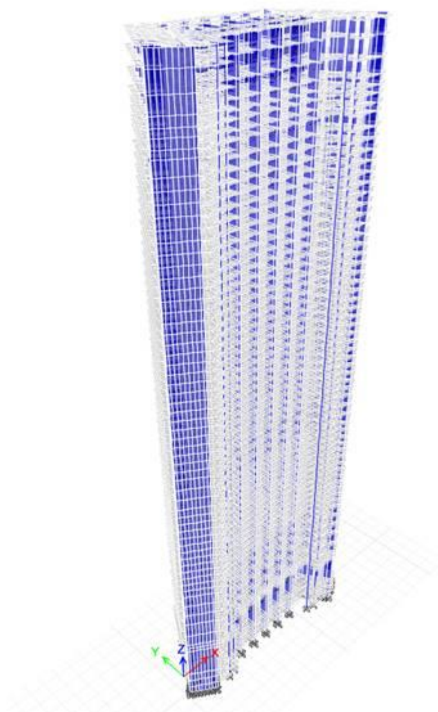
A Performance-Based Design Approach for Tall buildings Under Wind Loading

Wind design of buildings is typically based on strength provisions under ultimate loads unlike seismic design, where inelastic actions are allowed to take place in the structure under extreme seismic events. This research investigates the application of a similar concept in wind engineering.

A case study is conducted on a 65-storey building tested previously in the boundary layer wind tunnel facility. Wind pressures from tested rigid model are applied on a 3-D finite element model and a time-history dynamic analysis is conducted. Time histories of straining actions are decomposed into mean and fluctuating part. A reduction factor is applied to the fluctuating components and a modified time history response of the straining actions is calculated. This is followed by a non-linear static pushover analysis conducted on shear walls to evaluate ductility demand and assess inelastic actions



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Optimization of Composite Cable-Stayed Bridges under Permanent and Accidental Loads

Composite cross-sections are a leading option for medium span cable-stayed bridges. Steel girders are lightweight and offer high strength, while the concrete slab provides deck resistance to axial loads and an appropriate platform for traffic. Moreover, composite cable-stayed bridge deck costs are highly competitive.

The optimization of permanent and live loads was composed of three phases. The 1st and 2nd phase finite element models were composed of deck elements to optimize concrete slab thickness, steel girder dimensions (side panel), and cable areas. This is done to minimize total bridge mass. In contrast, the 3rd phase involves every structural component, and includes the optimization of pylon cross-sections and cable pretension forces.

Future work will combine wind and live loads during optimization, and will evaluate the influence of wind during the process of structural design.

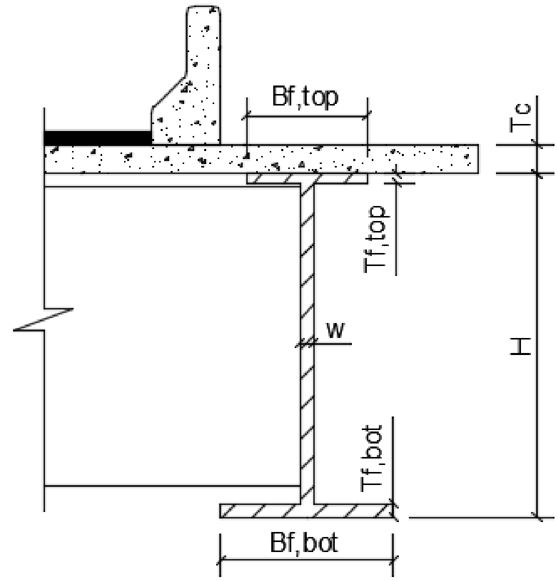

Diagram of steel girder

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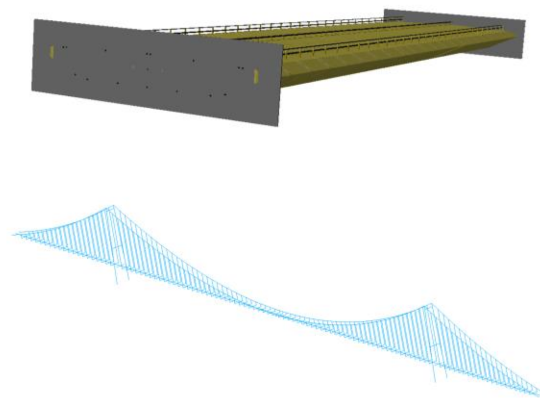
Effects of Structural Nonlinearities on Flutter of long-Span Bridges

Flutter, an aerodynamic instability, is a determining factor for the design of suspension and cable-stayed bridges. 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 geometric and material nonlinearities at high wind speeds. Furthermore, nonlinear dynamic phenomena could affect their stability. Therefore, this project aims at evaluating the effect of structural nonlinearities on flutter using numerical and experimental tools.

Finite element models of typical cable-supported bridges will be developed in order to conduct nonlinear time-domain flutter analyses. The developed numerical procedure will be validated using nonlinear section model tests and full aeroelastic model tests in the wind tunnel. This project would eventually allow safer designs with respect to flutter



Finite Element model of a typical cable supported bridge

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International Collaborations

Physical Reconstruction of Full-Scale Downburst Flow

Downbursts are strong downdrafts originating from thunderstorm which result in vigorous starburst outflows at or near the surface. Based on the horizontal scale of diverging winds, downbursts are divided into macrobursts and microburst. Damaging winds in intense microbursts can be as high as 75 m s^{-1}.

In this study that is currently on-going, the unique capabilities of the WindEEE Dome were used to physically replicate a downburst event captured in Genoa, Italy, using a combination of LiDAR and surface anemometer measurements. In addition, this study also investigates in details the geometric and kinematic scaling of WindEEE downbursts in respect to the full scale events.

A novel technique has been developed on order to quantitatively determine the ramp-up times of physically replicated as well as full scale downbursts. The methodology is based on the analyses of the frequency content of downburst spectrograms.

