CITY OF EDMONTON: WIND STUDY TERMS OF REFERENCE BACKGROUND REPORT

SPECIALITY WIND ENGINEERING SERVICES
RWDI # 2001621
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SUBMITTED TO

City Planning Branch
Policy Development Section
6th Floor, Edmonton Tower
10111 104 Avenue NW
Edmonton AB T5J 0J4 T: 780-442-6259

SUBMITTED BY

Neetha Vasan, M.A.Sc., LEED AP
Senior Microclimate Scientist
Neetha.Vasan@rwdi.com

Hanqing Wu, Ph.D, P.Eng.
Senior Technical Director / Principal
Hanqing.Wu@rwdi.com

Rodney Blanco
Project Manager
Rodney.Blanco@rwdi.com

RWDI
Suite 1000 – 736 8th Avenue SW
Calgary, AB, T2P 1H4
T: 403-232-6771 ext. 6215

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1 INTRODUCTION

The City of Edmonton has retained RWDI to assist Administration with the development of a Wind Study Terms of Reference document. The Terms of Reference provides technical guidance for standardized wind impact testing methodologies and wind comfort and safety criteria. It provides direction in determining wind impacts to areas surrounding potential developments as well as guidance around mitigation strategies. It also provides guidance around triggers for when a wind impact study or statement is required and outlines its impact on Edmonton's Land Development and Development Permit application process.

Wind plays a crucial role in defining human comfort. The mechanical force of wind on people can impact daily common activities in varying levels. Typically, the higher the wind speed, the greater the wind force on a person. The more active a person is in an instance, the greater the wind speed they can tolerate. The Wind Study Terms of Reference addresses the mechanical effects of wind on people and how conducive it is to pedestrian use in outdoor areas of the city.

This document provides technical criteria and other background information that is unique and specific to the geographic and meteorological conditions of Edmonton. This document will inform the preparation of a Wind Study Terms of Reference by the City of Edmonton Administration that is aligned with the City's specific graphic standards and processes. Implementation will include access to a public finalized version of the document on the City's website as well as amendments to the City's Zoning Bylaw to have it come into force.

2 QUALIFICATION OF APPLICATION

2.1 Applicants

Upon triggering the requirement for a wind study in accordance with section 2.3, an applicant shall procure a Consultant to produce a submission in accordance with these terms of reference.

2.2 Consultants

Pedestrian wind comfort and safety studies are to be conducted by professionals who specialize in and can demonstrate extensive experience in dealing with wind and microclimate issues in the built environment. The Consultant shall provide a declaration stating their professional experience and confidence in the content of the Wind Study Report to be included with submissions.

2.3 Triggers

It is important to consider the potential impacts of a proposed development on the local microclimate early in the planning and design process as this allows enough time to consider appropriate wind control and mitigation strategies, including significant changes to site and building designs. Properties, circumstances, etc. of a project that, through precedents, are known to be causative factors for noticeable wind impacts around the project are referred to as triggers. If the project meets the conditions specified under the list of triggers, then a wind assessment would be requested for the project.

To represent the intensity of the potential wind impact of a project on its surroundings, Trigger Levels are categorized as Low, Moderate and High. Projects are to be classified into one of the three Trigger Levels using the criteria in Table 1.

TABLE 1: TRIGGER EVALUATION

Applications shall be reviewed based on the determined Height Triggers. A proposed development or rezoning that increases the height of a site's current built form or increases the maximum height provisions of the current zone shall be considered for a wind impact assessment based on the following triggers and height classifications.

Low	Moderate	High
≥20 m and <40 m	≥40 m and <60 m	≥60 m

2.4 Development Process

TABLE 2: PLANNING APPLICATION TYPE AND ASSESSMENT METHODOLOGY

Trigger Level	Low ≥20 m to <40 m	Moderate ≥40 m to <60 m	High ≥60 m
Rezonings (Direct Control)	Wind Impact Statement*	Qualitative (CFD) Wind Impact Study**	Qualitative (CFD) Wind Impact Study**
Development Permits (Conventional Zone)	Wind Impact Statement*	Qualitative (CFD) Wind Impact Study**	Qualitative (CFD) Wind Impact Study**
Development Permits (Direct Control Zone)	As required by the Zone		

*Subsequent Wind Impact Study may be required dependent upon expert consultant's recommendations.
**A more detailed Quantitative (Wind Tunnel) Wind Impact Study may be required dependent upon expert consultant's recommendations.

