UNIVERSITÉ Concordia UNIVERSITY

The Canadian Academy of Engineering — L'Académie canadienne du génie

Centre for Zero Energy Building Studies
Centre d'études sur le bâtiment
à consommation nulle d'énergie

WIND RESILIENCE: PROCEEDING FROM WIND CODES AND STANDARDS OF BUILDING DESIGN PRACTICE

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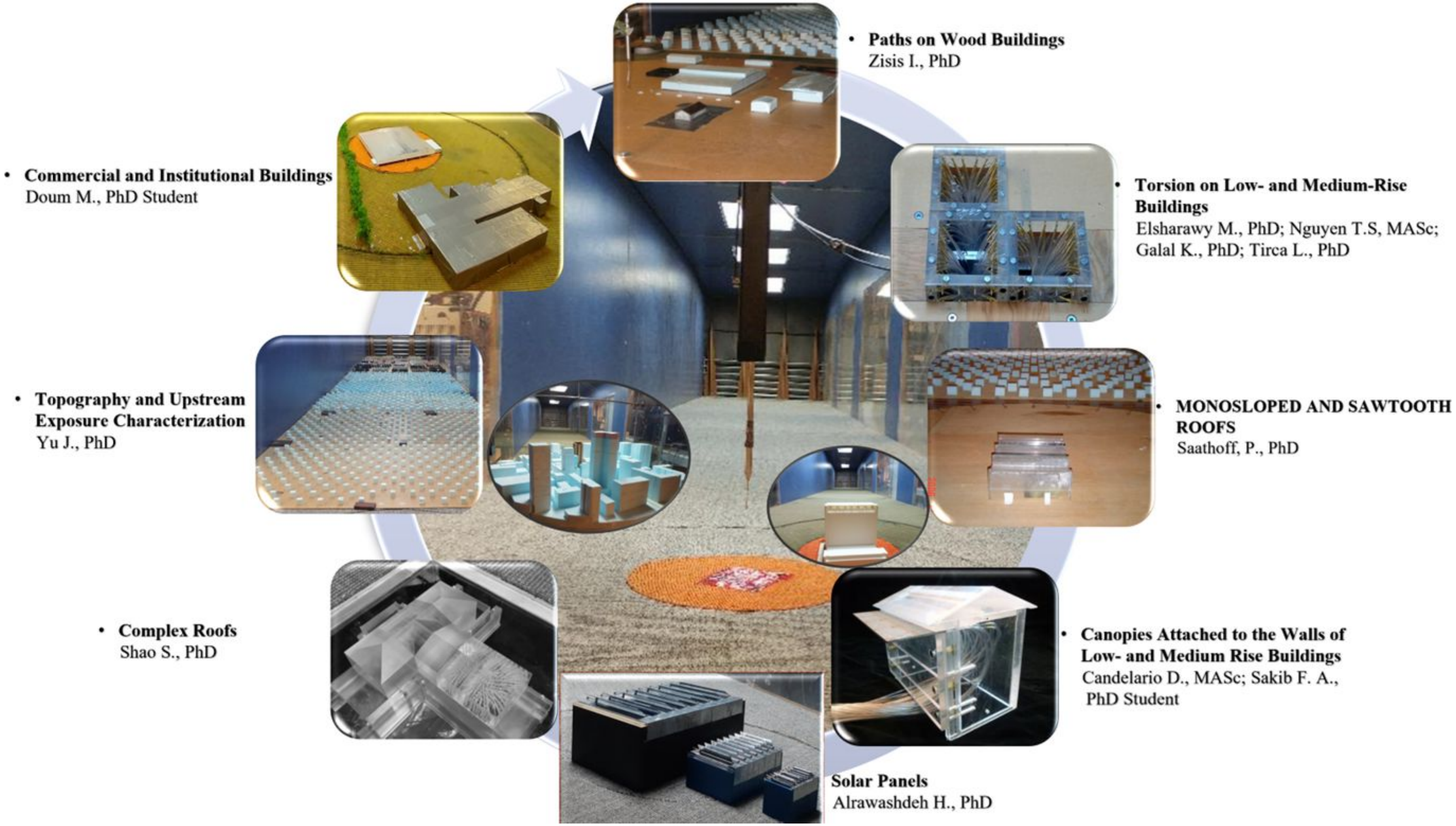
May 2025

Building Aerodynamics Laboratory



Background

- Particular interest and Contributions to Wind Codes and Standards
  - Member of the ASCE 7 Standard WLSC for the Min Design Load Provisions
  - Member of Task Group on Climatic Loads of the NBCC
  - Convenor of the International Standards Organization (ISO) TC 098/SC03/WG 02 “Wind Action on Structures” on behalf of Standards Council Canada (SCC)
  - Responsible for the revision of Chapter 24 “Airflow around Buildings” of ASHRAE Fundamentals (2013, 2017, 2021. 2025)

References (NBCC 2020-Commentary)

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I. Zisis and **T. Stathopoulos**, Wind-Induced Pressures on Patio Covers. Journal of the Structural Division, ASCE, Vol. 136, No. 9, 2010, pp. 1172-1181.