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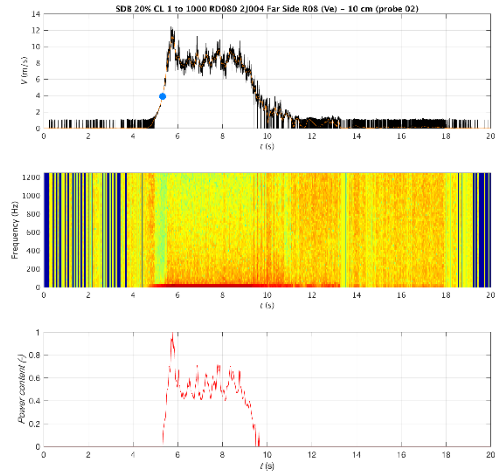
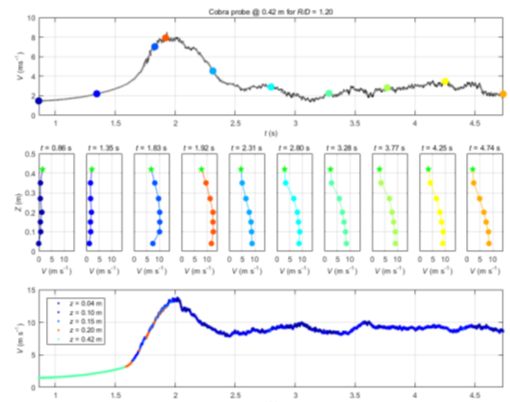
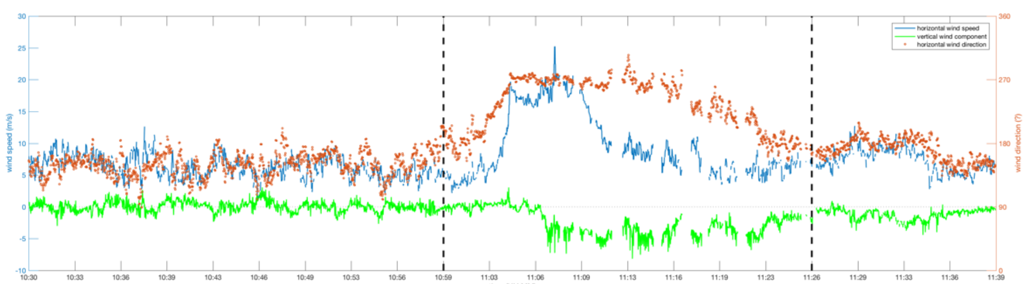


WindEEE downburst (top) with associated spectrogram (middle) and its power content (bottom)



Evolution of the wind speed at 0.42 m above surface (top), wind profiles (middle) and height of the maximum wind speed (bottom) at R/D=1.2

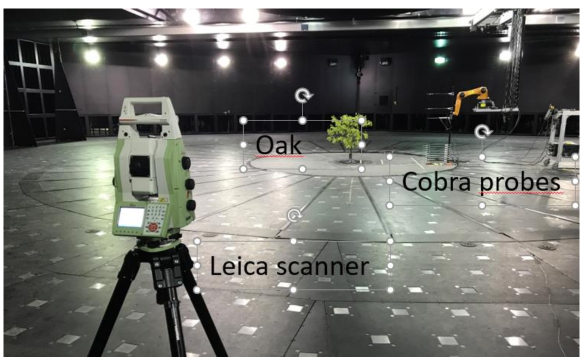


LiDAR measurements at 100 m above ground level of downburst event in Genoa, Italy

An investigation of how single trees interact with the wind

Single trees, alleys and small forests are commonly occurring in the landscape, but their effect on the wind field is not well known. Through a collaboration between Western University and the Technical University of Denmark (DTU), researchers at both institutes work towards a better understanding of wind–tree interaction. In July, an experiment using small trees in the WindEEE dome was carried out.

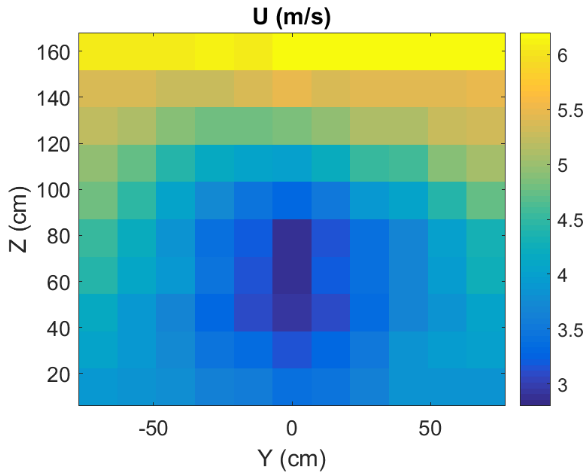
The purpose of this experiment was to determine the drag and drag coefficients for trees, which have complex fractal structures. A second purpose is to find out how trees and forests should be taken into account in future wind tunnel experiments in order to correctly represent the effect on the wind field.



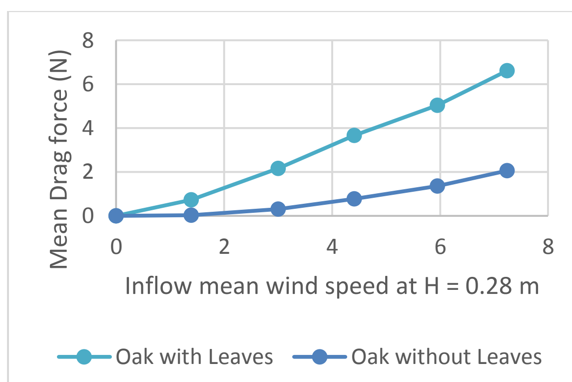
The first tree we studied in WindEEE was a small oak tree, trimmed down to a height of 1.1 m. Subsequently we tested a small garden tree and 3-D printed tree model. The three model had the same branch structure as a six meter tall oak tree at the DTU campus in Denmark. At this tree, the DTU researchers perform a full-scale experiment.

The trees in the WindEEE experiment were scanned with a Leica terrestrial scanner to determine the tree structure with high precision. During the wind experiments, they were filmed from two angles. Wind velocity (U) measurements were taken with a vertical array of cobra probes from 0.14 to 1.6 m in ten positions. The array was moved between eleven lateral positions such that wake planes could be reconstructed.

The tree reduces the wind speed most at the center of the crown. After taking wake planes with leaves on, the tree was stripped of all leaves and the experiment was re-run. The experimental data indicate that it is the leaves that cause the main velocity deficit.



Simultaneous to the wind measurements, we measured the forces acting on the tree using a six-component force mass balance. The mean drag of the tree with leaves turned out to be more than three times of the tree without leaves. Whereas the drag force on tree without leaves shows a wind speed proportionality close to U^2, this is not the case for the case with leaves, where the drag is close to linear in the range between 3 and 7m/s. One reason why the speed dependence is not quadratic is because of the streamlining of the tree elements. A first analysis of the video images indicate that compensation for the changed projected area can quantitatively explain the drag-wind speed relation.