2.4.1 Land Development Application (LDA)

Project triggers should be evaluated and the approach for a wind study should be decided using Table 2: Application Process and Assessment Methodology. The submission to the city should include a Wind Study Report detailing the wind impact of the proposed massing with respect to the Design Criteria (Section 3.5) and a description of design changes that will be implemented to achieve acceptable wind conditions on and around the project. This effort, earlier on in the design, will help reduce the wind study iterations required in subsequent applications. General issues to be addressed in the preliminary massing study include the following:

- Height of the proposed development in relation to the height of surrounding structures
- The orientation and general massing of the development with respect to the primary wind directions
- Location and shape of specific design features that induce wind activity
- Potential impact of wind speed increases created by the development on the surroundings
- Outline of basic wind mitigation features to be included in development design including base and podium conditions, canopies and tower orientation

The City, at their discretion, may ask for additional statements or studies.

2.4.2 Development Permit Application (DPA)

In conventional zone Development Permit Applications, a Wind Impact Study or Statement should be decided using Table 2: Planning Application Type and Assessment Methodology.

In Direct Control Zone Development Permit Applications, the requirements for a Wind Impact Study or Statement shall be in accordance with the provisions of the Direct Control Zone regulations.

2.4.3 Significant Design Changes

Significant building design revisions may occur during the Development Permit Application review process in conventional zones after a Wind Impact Statement or Study has identified wind impacts have been sufficiently addressed. This may occur because conventional zones do not prescribe the design of a building in as much detail as Direct Control Zones.

The significance of such revisions with respect to their impact on wind may need to be reevaluated for each project by the Consultant and through discussions with the Development Officer. Since defining a significant change is complex, some scenarios that could be considered significant include, but are not limited to:

- Reshaping, reorienting or relocating all or part of the building massing
- Increase in tower height in excess of five storeys
- Change of more than 3m in the offset distance of a tower from podium edges
- Change in the number of buildings on the site or in the surroundings
- Addition/change in canopy depth of 2m or more on a windward façade
- Increase or decrease in excess of 5m in the setback of a (part of a) building from a public sidewalk

The list is not exhaustive but serves as a benchmark that acts as a point of reference in defining a significant change.

Where a significant building design revision has occurred during the Development Permit Application review process in a standard zone, the Development Officer may require a new wind impact study or statement to be submitted.

Where a significant building design revision has occurred during the Land Development Application (rezoning) review process, the File Planner may require a new wind impact study or statement to be submitted.

2.5 Assessment Methodologies

Wind assessments can be done through experience-based desktop reviews, computational fluid dynamics (CFD) modelling, and physical scale modelling in wind tunnels. Each method has its benefits and limitations; thus, it is essential that the right approach be chosen for the type, context and approval stage of the project. The following is a description and technical requirements of the different methodologies.

2.5.1 Wind Impact Statement (Desktop Assessment)

Desktop reviews are qualitative in nature and are largely based on the Consultant's knowledge of and experience with wind flows in the built environment. Basic numerical modelling and calculations are often used to assist in the assessment. Previous wind tunnel results for nearby projects and/or for a similar development in Edmonton or other cities may be used as a reference. This type of assessment can be used to provide conservative estimates of pedestrian wind comfort around projects and are helpful for initial assessments of the impact of new developments on the wind environment and comparative assessments of the nature of the impact of changes to a design. Desktop studies cannot provide accurate wind speeds and frequencies and cannot always predict with certainty the possibility of an exceedance of the wind criteria. While it is possible to assess the wind impact of a multi-building development, because the effort is mostly manual, the qualitative assessment of multi-building projects would be more time-consuming than using computational or physical modelling techniques.