I. Zisis, **T. Stathopoulos** and J.D. Candelario, Codification of Wind Loads on a Patio Cover Based on a Parametric Wind Tunnel Study. 13th International Conference on Wind Engineering, July 10-15, Amsterdam, Netherlands, 2011.

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F.A. Sakib, **T. Stathopoulos** and A.K. Bhowmick, A Review of Wind Loads on Canopies Attached to Walls of Low-Rise Buildings. Engineering Structures, Vol. 230, 2021, 111656.

F.A. Sakib, Wind Load on Canopies Attached to Buildings of Different Heights. M.A.Sc. thesis, Concordia University, Montréal, 2020. Thesis Supervisor

Codes and Standards

RESILIENCE

"the capacity of individuals, communities, institutions, businesses, and systems within a city

to survive, adapt, and grow,

no matter what kinds of chronic stresses and acute shocks they experience" [1]

[1] Pape-Salmon, Montgomery, Lau, 2017. Codes and Standards Options for Existing Buildings in BC. ASHRAE conference paper.
https://buildingsciencelabs.com/wp-content/uploads/2017/08/Codes-and-Standards-Options-for-Existing-Buildings-in-BC-final.pdf

Background

- Wind can affect both **POSITIVELY** and **NEGATIVELY** the building/community resilience during or in the wake of acute shocks

ENERGY RESILIENCE: Wind can promote energy self-efficiency and may provide minimal energy necessary to power basic domestic appliances and services during or in the wake of strong events

STRUCTURAL RESILIENCE: Strong-wind events (tornados) can diminish occupation, serviceability, and functionality of the building itself and other renewables integrated or attached into the building

ENERGY RESILIENCE

ICE STORM 1998

- January 4-10, 1998: freezing rain fell on eastern Ontario, southwestern Quebec, southern New Brunswick and Nova Scotia
- These areas were pelted with 80 millimeters or more of freezing rain
- In Canada, 28 deaths were attributable to the storm
- In the affected areas, 4.7 million people (16% of the population) were deprived of power (heat, light and in many instances water) in the cold of the mid-winter

STRUCTURAL RESILIENCE

TREES near BUILDINGS

Fallen Tree (Montreal, QC)

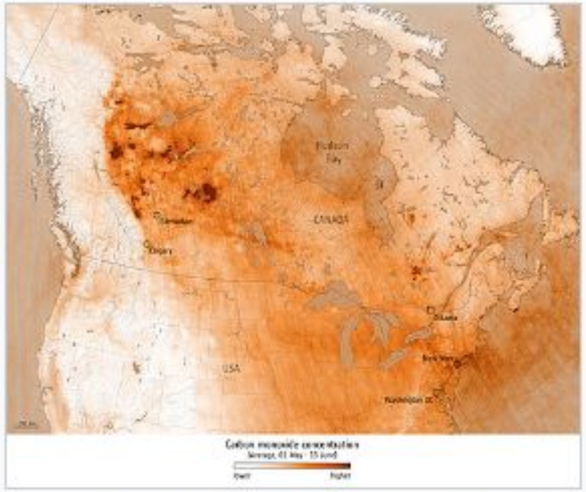
https://www.cbc.ca/news/canada/montreal/weather-humidex-montreal-1.4802847

Fallen Tree

https://www.erieinsurance.com/blog/neighbors-tree-falls-in

Climate Change and Extreme Weather

Canadian wildfires of 2023



Top-to-bottom, left-to-right: Wildfires in Quebec · Wildfire smoke in Calgary · Wildfire smoke in Minneapolis · Wildfires in Nova Scotia · Map of carbon monoxide concentration caused by wildfire smoke