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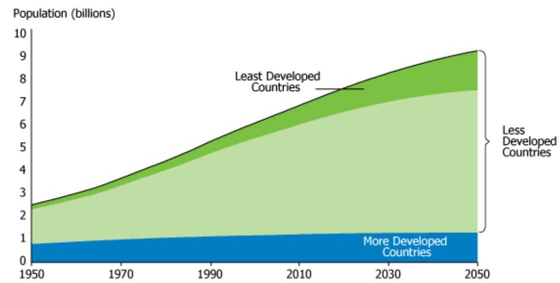
Urban Physics

The Revision of World Urbanization Prospects of the United Nation in 2014 (1) alarms that currently in the world more people live in cities than in rural areas. In 2014 not less than 54% of the world's population lived in urban areas against 30% in 1950, and it is expected that by 2050 close to 66% or more of the world's population will live in cities. All regions of the world are concerned with invasion of the cities however; this trend will be more accentuated in Africa, Asia and Latin America. Almost all population growth in the future will be in the less developed countries (Fig. 1).

This fast urbanization trend is mainly driven by the advantages and opportunities that cities provide to their inhabitants: more and better jobs, easier and cheaper access to health, education, sport and cultural services, better housing and transport. However, it entails enormous problems related to land availability and urban expansion, perturbations of the environment, climate change, energy demand, transport and mobility needs, natural hazards, health and aging, poverty, crime, and very often segregation and social unrest. These challenges grow increasingly and are interrelated in such a way that they constitute one of the major challenges to the near future of humanity. Faced to this situation no single scientific discipline can pretend to have a solution by itself alone; the challenge is interdisciplinary and worldwide. This assessment has driven a large number of scholars from a wide range of scientific disciplines (physics, biology, chemistry, mathematics and information technology, engineering, economics, sociology and anthropology, history and geography, art-architecture-urbanism, health sciences, management and business administration, security and risk management) to focus their attention on this global challenge to humanity.

In response to this challenge, in the last decade a new scientific discipline has emerged to study the modifications of the urban climate due to global warming and heat islands as well as their impact on energy demand and urban pollution. Of interest are also hurricanes and tornados and their impact on the built environment as well as sustainability and resilience of cities, urban comfort (pedestrian wind, thermal comfort, etc.), pollution dispersion, wind driven rain, health, interaction between urban environment and humans, fauna and flora. Often called *Urban Physics*, this is now a rather well established scientific discipline which incorporates relevant branches of physics, aerodynamics and fluid mechanics, heat transfer, chemistry, meteorology and urban climate studies, chemistry, urbanism and building science.



Trend of the world population growth (United Nations Population Division, World Population Prospects: The 2010 Revision, medium variant (2011)).

While Urban Physics defined above and practiced currently constitutes a solid basis in response to the challenges that uncontrolled fast urbanization poses the cities, it appears however to suffer from the lack of some main issues that will be addressed below.

* One of the shortcomings of the current Urban Physics practice is its weakness in interrelation of physical challenges (scientific and engineering) with human and social challenges. Concerning the fast urbanization, for instance, many fundamental questions can be raised:

- Is this fast urbanization trend inevitable?

- How can it be moderated and even reversed?

- What can we learn from human and social sciences in this respect?

- Are there alternative models available, especially in the case of developing countries where the problem is more explosive?

- Is it possible to develop balanced predictive models (hard science and human science) for the development and different consequences of fast urbanization?

Problems facing cities are not only interdisciplinary (disused above) but also inter-scaled. Therefore, it is needed to work not only on the issues at the scale of the city, province, region etc. but also on the scale of elements and their components. This is valid for the technical aspects (buildings, streets, pedestrian roads etc.) as well as non-technical issues (urban individual behavior, consumption behavior, urban psychology).

* Sustainability and resilience of cities are two domains of very active intellectual activities and knowledge production. However, they have developed their theories and practice independently and sometimes in reciprocal opposition. The worst is that none of them have been invited to Urban Physics. It will be counterproductive to separate sustainability, resilience and Urban Physics.

Urban Physics is one of the important topics that will be addressed in the framework of *Western Research Cahir in Urban Resilience & Sustainability.*

Reference

1. World Urbanization Prospects, the 2014 Revision (ST/ESA/SER.A/352)- 2014, *United Nations Department of Economic and Social Affairs, Population Division.*

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Publications

1. Ashton, R., Refan, M., Hangan, H., Iungo, V., “Wandering corrections from PIV measurements of tornado-like vortices”, Wind & Structures, submitted October 2017

2. Jubayer, C., Romanic, D., Hangan H., “Aerodynamic loading of a typical low rise building for an experimental stationary and non-Gaussian impinging jet”, Engineering Structures, submitted September 2017

3. Jubayer, C., Hangan, H., “A hybrid approach for evaluating wind flow over a complex terrain”, Journal of Wind Engineering and Industrial Aerodynamics, submitted September 2011

4. Refan, M., Hangan, H., “Near Surface Experimental Exploration of Tornado Vortices”, Journal of Fluids Engineering, FE-17-1327, submitted June 2017

5. Nasir, Z., Bitsuamlak, G.T. and Hangan, H. “Computational modeling of tornadic load on a typical building with flat roof”, ASCE Natural Hazards Review, submitted September 2015

6. Elawady, A., Aboshosha, H., El Damatty, A., Bitsuamlak, G., Hangan, H., Elatar, A., “Aero-elastic testing of multi-spanned transmission line subjected to downbursts”, J. Wind Eng. And Ind. Aerodynamics, 169: 194-216 (2017).

7. Hangan, H., Refan M., Jubayer, C., Romanic, D., Parvu D., LoTufo, J., Costache A., “Novel Techniques in Wind Engineering”, J. Wind Eng. And Ind. Aerodynamics, 171: 12-33 (2017).

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

9. Lange J, Mann J, Berg J, Parvu D, Kilpatrick R, Costache, A., Jubayer, C., Siddiqui, K, Hangan H., “For wind turbines in complex terrain the devil is in the detail”, Energy Research Letters, ERL-103706.R2, (2017).

10. Refan, M., Hangan H., Wurman, J., Kosiba, K., “Doppler radar-derived wind field of several tornadoes with application to engineering simulations”, Engineering Structures, 148: 509-521 (2017).