Requirements

- Assessments should be based on the proposed heights of the project in contrast to the Design Criteria described in Section 3.5. Where no design elements are included, assessment shall consider the maximum buildout comparisons based on the current or proposed zoning regulations.
- Assessment should be based on the Design Criteria described in this document.
- Comfort and Safety categories generally expected at key pedestrian areas should be estimated and presented graphically on a site plan.
- See Section 3.6 for more details on reporting and presentation.

2.5.2 Qualitative Wind Impact Study (CFD Study)

For urban wind modelling, computational fluid dynamics (CFD) techniques are used to generate a virtual wind tunnel where flows around the site, surroundings and the study building are simulated at full-scale. The computational domain that covers the site and surroundings is divided into millions of small cells where calculations are performed, allowing for results to be presented in high spatial resolution. There are no limitations to the number of points of measurement and results can be obtained from any data point in the computational domain even after the simulation is over. CFD allows for the "mapping" of wind conditions across the entire study-domain. CFD excels as a tool for urban wind modelling for providing early design advice, resolving complex flow physics, and helping diagnose problematic wind conditions. It is useful for the qualitative assessment of complex buildings and contexts and provides a visual representation of the potential wind conditions which makes it easy to judge or compare designs and site scenarios. At present, the technological advancements available are not ready to quantify the transient behaviour of wind, including wind gusts, quickly and accurately. Therefore CFD, in our opinion, remains a tool for qualitative assessments and must be used by consultants with extensive experience in wind engineering.

Requirements

- Assessments should be based on the proposed heights of the project in contrast to the Design Criteria described in Section 3.5. Where no design elements are included, assessment shall consider the maximum buildout comparisons based on the current or proposed zoning regulations.
- The CFD software used should follow the *COST 732 Best Practice Guideline for CFD Simulations* in an urban environment.
- The CFD simulation should appropriately represent the atmospheric boundary layer for winds approaching the project.
- The Consultant should be confident with the results produced and ensure that it is technically correct.
- A minimum of sixteen (16) wind directions at equal intervals should be simulated. The complete assessment should consider the probability of all wind directions using meteorological data obtained in accordance with Section 3.4.
- Assessment should be based on the standard wind comfort and safety criteria described in this document.
- Simulation results should be scaled to represent comfort categories and presented in accordance with the Design Criteria colour coding in Section 3.5
- The potential wind safety impacts should be estimated through numerical or experience-based methods and areas where an exceedance of the criterion is estimated should be indicated.
- See Section 3.6 for more details on reporting and presentation.

2.5.3 Quantitative Wind Impact Study (Wind Tunnel Study)

Wind tunnel testing is the established tool used for modelling wind flow around buildings and structures in order to quantify and assess wind conditions, among other types of assessments. A scale model of the study area and surroundings are placed in a wind tunnel, instrumented appropriately for wind speed measurements, and subjected to wind flows physically simulated to represent winds approaching the actual site. In general, such modelling provides a good quantified representation of both mean and gust effects and the transient behavior of wind. It is a complex tool and requires experience and expertise to produce useful information and to interpret data, and therefore are accessibly only through consultants and universities that specialize in wind engineering.

Requirements

- Assessments should be based on the proposed heights of the project in contrast to the Design Criteria described in Section 3.5. Where no design elements are included, assessment shall consider the maximum buildout comparisons based on the current or proposed zoning regulations.
- The wind simulation facility must be capable of simulating the earth's atmospheric boundary layer and appropriate wind speed and turbulence profiles for each of the wind directions tested.
- Wind speed measurement
    - 36 wind directions shall be tested
    - Sensors shall be omni-directional and shall measure the magnitude of wind speeds.
    - The measurements should represent the wind speed at a full-scale height of approximately 1.5 m above local grade.
    - Sensors and instrumentation should be capable of measuring mean wind speed and wind speed fluctuations with time, including peak gusts of three to ten second duration. Peak gusts can be directly measured from wind tunnel testing or estimated by "mean wind speeds + 3*RMS" wind speed.
    - Sampling time in the wind tunnel shall represent a minimum of one hour of full-scale time and sampling frequency a minimum 1 Hz in full scale.
- Sensor placement
    - Sensors shall be placed at a full-scale interval of approximately 10 m along street frontages of the project buildings and at all locations where pedestrians will gather. The interval may be increased farther away from the project site.
    - Locations should include all areas of interest in accordance with Section 3.2.
    - A typical development project would require a minimum of 50 sensor locations on and around the proposed development to provide adequate coverage.
- Analysis and Results
    - The analysis should consider the probability of all wind directions tested using meteorological data obtained in accordance with Section 3.4.
    - Assessment should be based on the Design Criteria.
    - The results shall be presented in both tabular and graphic forms for all the test scenarios, with seasonal comfort data and annual safety data. The table must include wind speed and associated wind speed category (refer to Design Criteria) at each measurement location.
- See Section 3.6 for more details on reporting and presentation.