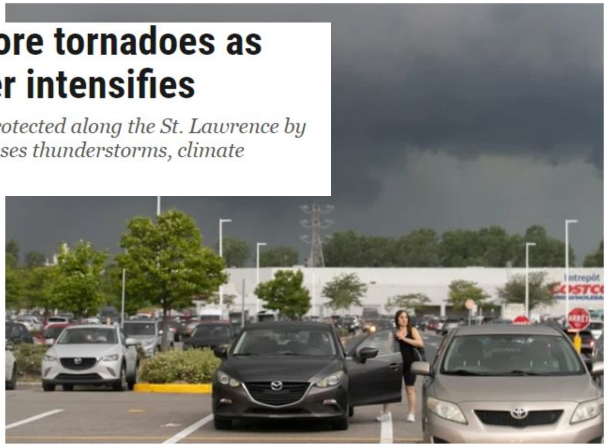
Location	Canada (all 13 provinces and territories)[1]
Statistics	
Total fires	6,074[2] (as of August 31, 2023)
Total area	15.583 million ha (38.51 million acres)[2] (as of August 31, 2023)
Date(s)	March 1, 2023 – present
Deaths	6
Evacuated	155,856 people[3] (as of July 7, 2023)

MONTREAL | News

First heat wave of the year expected this week in Montreal

Quebec sees more tornadoes as extreme weather intensifies

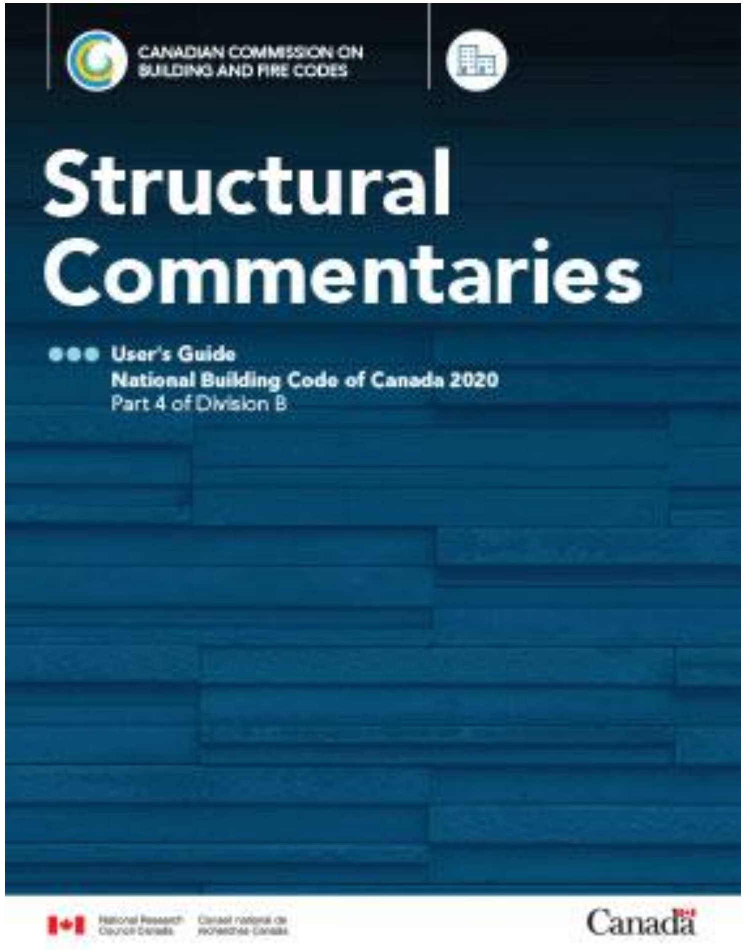
But Montreal seems to be protected along the St. Lawrence by a cooling effect that suppresses thunderstorms, climate scientist David Sills says.



Storm clouds make their way across the northern part of Montreal near Marché Central on July 13, 2023. PHOTO BY PIERRE OBENDRAUF /Montreal Gazette