11. Burlando, M., Romanic, D., Solari, G., Hangan, H., Zhang, S., Field data analysis and weather scenario of a downburst event in Livorno, Italy on October 1, 2012, Monthly Weather Review/American Meteorological Society, https://doi.org/10.1175/MWR-D-17-0018.1; 145: 3507-3527 (2017).

12. Romanic D., Rasouli, D., Hangan, H. “Urban wind resource assessment in changing climate: Case study.” Wind Engineering, 41(1): 3-12 (2017).

13. Dodipatla L., Hangan H. Durghes, V., Naughton J, “Wake Dynamics Resulting From Trailing Edge Spanwise Sinusoidal Perturbation”, AIAA Journal, 55(6): 1833-1851, 10.2514/1.J055048 (2017).

14. Romanic D., Hangan H., Curic M, "Wind climatology of Toronto based on the NCEP/NCAR reanalysis 1 data set and its potential relation to solar activity", Theoretical and Applied Climatology, doi: 10.1007/S00704-016-2011-7 (2016).

15. Kilpatrick, R., Hangan, H., Siddiqui,K., Parvu, D., Lange, J., Mann,J., and Berg, J., "Effect of Reynolds number and inflow parameters on mean and turbulent flow over complex topography", Wind Energy Science, 1; pp. 237-254; doi:10.5194/wes-1-237-2016 (2016).

16. Kilpatrick, R., Siddiqui, K., Hangan, H., "Analysis of Turbulent Coherent Structures in a Flow over an Escarpment using Proper Orthogonal Decomposition", Journal of Physics. Conference Series, 753 (3): 032045, (2016).

17. Jubayer, C., Siddiqui K., Hangan, H., "CFD analysis of convective heat transfer from ground mounted solar panels in the atmospheric boundary layer", J. Solar Energy, 133: 556-566, (2016).

18. Jubayer, C., Hangan H., "A numerical approach to the investigation of wind loading of on an array of ground mounted solar Photovoltaic (PV) panels", J. Wind Eng. And Ind. Aerodynamics, 153: 60-70 (2016).

19. Refan, M., Hangan, H., "Characterization of tornado-like flow fields in a new model scale windcross testing chamber", J. Wind Eng. And Ind. Aerodynamics, 151: 107-121 (2016).

20. Hashemi-Tari, P., Siddiqui, K., Hangan, H., "Flow characterization in the near-wake region of a horizontal axis wind turbine", Wind Energy, DOI 10.1002/ WE 1895, 19(7): 1249-1267 (2016).

21. Bashar, M., Siddiqui, K. (2017). Investigation of heat transfer during melting of a PCM by a U-shaped heat source. International Journal of Energy Research. 41: 2091-2107.

22. Bashar, M., Siddiqui, K. (2017). Experimental investigation of transient melting and heat transfer behavior of nanoparticle-enriched PCM in a rectangular enclosure. International Journal of Heat and Mass Transfer.

23. Kalbfleisch, A., Siddiqui, K. (2017). The effect of mesh-type bubble breaker on two-phase vertical co-flow. International Journal of Multiphase Flow. 94: 1-16.

24. Steen, B. and Siddiqui, K. (2017). Investigation of flow and thermal behavior in a pipe submerged in a hot fluid. International Journal of Thermal Science. 111: 18-29.

25. Jobehdar, M.H., Siddiqui, K., Gadallah, A.H. and Chishty, W.A. (2017). Effect of atomizer internal geometry on the internal and external two-phase flow in effervescent atomization. Atomization and Sprays. 27: 169-188.

26. Jobehdar, M.H., Siddiqui, K., Gadallah, A.H. and Chishty, W.A. (2016). Effect of single- and multi-hole bubble breakers on the effervescent atomization process. Atomization and Sprays. 26: 135-162.

27. Jobehdar, M.H., Siddiqui, K., Gadallah, A.H. and Chishty, W.A. (2016). W.A. "Bubble formation process from a novel nozzle design in liquid cross-flow. International Journal of Heat and Fluid Flow. 61: 599-609.

28. Birhane*, T.H., Bitsuamlak, G.T., Kahsay*, M., and Demsis*, A.(2017). Air permeability factors for evaluating wind load on roof pavers. ASCE Journal of Structural Engineering.

29. Elshaer*, A., and Bitsuamlak, G.T. (2017). Multi-objective aerodynamic optimization through openings to reduce wind loads on of tall buildings. ASCE Journal of Structural Engineering.

30. Birhane*, T.H., Bitsuamlak, G.T., and King, P. (2017). Aerodynamic optimization framework for long span bridge sections. ASCE Bridge Engineering.

31. Chowdhury, A.G., Zisis, I., Irwin, P. Bitsuamlak, G.T., and Jean -Paul Pinelli. (2017). Large-scale experimentation using the 12-fan wall of wind to assess and mitigate hurricane wind and rain impacts on buildings and infrastructure systems. ASCE Journal of Structural Engineering. 143(7)

32. Dai, K., Sheng. C., Zhao, Z., Yi, Z., Camara, A., and Bitsuamlak, G.T. (2017). Non-linear response history analysis and collapse mode study of a wind turbine tower subjected to cyclone wind. Wind and Structures. 25(1): 79-100.

33. Nasir* Z., and Bitsuamlak, G.T. (2017). Topographic effect on tornado like vortex. Wind and Structures.

34. Abdelkader**, A., Aly*, A.M., Rezaee*, M. Bitsuamlak, G.T., and El Naggar, M.H. (2017). On the evaluation of wind loads for wind turbines foundation design: experimental and numerical investigations. The structural design of tall and special buildings. 6(9)

35. Araya*, D.B., Grolinger**, K., El Yamany**, H.F., Capretz, M.A.M, and Bitsuamlak, G.T. (2017). An ensemble learning framework for anomaly detection in building energy consumption for consideration to energy and buildings. Energy and Buildings. 144(1): 191-206.

36. Adamek*, K., Vasan, N., Elshaer*, A, English, E., and Bitsuamlak, G.T.(2017). Pedestrian level wind assessment through city development: A study of the financial district in Toronto. Sustainable Cities and Societies. 35: 178-190.

37. Elshaer*, A., Bitsuamlak, G.T. and El Damatty, A.(2017). Enhancing wind performance of tall buildings using corner aerodynamic optimization. Engineering Structures. 136(1): 133-148.