3 TECHNICAL REQUIREMENTS

The requirements specified in the following sections applies to all assessments, regardless of methodology, unless specified otherwise.

3.1 Project Context Scenarios / Massing Scenarios

The perception of wind can vary regionally, based on differences in climatic parameters like daylight, temperature, humidity, etc. and parameters like clothing, age, health, and even tolerance to wind developed through acclimatization to the local climate. Therefore, the most objective way to assess the impact of a proposed development on wind conditions around it is to compare it to existing conditions. If the Project is expected to result in less than acceptable wind comfort, then further assessments should be conducted to evaluate a wind mitigation plan that can be implemented in the final design of the Project.

The following four scenarios should be assessed for every project:

- **Existing Scenario:** Existing site and all existing surrounding buildings, significant topographic features, developments under construction and projects that were approved for construction in the preceding 5 years.
- **Proposed Scenario**: Proposed project in place of existing site.
- **Mitigation Scenario(s), if warranted:** Where mitigation is required to achieve acceptable pedestrian wind comfort levels, as concluded from the Proposed Scenario, re-evaluate the Proposed scenario with recommended mitigation measures in order to demonstrate the benefits of those measures.
- **Phasing Scenario(s), if applicable:** Where the site construction is phased, there is a need to assess interim scenarios, as well as scenarios that may create adverse conditions before subsequent buildings are added to the site. The City may ask for different site configurations.

3.2 Areas of Interest

The scope of the assessment should cover all key pedestrian areas on and within one block of the Project in all directions. Key pedestrian areas where wind conditions should be assessed include, but are not limited to:

- Entrances and perimeter of the Project
- Project perimeter and major entrances of neighbouring buildings.
- Communal and private on-site amenity areas
- Privately Owned Public Spaces (POPS)
- Public parks or recreational areas.
- Publicly accessible above-grade locations

Designated seating and waiting areas are to be outlined through discussions with the City prior to a wind assessment. The applicant is required to submit the intended test scenarios and sensor locations for review by the Development Authority prior to any wind assessment.

3.3 Project and Proximity Model

The requirements in this section are applicable to Qualitative (CFD) Wind Impact Studies and Quantitative (Wind Tunnel) Wind Impact Studies only. The model for these studies should be constructed to include all massing and architectural features on the project that would influence wind flow around it.

- The surrounding context (proximity model) within a minimum radius of approximately 350 m from the centre of the proposed development site should be modelled. Tall buildings outside of this zone that could have an influence on wind conditions within the project site – based on the expert opinion of the Consultant – should be included.
- Structures and natural features beyond the modelled surroundings shall be represented physically and/or numerically, as appropriate for the study type.
- Typically dimensions less than 1 m do not have a notable impact on wind related to pedestrian comfort.
- Landscaping features should be ignored for wind studies, unless, through discussions with the City, such features are to be included for wind mitigation.
- Models for CFD studies are typically at 1:1 scale.
- For Wind Tunnel Studies, model scale of 1:500 to 1:300 have proven to be effective at representing relevant architectural details on the project and surrounding context. A scale outside the range may be used provided and explanation for the choice of scale and why the recommended scales would not be appropriate is included in the Wind Study Report. Note that the model scale chosen for optimal data quality could vary, depending on the test equipment and instrumentation use.

3.4 Meteorological Data

The most recent wind records available from Edmonton International Airport should be used for the assessment of pedestrian wind comfort and safety.