CODES AND STANDARDS

- Well developed for synoptic wind structural design aspects



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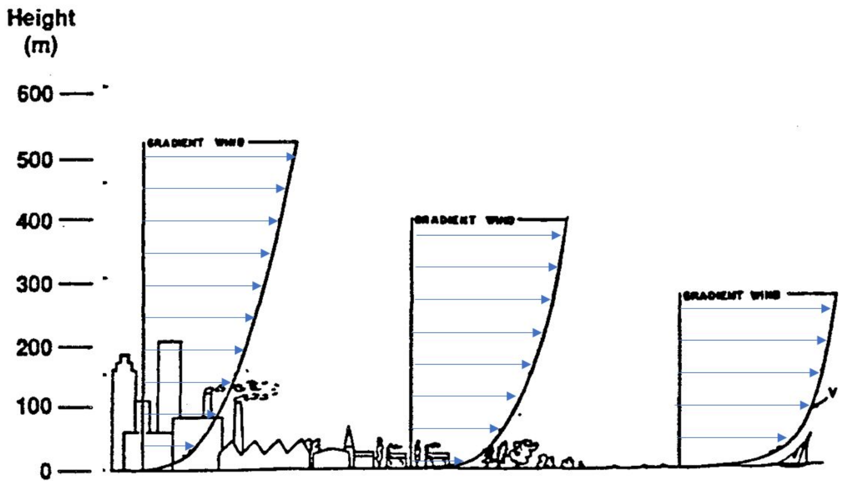
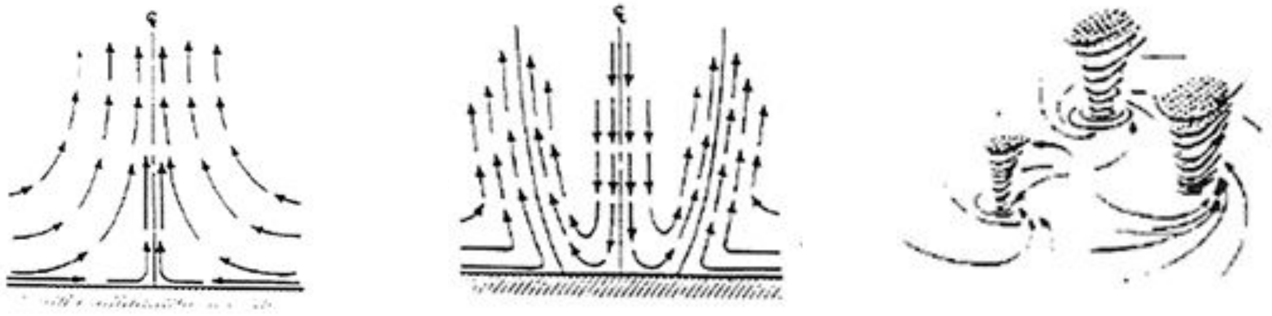
CODES AND STANDARDS

- Synoptic: Atmospheric Boundary Layer wind velocity profiles for sites of different exposures (Davenport 1967)

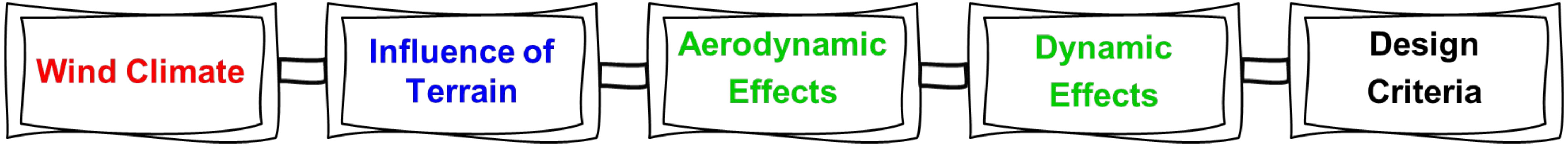


- Non-Synoptic: Tornado flow

one-spiral, two-spirals, and multiple-spirals (Davies-Jones, 2015).



CODES AND STANDARDS



$$P = I_w q_h C_e C_t (C_g C_p)$$

I_w: Building importance factor

q_h: Reference wind pressure ($0.5\rho V^2_h$)

V_h: Basic wind speed at reference height (h)

C_e: Terrain factor

C_t: Topography factor

$C_g C_p$: Peak pressure coefficient

CODES AND STANDARDS

Wind Climate

$$P = I_w q_h C_e C_t (C_g C_p)$$

Appendix C of the NBCC (2015)

- q_h = 0.30 - 0.70 kPa.
- $q_{h,max}$ = 1.23 kPa (at Resolution Island, Nunavut for a return period of 50 years).
- q_h may be revised and magnified to accommodate the risk of F-2 tornado pressure forces (which covers the occurrence of 75% of the Canadian tornadoes), particularly in dense population regions.