38. Bezabeh*, M.A., Bitsuamlak, G.T., Popovski, M., and Tesfamariam, S.(2017). Probabilistic performance assessment of tall mass-timber buildings subjected to stochastic wind loads. ASCE Structural Engineering.

39. Elshaer*, A., Gairola*, A., Adamek*, K., and Bitsuamlak*, G.T.(2017). Variations in wind load on tall buildings due to urban development. Sustainable Cities and Society. 34: 264-277.

40. Elawady**, A., Aboshosha*, H., El Damatty, A. Bitsuamlak, G,T., Hangan, and H. Elatar*, A.(2017). Aero-elastic testing of multi-spanned transmission line subjected to downbursts. Journal of Wind Engineering and Industrial Aerodynamics. 169: 194-216.

41. Kahsay*, M.T., Btisuamlak, G.T., and Tariku, F.(2017). Numerical analysis of convective heat transfer coefficient for building facades. Journal of Building Physics.

42. Hamada**, A. King, J.P.C., Hamada**, A.M., El Damatty, A., and Bitsuamlak G.T.(2017). The response of a guyed transmission line system to boundary layer wind. Engineering Structures. 139: 135-152.

43. Delavar*, M., Bitsuamlak, G.T.,and Dickenson, J.(2017). Automated BIM-based process for wind engineering design collaboration. ASCE Journal of Computing in Civil Engineering.

44. Awol, AD., Bitsuamlak, G.T., and Tariku, F.(2017). Novel analytical model for air flow in canopies of all packing densities. Boundary-Layer Meteorology.

45. Abdi*, D. and Bitsuamlak, G.T.(2016). Wind flow simulations in idealized and real built environments with models of various level of complexity. Wind and Structures. 22(4): 503-524.

46. Elshaer, A., Aboshosha, H., Bitsuamlak, G.T. and El Damatty, A. (2016). LES evaluation for wind induced responses of a tall building with isolated and complex surrounding. Engineering Structures. 115(15):179-195.

47. Li**, R., Chowdhury, A.G., Bitsuamlak, G.T., and Hajra*, B.(2016). Assessment of wind-induced loads on tiled and shingled roofs through large-scale measurements at the 6-fan wall of wind. Journal of Wind Engineering. 13(1): 21-33.

48. Ibrahim, A., El Damatty, A.A., and El Ansary, A., "Finite Element Modelling of Pre-stressed Concrete Poles under Downbursts and Tornadoes", Accepted in Engineering Structures, October 2017.

49. Elawady, A. and El Damatty, A.A., Longitudinal Forces on Transmission Towers due to Non-Symmetric Downburst Ground Wire Loads", Special ASCE Publication, accepted June 2017.

50. Musa, A. and El Damatty, A.A., "Design procedure for liquid storage steel conical tanks under seismic loading", Canadian Journal of Civil Engineering, Accepted June 2017.

51. Semelawy, M., El Damatty, A.A. and Soliman, A., "Finite element analysis of anchor jointed precast wall system", Structures and Buildings, 170(8), 543-554, 2017.

52. Elansary, A.A. and El Damatty, A.A., "Behaviour of Composite Conical Tanks under Hydrostatic Pressure", Engineering Structures, 134, 172–189, 2017.

53. Darwish, M.M. and El Damatty, A.A., "Critical Parameters and Configurations Affecting the Analysis and Design of Transmission Lines under Downburst Loading, ASCE's Practice Periodical on Structural Design and Construction, 22(1): 04016017, 2017.

54. Elawady, A., and El Damatty, A.A., "Longitudinal Force on Transmission Towers due to Non-Symmetric Downburst Conductor Load", Engineering Structures, 127, 206-226, 2016.

55. Elansary, A. and El Damatty, A.A. and El Ansary, A. "Assessment of equivalent cylinder method and development of charts for analysis of concrete conical tanks", Engineering Structures, 126, 27–39, 2016

56. Soliman, I.M., Tait, M.J. and El Damatty, A.A., "Modelling and Analysis of a Structure Semi-Active Tuned Liquid Damper System", Journal of Structural Control and Health Monitoring, 24: e1865, 2017.

57. El Damatty, A.A. and Hamada, A., "F2 Tornado Velocity Profiles Critical for Transmission Line Structures", Engineering Structures, 106: 436–449, 2016.

58. Hamada, A. and El Damatty, A.A., "Behaviour of Transmission Line Conductors under Tornado Wind Loads", Wind and Structures, an International Journal, 22(3): 369-391, 2016.

59. Azabi, T.M., El Ansary, A.M. and El Damatty, A.A., "Analysis and Design of Elevated Liquid-Filled Reinforced Concrete Conical Tanks.", Advances in Structural Engineering, 19(6), pp.995-1008, 2016.

60. Aboshosha, H., Elawady, A., El Ansary, A. and El Damatty, A.A., "Review on Dynamic and Quasi-Static Buffeting Response of Transmission Lines under Synoptic and Non-Synoptic Winds.", Engineering Structures, 112, pp.23-46, 2016.

61. Musa, A. and El Damatty, A.A., "Capacity of Liquid Steel Conical Tanks under Hydrodynamic Pressure Due to Horizontal Ground Excitations", Thin-Walled Structures, 103:157-170, 2016.

62. Musa, A. and El Damatty, A.A., "Capacity of Liquid-Filled Steel Conical Tanks under Vertical Excitation", Thin-walled structures, 103:199-210, 2016.

63. El Ansary, A., El Damatty, A.A. and El Ansary, A.M., "Nonlinear Behaviour of Reinforced Concrete Conical Tanks under Hydrostatic Pressure", Canadian Journal of Civil Engineering, 43(2): 85-98, 2016

Conferences

1. LoTufo J, Romanic D, Hangan H. 2017. Non-Gaussian turbulent flow over a coastal escarpment. International Conference on Future Technologies for Wind Energy (WindTech2017), 24–26 October, 2017, Boulder, Co, USA.

2. Romanic D, Hangan H. 2017. Wind resource assessment in tornado prone area in the United States. International Conference on Future Technologies for Wind Energy (WindTech2017), 24–26 October, 2017, Boulder, Co, USA.

3. Romanic, D., Hangan, H., "Influence of background winds and storm motion on downburst outflow", European and African Conference on Wind Engineering (EACWE), Liege, July 3-6, 2017.

4. Refan, M., Elatar, A., Hangan, H., "Pressure distribution over a typical low-rise building under laboratory simulated tornado vortices", European and African Conference on Wind Engineering (EACWE), Liege, July 3-6, 2017.