- A minimum of 30 years of hourly wind data should be used.
- The Data is to be presented and used on a two-season basis defined as follows:
    - Summer: Hourly winds occurring during the period of May through October.
    - Winter: Hourly winds occurring during the period of November through April.
- Appropriate hours of pedestrian usage for a typical project (e.g., between 6:00 and 23:00) should be considered for wind comfort, while data for 24 hours should be used to assess wind safety.

3.5 Design Criteria for Wind Comfort and Safety

Comfort and Safety Criteria in Table 3 should be met for all development applications.

- **Comfort**: Commonly experienced wind speeds have been categorized into ranges based on the activity level of a person that the winds would be conducive to. Lower wind speeds are desirable for relaxed activities and active pedestrians would be tolerant of higher wind speeds.

- **Safety**: It is important to assess wind conditions in the pedestrian realm from a safety perspective as strong wind gusts can deter safe pedestrian use of outdoor spaces. Wind speeds associated with such conditions are infrequent but deserve special attention due to their potential impact on pedestrian safety.

TABLE 3: WIND CRITERIA FOR PEDESTRIAN COMFORT AND SAFETY

COMFORT CATEGORY	GEM SPEED (km/h)		DESCRIPTION	AREA OF APPLICATION
	SUMMER May - Oct	WINTER Nov - Apr		
Sitting	≤ 10	≤ 8	Light breezes desired for outdoor seating areas where one can read a paper without having it blown away.	Park benches, restaurant seating, balconies, amenity terraces, etc. intended for relaxed, and usually seated activities.
Standing	≤ 15	≤ 12	Gentle breezes suitable for passive pedestrian activities where a breeze may be tolerated	Main entrances, bus-stops and other outdoor areas where seated activities can be avoided.
Walking	≤ 20	≤ 16	Relatively high speeds that can be tolerated during intentional walking, running and other active movements.	Sidewalks, parking lots, alleyways and areas where pedestrian activity is infrequent.
Uncomfortable	> 20	> 16	Strong winds, considered a nuisance for most activities.	May be accepted in areas not intended for pedestrian access

NOTES:
1) The required seasonal compliance is 80% of the time for the Sitting, Standing and Walking categories. The Uncomfortable categorization is applicable if the criteria for Walking are not met.
2) Gust Equivalent Mean (GEM) speed = maximum of either mean speed or gust speed/1.85. The gust speed can be measured directly from wind tunnel or estimated as ***mean speed + (3 x RMS speed)***.
3) Comfort calculations are to be based on wind events recorded between 6:00 and 23:00 daily.
4) Threshold wind speeds are lower in the winter to account for wind-chill, in order to consider outdoor comfort in alignment with the Winter City Design Guidelines.

SAFETY CRITERION	GUST SPEED (km/h)	MINIMUM OCCURRENCE (% OF TIME)	DESCRIPTION	AREA OF APPLICATION
Exceeded	> 90	0.1 (9 hours in a year)	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.	All areas assessed

NOTES:
5) Wind safety assessment is to be based on wind events recorded for 24 hours a day.

3.6 Wind Study Report

A written report documenting the wind study and conclusions, including the following, should be provided:

- Consultant's declaration
- Objectives of the Wind Impact Assessment
- Brief description of the project (at minimum describe height and location, including a location map)
- Description of the method chosen for the assessment
- Description and images of the study and proximity models
- Description of the source and period of meteorological data use, including a graphical representation of the data
- Wind Criteria for Pedestrian Comfort and Safety
- Presentation of results
    - Wind speeds must be presented in km/h
    - Results should correspond to pedestrian level (i.e. approximately 1.5 m above the concerned level).
    - For all assessment methodologies, results should be presented in graphic form for each study scenario, with a colour coded representation of seasonal comfort and annual safety categories using the colour coding in Table 3 in Section 3.5. Vertical slices or axonometric views depicting flow patterns may be included to understand flow mechanisms in critical areas.
        - For a Quantitative Wind Study, results must also be presented in tabular forms for all the test scenarios, with seasonal comfort data and annual safety data. The table should include wind speed and associated comfort and safety category at each measurement location.
- Discussion of results and recommendations
        - Separate discussions for each scenario, relating to seasonal comfort and annual safety in accordance with the Design Criteria.
        - The discussion should include interpretation of the results as it relates to the standard wind criteria described in this document, discussions about causative flow mechanisms and recommendations for mitigation of adverse or undesirable wind conditions.
        - Where conditions are predicted to be unacceptable for the intended pedestrian usage, design alternatives and wind control strategies should be recommended to improve the wind comfort to acceptable levels or appropriate adjustments to pedestrian usage shall be suggested, if applicable.