Appendix C (Quoted Sample)

Division B

Table C-2 (Continued)

Province and Location	Elev., m	Design Temperature				Degree-Days Below 18°C	15 Min. Rain, mm	One Day Rain, 1/50, mm	Ann. Rain, mm	Moist. Index	Ann. Tot. Ppn., mm	Driving Rain Wind Pressures, Pa, 1/5	Snow Load, kPa, 1/50		Hourly Wind Pressures, kPa	
		January		July 2.5%												
		2.5% °C	1% °C	Dry °C	Wet °C								S_s	S_r	1/10	1/50
Watson Lake	685	-46	-48	26	16	7470	10	54	250	0.55	410	60	3.2	0.1	0.27	0.35
Whitehorse	655	-41	-43	25	15	6580	8	43	170	0.49	275	40	2.0	0.1	0.29	0.38
Northwest Territories																
Aklavik	5	-42	-44	26	17	9600	6	49	115	0.67	250	60	2.8	0.1	0.37	0.48
Echo Bay / Port Radium	195	-42	-44	22	16	9300	8	60	160	0.70	250	80	3.0	0.1	0.41	0.53
Fort Good Hope	100	-43	-45	28	18	8700	9	60	140	0.60	280	80	2.9	0.1	0.34	0.44
Fort McPherson	25	-44	-46	26	17	9150	6	50	145	0.67	315	60	3.2	0.1	0.31	0.40
Fort Providence	150	-40	-43	28	18	7620	10	71	210	0.56	350	100	2.4	0.1	0.27	0.35
Fort Resolution	160	-40	-42	26	18	7750	10	60	175	0.61	300	140	2.3	0.1	0.30	0.39
Fort Simpson	120	-42	-44	28	19	7660	12	76	225	0.56	360	80	2.3	0.1	0.30	0.39
Fort Smith	205	-41	-43	28	19	7300	10	65	250	0.56	350	80	2.3	0.2	0.30	0.39
Hay River	45	-38	-41	27	18	7550	10	60	200	0.62	150	140	2.4	0.1	0.27	0.35
Holman/ Ulukhaqtuuq	10	-39	-41	18	12	10700	3	44	80	0.93	250	120	2.1	0.1	0.66	0.86

CODES AND STANDARDS

- Climate change might also negatively affect the frequency and in-tensity of severe weather events; and thereby increasing their related disasters and compromising the safety of existing buildings (Auld, 2008; Wilby and Dessai, 2010).

Auld, H., 2008: Adaptation by design: The impact of changing climate on infrastructure. Journal of Public Works and Infrastructure. 1, 276–288.
Wilby R.L. and Dessai, S., 2010: Robust adaptation to climate change. Weather, 65, 180-185.

Construction Measures for Increasing the Building Resistance for High Winds (tornadoes)

- Changes in the spacing of roof sheathing fasteners of intermediate supports from 300 mm to 150 mm was made into the Ontario Building Code (OBC, 2010).

- A periodic maintenance and check for inherent deficiencies in the building construction should be undertaken particularly for roof to wall connections.

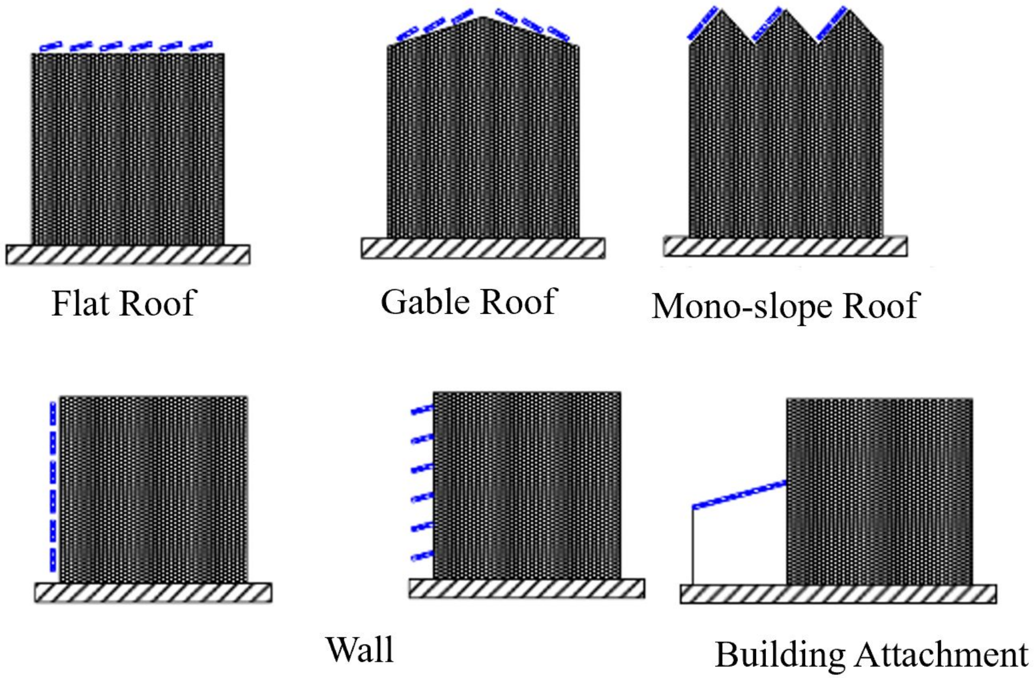
- Buildings of public service facilities (hospitals, educational institutions, airports, and power plants) could be designed for severe tornados (i.e., F-3 intensity of mean wind speed 250-320 km/hr) or higher (Haan et al 2008).