5. Delwick, E., Mann, J., Angelou, N., Sogachev, A., Troldborg N., Gardiner, B., Newson, T., Hangan, H. "Early results from the Single-Tree Experiment", Wind and Trees Conference, Boulder Colorado, USA, July 2017.

6. Jubayer, C., Hangan, H., "Effect of steady stationary laboratory simulated downburst flow on a standard tall building", European and African Conference on Wind Engineering (EACWE), Liege, July 3-6, 2017.

7. Jubayer, C., Hangan, H., "Multi-scale diverse flows at the WindEEE Dome", 53rd Annual Meeting, Subsonic Aerodynamic Testing Association, Wichita, Kansas, June 4-8, 2017.

8. Hangan, H., "Wind Resource Assessment: Experimental investigation of the impact of inflow on the flow field over a coastal escarpment", Wind Energy Science Conference (WESC), Denmark, June 26-27, 2017.

9. Jubayer, C., Hangan, H., "Effect of laboratory simulated dynamic and translating downburst on the pressure distrubutions of a low-rise building", 13th Americas Conference on Wind Engineering (ACWE), Gainesville, Florida, May 21-24, 2017.

10. Refan, M., Hangan, H., "Surface pressures dependency on Reynolds number and swirl ratio in tornado vortices", 13th Americas Conference on Wind Engineering (ACWE), Gainesville, Florida, May 21-24, 2017.

11. Chowdhury C, Hangan H, Romanic D. 2017. Combined numerical and large scale experimental study of wind flow over a complex topographic terrain. 1000 Islands Fluid Mechanics Meeting (T.I.M. 2017), 21-23 April, 2017, Gananoque, On, Canada.

12. Karami M, Romanic D, Refan M, Hangan H. 2017. Modeling of tornado-like vortices. 1000 Islands Fluid Mechanics Meeting (T.I.M. 2017), 21-23 April, 2017, Gananoque, On, Canada.

13. Kassab A, Romanic D, Costache A, Hangan H. 2017. Simultaneous pressure and PIV

measurements on low-rise building. 1000 Islands Fluid Mechanics Meeting (T.I.M. 2017), 21-23 April, 2017, Gananoque, On, Canada.

14. Hangan, H., "New Frontiers in Wind Engineering", 14th International Symposium in Structural Engineering, Beijing, 2016.

15. Hangan H, Jubayer C, Refan M, Romanic D, Parvu D, LoTufo J, Costache A. 2016. New frontiers in wind engineering. 14th International Symposium on Structural Engineering (ISSE-14), pages 1-11, 12-15 October, 2016, Beijing, China.

16. Romanic D, Parvu D, Hangan H, Solari G, Burlando M. 2016. New methodology for determining downburst touchdown location. XIV Conferece of the Italian Association for Wind Engineering (IN-VENTO 2016), pages 1-2, 25-28 September 2016, Terni, Italy.

17. Romanic D, Parvu D, Hangan H. 2016. Downburst reconstruction using physical simulation and analytical model with application to urban environments. In Proceedings of the First International Conference on Urban Physics (FICUP), pages 1–12, 28 September- 2 October, 2016, Quito – Galapagos, Ecuador.

18. Kilpatrick, R., Hangan, H.,Siddiqui, K., Parvu, D., Lange J., Mann, J., Berg, J., "Investigation of the effect of Reynolds number and inflow parameters on mean and turbulent flow over complex topography", TORQUE 2016, Munich, Germany, October 2016.

19. Jubayer, C., Elatar, A., Hangan H., "Pressure distributions on a low-rise building in a laboratory simulated downburst", Bluff Body Aerodynamics and Applications 8 (BBAA 8) Conference, Boston, USA, July 2016.

20. Jubayer C., Hangan, H, "Multiscale ABL simulations and applications", 1000 Islands Fluid Mechanics Meeting, TIM 2016, April 2016.

21. LoTufo J., Costache A., Parvu D., Hangan, H., Siddiqui K., "Intrusive and Non-intrusive full scale topography measurements", 1000 Islands Fluid Mechanics Meeting, TIM 2016, April 2016.

22. Romanic D., Parvu, D., Hangan H., "A Downburst Turbulence Model: Concept and Implementation", 1000 Islands Fluid Mechanics Meeting, TIM 2016, April 2016.

23. Kilpatrick, R., Parvu, D., Siddiqui, K., Hangan, H., "Investigation of mean and turbulent flow behaviour over an escarpment", ASME FEDSM Conference, Washington DC, July 2016.

24. Dennis, K., Siddiqui, K. (2017). A multicolor grid technique for volumetric velocity measurements. ASME Fluids Engineering Summer Conference, Waikoloa, Hawaii, United States

25. Steen, B., Siddiqui, K. (2017). Turbulent flow behavior in a pipe fully submerged in a hot fluid. ASME Fluids Engineering Summer Conference, Waikoloa, Hawaii, United States

26. LoTufo, J, Siddiqui, K., Hangan, H. and Jubayer, C. (2017). Experimental investigation of the influence of inflow conditions on the flow over an extended edge escarpment. ASME Fluids Engineering Summer Conference, Waikoloa, Hawaii, United States

27. Jevnikar, S. and Siddiqui, K. (2017). Investigation of the flow behavior in a PCM-based energy storage using particle image velocimetry. 2017 Energy & Natural Resources Symposium, Windsor,

Canada

28. Ramadan, A., Siddiqui, K. and El Naggar, H. (2017). Investigation of the concentric vertical ground loop of a heat pump in an energy pile. 13th International Workshop on Micropiles, Vancouver, Canada

29. Siddiqui, K. (2016). Learning Outcomes Assessment of Master and PhD Theses. Learning Outcomes: Evolution of Assessment, Toronto, Canada

30. Bashar, M. and Siddiqui, K. (2016). Effect of heat source geometry on the transient heat transfer during melting process of a PCM. ASME Heat Transfer Conference, Washington DC, United States

31. Kalbfleisch A. and Siddiqui, K. (2016). Heat transfer in two-phase vertical co-flow in the presence of a mesh-type bubble breaker. ASME Heat Transfer Conference, Washington DC, United States

32. Bashar, M. and Siddiqui, K. (2016). Investigation of the heat transfer enhancement in a phase change material using nanoparticles. Canadian Congress of Applied Mechanics, Kelowna, Canada