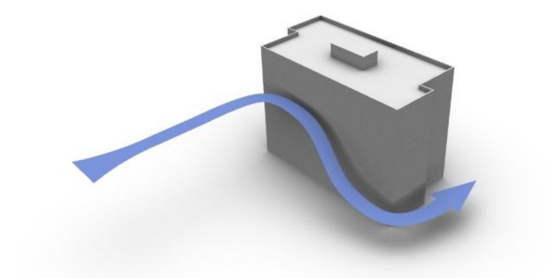
4 WIND-RESPONSIVE DESIGN GUIDELINES

4.1 Wind Flow in the Built Environment

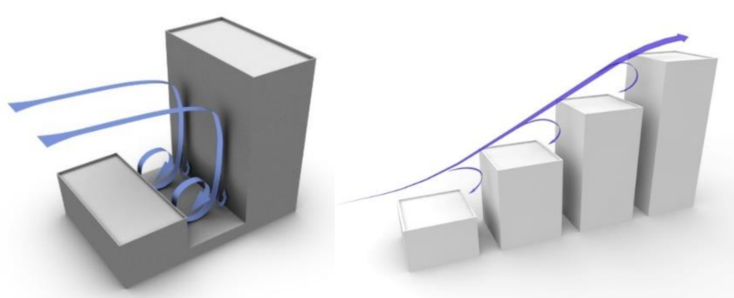
Wind speed increases with elevation; wind typically flows unobstructed and at high speeds over areas of uniform height (built structures or natural terrain). Short buildings typically do no deflect winds to a level that would result in adverse wind impacts. Wind, when obstructed by a structure such as a building, will find the path of least resistance to continue its motion, in the process, creating zones of high-wind activity around the building. The following is an overview of some of the common wind flow mechanisms seen in the built environment. One or a combination of such mechanisms could result in undesirable wind activity in the pedestrian realm, depending on the local climate, building form and its exposure to winds and the surrounding terrain.

Consider a tall building with the broad façade facing a strong wind stream. When the stream is intercepted by the building, some of the flow moves upward and over the building, but a majority of the stream is redirected downward (Downwashing) and around the lower portion of the building.

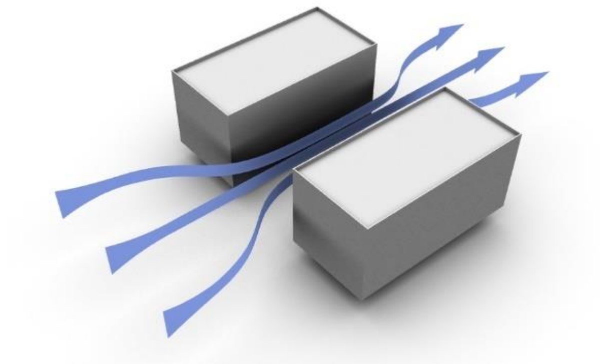
The flow attaches to the building, and then separates at the edges creating high wind activity at the corners (Corner Acceleration).



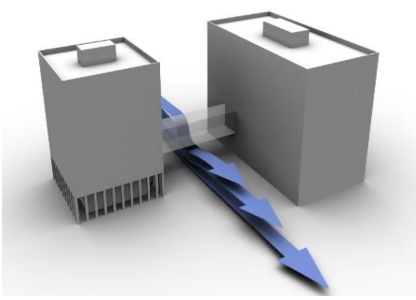
This effect could be intensified if a short building is located upwind; because of the air pressure differential between the top and bottom of the building. The area between the buildings could be very windy as a result. However, strategic master planning uses this arrangement to an advantage as locating shorter buildings upwind of taller ones reduces the exposure of the taller and more impactful buildings to wind, thereby reducing the potential for adverse wind impacts.