Haan, F.L. , Sarkar, P.P., Gallus, W.A. 2008. Design, Construction and Performance of a Large Tornado Simulator for Wind Engineering Applications. Engineering Structures, 30 (4), 1146-1159.

Energy Resilience CROSS Structural Resilience

PV Technology

Building Attached Photovoltaics (BAPV)



Our Review - Methods and Issues

“Urban Microclimate” (23%),
“Urban heat island” (17%), and
“CFD”(14%)


ELSEVIER
Building and Environment
Volume 238, 15 June 2023, 110334

Urban microclimate and its impact on built environment – A review

Senwen Yang, Liangzhu (Leon) Wang, Ted Stathopoulos, Ahmed Moustafa Marey

https://doi.org/10.1016/j.buildenv.2023.110334

- **Practical issues**
1. Urban heat island
2. Climate
3. Outdoor thermal comfort
4. Energy demand
5. Urban ventilation Urban physics
6. Pollutant dispersion

- **Methods or tools**
1. Numerical simulation – e.g., CFD
2. Field measurements (e.g., remote sensing etc.)
3. Wind tunnel

- **Building/community parameters**
1. Urban geometry (street canyon, building blocks)
2. Vegetations (i.e., urban greenery, urban park)
3. Water bodies (i.e., coastal cities)
4. Building characteristics (i.e., albedo, green roof)

Research Challenges and Needs

Research Needs

- Still VERY limited study on resilience of buildings and communities
- Advanced sensing and laboratory techniques for both built and urban environments
- Interactions of urban thermal flow with surrounding surfaces, such as local water bodies
- UHI under combined physics of wind, solar, shading, vegetation, and building configuration
- AI urban aerodynamics and urban building energy performance
- Generation and public sharing of high-quality research datasets

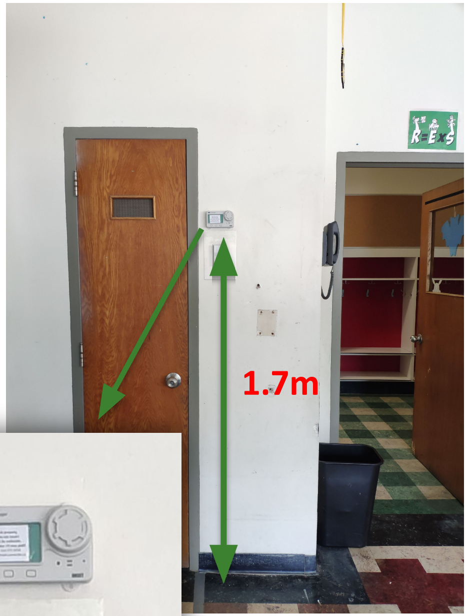
Measurements - Monitored buildings and instrumentation

Outdoor climatic conditions
Dry-bulb temperature,
Relative humidity,
Solar radiation,
Wind speed,
Wind direction,
Rainfall intensity

Indoor thermal conditions
Dry-bulb temperature,
Relative humidity, CO_2

Indoor RH/T sensor

Indoor RH/T & CO_2 sensor



Conclusion

- Severe weather extreme events have caused costly damages notwithstanding their low probability of occurrence
- NBCC (2020) defines risk zones based on the Enhanced Fujita (EF) scale and probability of occurrence and provides structural guidance for anchorage improvements in commentary.
- However, ASCE/SEI 7 (2022) has recently incorporated explicit and detailed provisions for tornado-induced loads “Chapter 32: Tornado Loads”.

Conclusion

- More research and development for both wind code and standard provisions and engineering practice for construction and maintenance are urgently needed to achieve the desired level of safety

- There is a thrust to upgrade and develop wind engineering facilities that can produce downbursts and tornadoes with the aim to better understanding the effect of non-synoptic winds on structures

Thank You