33. Woldeyes, K., Shifferaw, Y., Birhane,T.H., and Bitsuamlak, G.T. . (2017). Numerical evaluation of wind effects on low and mid rise hybrid structures. 2017 Americas Conference on Wind Engineering, Gainsville, United States

34. Woldeyes, K., Shifferaw, Y., Birhane,T.H., and Bitsuamlak, G.T. . (2017). Structural response of lightweight composite wall systems under spatiotemporal variation of wind pressure. 2017 Americas Conference on Wind Engineering, Gainsville, United States

35. Birhane, T.H., Bitsuamlak, G.T., and King, J.P.(2017). Computational aerodynamic shape optimization of long-span bridge decks –optimal fairing design for H-shaped decks. 2017 Americas Conference on Wind Engineering, Gainsville, United States

36. Melaku, A., Bitsuamlak, G.T., Elshaer, and A., Aboshosha, H. . (2017). Synthesized inflow turbulence generation methods for LES study of tall building aerodynamics. 2017 Americas Conference on Wind Engineering, Gainsville, United States

37. Birhane, T.H., Bitsuamlak, G.T., and King, J.P.(2017). Assessment of aerodynamic and aeroelastic performance improvement of computationally optimized bridge deck sections using LES and FSI simulations. 2017 Americas Conference on Wind Engineering, Gainsville, United States

38. Awol, D.A., Bitsuamlak, G.T., and Tariku, F.(2017). Consistent analytical urban canopy layer velocity profile for dense building arrangement. 2017 Americas Conference on Wind Engineering, Gainsville, United States

39. Birhane, T.H., Bitsuamlak, G.T., and King, J.P.(2017). A computational framework for the aerodynamic shape optimization of long-span bridge decks. ASCE - Structures congress 2017. Structures Congress 2017: Bridges and Transportation Structures, Denver, United States (223 - 239)

40. Khasay, M., Bitsuamlak, G.T., and Tariku, F.(2017). Numerical simulation of forced convective heat transfer coefficients on the facade of low-and high-rise buildings. Architectural Engineering Institute. AEI 2017: Resilience of the Integrated Building, Oklahoma City, United States (266-278)

41. Araya, D.B., Grolinger, K., El Yamany, H. F., Capretz, M. A. M., and Bitsuamlak., G.T.(2016). Collective contextual anomaly detection framework for smart buildings. IEEE. International Joint Conference on Neural Networks (IJCNN), Vancouver, Canada (511-518)

42. Elshaer A., Bitsuamlak G.T., and El Damatty A.(2016). Aerodynamic optimization to reduce wind loads on tall buildings. Canadian Society of Civil Engineers,

43. Elshaer, A., Aboshosha, H., Bitsuamlak, G.T., and El Damatty, A.(2016). Numerical evaluation of wind loads on a tall building located in a city center. UWO library. CSCE 2016 Natural Disaster Mitigation specialty conference, (NDM 529: 1-11)

44. Delavar, M., Dickenson, J., and Bitsuamlak, G.T.(2016). Discussion on BIM implementation in pre-engineered building (PEB) industry. CSCE 2016 Resilient Infrastructure, London, Canada

45. Nasir, Z., and Bitsuamlak, G.T.(2016). Computational modeling of topographic effect on tornado like vortex. UWO library. CSCE 2016 Natural Disaster Mitigation specialty conference, London, Canada (NDM 557: 1-11)

46. Birhane, T,H., and Bitsuamlak, G.T.(2016). Adaptive mesh refinement strategy for CFD based aerodynamic analysis of a cubical bluff object. 8th International Colloquium on Bluff Body Aerodynamics and Applications, Boston, United States

47. Nasir, Z., Bitsuamlak, G.T.(2016). Tornado like vortex induced load on a bluff-body with and without openings. 8th International Colloquium on Bluff-Body Aerodynamics and Applications, Boston, United States

48. Elshaer, A., Bitsuamlak, G.T., and El Damatty, A.(2016). Aerodynamic shape optimization of tall buildings using twisting and corner modifications. 8th International Colloquium on Bluff Body Aerodynamics and Applications, Boston, United States

49. Samani, Z., Bitsuamlak, G.T., and Hangan, H.(2016). Full-scale evaluation of wind load on a solar panel. 8th International Colloquium on Bluff Body Aerodynamics and Applications, Boston, United States

50. Hajra B., Bitsuamlak G., Aboshosha H., and Elshaer, A.(2016). Large eddy simulation of wind induced loads on a low rise building with complex roof geometry. UWO library. CSCE 2016 Natural Disaster Mitigation specialty conference, London, Canada (NDM 514: 1-9)

51. Elawady, A., Aboshosha, H. , El Damatty, A., and Bitsuamlak, G.T.(2016). Large scale wind tunnel

testing of a multiple span aeroelastic transmission line subjected to downburst wind. UWO library. CSCE 2016 Natural Disaster Mitigation specialty conference, London, Canada

52. Nasir, Z., and Bitsuamlak, G.T.(2016). Computational modeling of tornadic load on a tall-building. UWO library. CSCE 2016 Natural Disaster Mitigation specialty conference, London, Canada (NDM 558: 1-9)

53. El Ezaby, F.Y and El Damatty, A.A." Preliminary Investigation to Assess the Application of Ductility Based Approach for High Rise Buildings Under Extreme Wind Loads " The 2017 European- African Conference on Wind Engineering (EACWE17), Liege, Belgium, 2017.

54. Ibrahim, I., Aboshosha, H., El Damatty, A.A."Numerical Simulation of WindEEE Dome Downburst for Open Terrain Using Physical Roughness Elements" The 2017 European- African Conference on Wind Engineering (EACWE17), Liege, Belgium, 2017.

55. Elawady, A., and El Damatty, A.A. "Lessons learned from the testing of a transmission line model at the WindEEE dome under simulated downbursts" The 2017 European- African Conference on Wind Engineering (EACWE17), Liege, Belgium, 2017.

56. El Damatty, A.A., and Elawady, A., "Development of Code Provisions for Transmission Lines under Downbursts Using Numerical Modeling and WindEEE Testing " The 2016 World Congress on Advances in Civil, Environmental, and Materials Research (ACEM16), Jeju Island, South Korea, 2016.

57. El Damatty, A.A., Elawady, A., and M. Hamada, (2016), “Transmission Line Failures during Tornadoes and Downbursts- Can they be avoided”, SEMC 2016 - Sixth International Conference on Structural Engineering, Mechanics and Computation, Cape Town, South Africa, 2016.