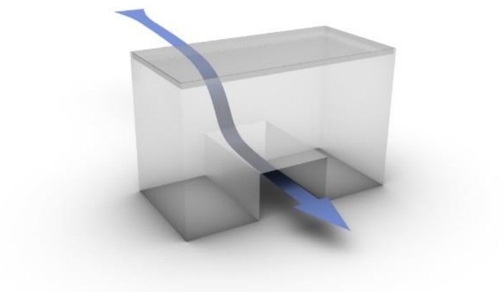


When gaps between buildings, that are narrow relative to the building heights, are aligned with the prevailing winds, wind accelerates in the gaps because of what's commonly called Venturi effect.

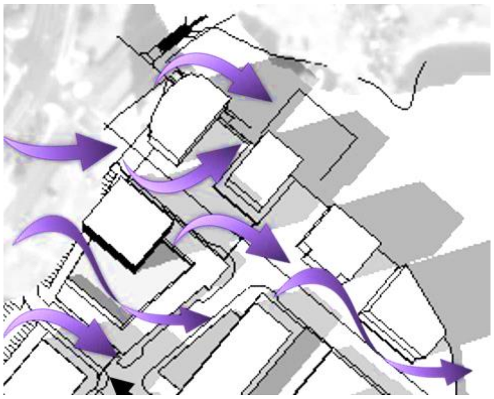


A similar acceleration is also common under bridges and in underpasses as the air is forced to go through a narrow passage.





In a typical urban setting, wind interacts with multiple buildings and the resulting flow is much more complex. Depending on the wind-rearrangement caused by building groups (or a single building on its own), the causative flow mechanisms involved and design flexibility, the choice between "spot-treatments" and measures that have a large-scale impact becomes critical.

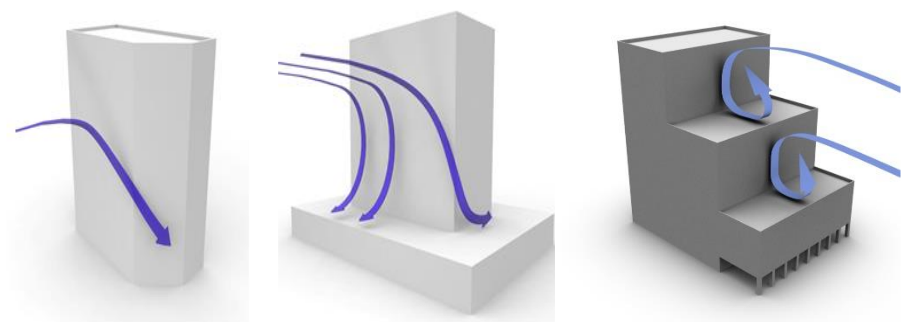


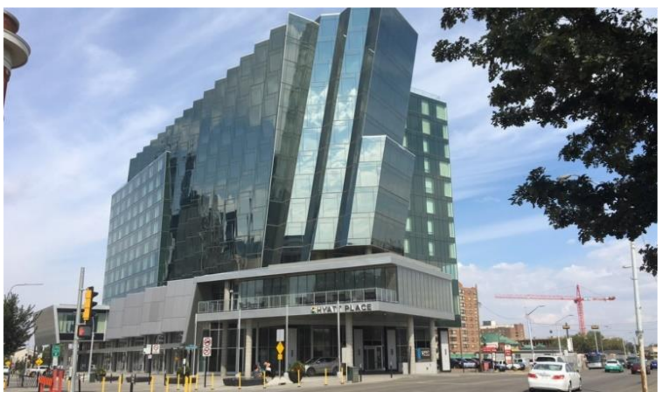
4.2 Wind Control Strategies

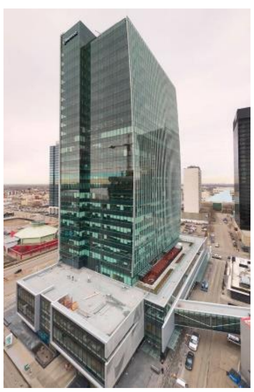
The most effective wind control measures involve adjustments to the building early in the design process and relate to the location, orientation, height, massing and form of buildings. Such adjustments are more responsive to the local wind climate. These large-scale modifications can be assisted by features like tower setbacks, large podiums, tower shapes, corner articulations, colonnades/arcades, etc. The following is a description of general large-scale wind-responsive features, followed by examples taken from urban areas in North America.

Building Form

Strategic reshaping of the building can allow wind flow around it to be either more streamlined (chamfered or rounded corners) or diffused at the corners (stepped or re-entrant corners). Low buildings may also be designed with a stepped form to achieve a similar wind speed reduction. This approach is considered a large-scale solution that would lower the potential for severe wind impact at grade and has a large area of influence.





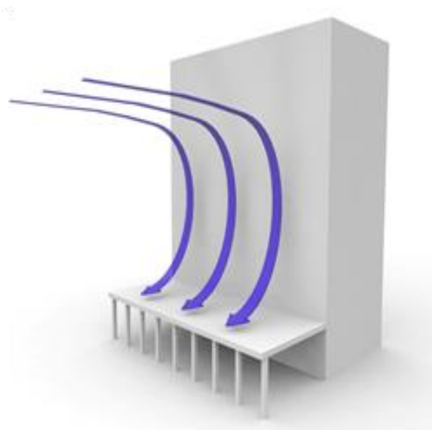


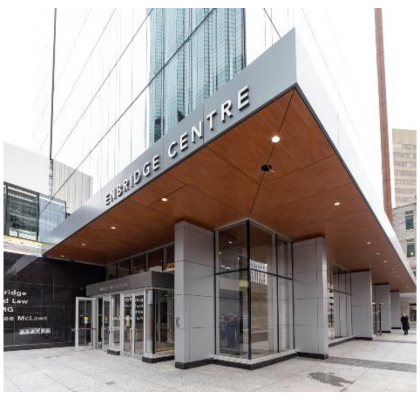
Architectural Details

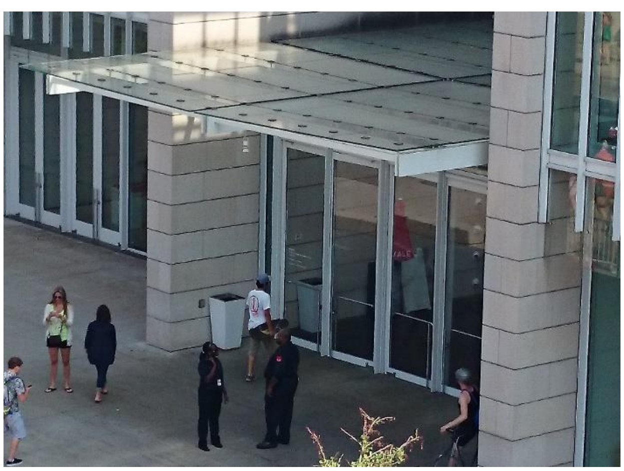
Features such as façade articulations, canopies, covered walkways and recessed entrances are effective solutions for localized wind mitigation.

Recessed Walls create areas that will be protected from ambient wind activity. If entrances are located in such recessed areas, it also creates a waiting area for patrons using the entrance, as well as a transition zone for patrons exiting to get acclimatized to the ambient conditions.

Covered walkways, similarly, provide a protected area for pedestrians at the base of tall towers that are prone to downwash impacts







Localized Accessory Elements

Smaller-scale measures such as wind screens, street art, landscaping and other localized features can be considered at an advanced design stage for area-specific wind speed reductions and refinements. The impact of these features is typically limited to a small area around them.

Wind screens may be placed on both sides of entrances, on sidewalks and in parks and other open spaces to create localized low wind areas. It is recommended that wind screens be at least 2 m tall and approximately 30% open/porous for good wind control efficacy. Landscaping elements, especially coniferous and marcescent species, are commonly used to improve wind conditions to appropriate levels, all year round. Deciduous landscaping is most effective during the summer months. The use of landscaping as part of a mitigation strategy is acceptable but should be selected and sized to be effective at the time of installation. Landscaping can only be recommended as a mitigation measure, where the wind conditions are suitable for it to thrive and for its maintenance.