58. Azabi, T.M., El Ansary, A.M. and El Damatty, A.A., “Cost Analysis of Conical Tanks; Comparison between Reinforced Concrete and Steel”, CSCE Conference, London, ON, Canada, June 1-4, 2016.

59. Haddadin, S., Aboshosha, H., El Ansary, A., El Damatty, A.,A., “Sensitivity of Wind Induced Dynamic Response of A Transmission Line To Variations In Wind Speed”, CSCE Conference, London, ON, Canada, June 1-4, 2016.

60. Hamada, A. and El Damatty, A.A., “Investigation of L-Shaped High and Low Rise Buildings Response to National Building Code of Canada 2005 and 2010 Seismic Loads”, CSCE Conference, London, ON, Canada, June 1-4, 2016.

61. Musa, A. and El Damatty, A.A., “Effect of Geometric Imperfections on the Buckling Capacity of Steel Conical Tanks under Hydrodynamic Pressure”, CSCE Conference, London, ON, Canada, June 1-4, 2016.

62. Musa, A., Aboshosha, H. and El Damatty, A.A., “Effect of Wind Speed and Terrain Exposure on the Wind Pressures for Elevated Steel Conical Tanks”, CSCE Conference, London, ON, Canada, June 1-4, 2016.

63. Ibrahim, A., El Damatty, A.A., “Case Study to Assess the Sensitivity of Prestressed Concrete Poles to Tornadoes”, CSCE Conference, London, ON, Canada, June 1-4, 2016.

64. Rosenkrantz, J.D., Enajar, A., and El Damatty, A.A., “Structural Modeling and Verification Methods to Develop a Cable Roof Harness Retrofit System”, CSCE Conference, London, ON, Canada, June 1-4, 2016.

65. Elawady, A., El Damatty, A. and El Ansary, A., “Critical Load Cases Simulating Downbursts: Economical Implications for Design of Transmission Lines.”, CIGRE-IEC Colloquium, Montréal, QC, Canada, May 9-11, 2016.

66. Aboshosha, H., Ibrahim, A. M., El Damatty, A. A. and Hamada, A., “Dynamic Behaviour of Transmission Lines Structures under Synoptic Wind Loads”, CIGRE-IEC Colloquium, Montreal, Canada, May 9-11, 2016.

67. Hamada, M. and El Damatty, A.A., "Load Cases Simulating Tornadoes - Economic Implications for Transmission Line Structure Design", CIGRE-IEC Colloquium, Montreal, QC, Canada, May 9-11, 2016

Grants

Ontario Centres of Excellence / $ 75,000 / 2016
Design wind speeds in complex terrain
Hangan.

Canada Foundation for Innovation / $ 5,491,391 / 2015 –
Enhancing the Resilience and Sustainability of Critical Geotechnical Infrastructure
Newson, T., Hangan, H + 7 others

NSERC Discovery Grant / $ 275,000 / 2017 – 2022
Non-stationary wind fields and their application to wind engineering, energy and environment
Hangan

NIST – Disaster Resilience Research Grants Program / $412,718 US / 2017-2018
Development of Tornado Design Criteria for Buildings and Shelters Subject to Tornado Induced Loads
Twisdale, L, Hangan, H., Vickery, P., Banik, S.

Vineland Research and Innovations Centre / $ 21,000 / 2017
Energy modeling of greenhouses
Siddiqui

Ontario Center of Excellence (OCE) / $ 25,000 / 2016
Energy modelling of ice arenas and ice resurfacing process
Siddiqui

Natural Sciences and Engineering Research Council of Canada (NSERC) / $ 149,796 / 2016
Micro-PIV system
Siddiqui

NSERC-CRC/$500,000/2017-2022
Canada research chair in wind engineering (Tier II) (Renewal)
Bitsuamlak

National Science Foundation NHERI/11,000,000/2017-2022
Natural Hazards Engineering Research Infrastructure (NHERI): Computational Modeling and Simulation Center
Bitsuamlak

Ontario Center of Excellence (OCE)/ $114,000/2017-2019
Natural Hazards Engineering Research Infrastructure (NHERI): Experimental Facility with Twelve-Fan Wall of Wind, Grant
Bitsuamlak

OCE/ $114,000/2017-2019
High performance computing for assessing and mitigating the effect of extreme wind on buildings & cities
Bitsuamlak

FM Global/$100,000/2017-2018
Enhancing OpenFoam's wind engineering modeling capability
Bitsuamlak

CFI- John R. Evans Leaders ($200,000)/ ORF($200,000)/ Western University Machine Shop($100,000)/2017-2018
Printing adaptive aerodynamic and aeroelastic test models
Bitsuamlak

NSERC/$141,000/2017-2018
Drones to enable computational modeling of environmental flows
Bitsuamlak

NSERC/$25,000/2016
Development of aerodynamic database via CFD and wind tunnel testing: Application for the performance based wind design of highrise wood-based buildings
Bitsuamlak

Hydro One/ $300,000/ 2016-2020
Progressive Failure Analyses of Transmission Line Structures under the Action of Downbursts and Tornadoes
El Damatty

NSERC Discovery/$225,000/2016-2021
Performance Based Design of Transmission Line Structures Under Tornadoes and Downbursts
El Damatty

Awards

2016

Horst Leipholz Medal, for outstanding contributions to engineering materials and mechanics in Canada, CSCE.
Ashraf El Damatty

Fellow, Canadian Society of Mechanical Engineers
Horia Hangan

Terry Base Award for Excellence in Teaching (MME)
Kamran Siddiqui

Bikila Award, distinction for professional excellence
Bitsuamlak

High-end Foreign Expert, distinction from Tongji University (China) for a guest professorship position
Bitsuamlak

High-end Foreign Expert, distinction from Tongji University (China) for a guest professorship position
El Damatty

Fellow, Engineering Institute of Canada
El Damatty

2017

American Association of Wind Engineering-Industry Innovation Award
Horia Hangan

Canadian Research Chair in Wind Engineering (Tier II, renewal period), NSERC
Bitsuamlak

Fellow, Canadian Society for Civil Engineers
Bitsuamlak

Events

SHAD 2017 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 STEAM (Science, Technology, Engineering, Arts 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.

Fueled by the enthusiastic feedback on last year's event, the WindEEE Research Institute team welcomed the opportunity to host the SHAD group again. 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.

Notes

Notes

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