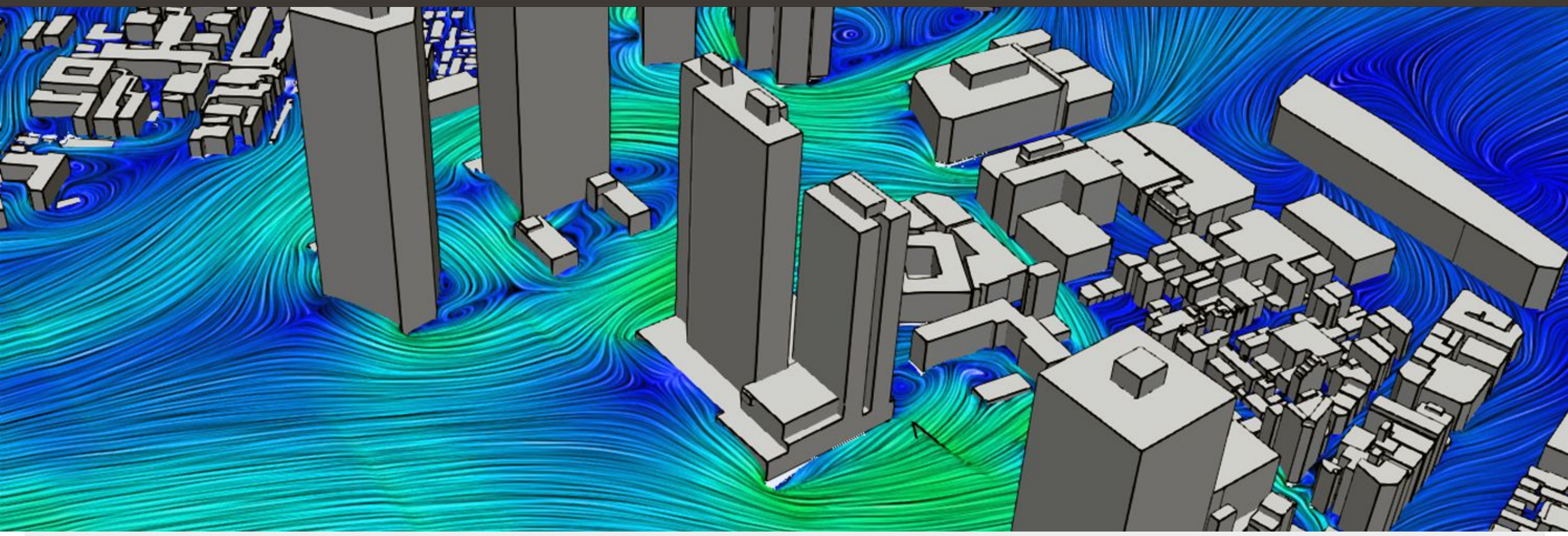
WHITE PAPER

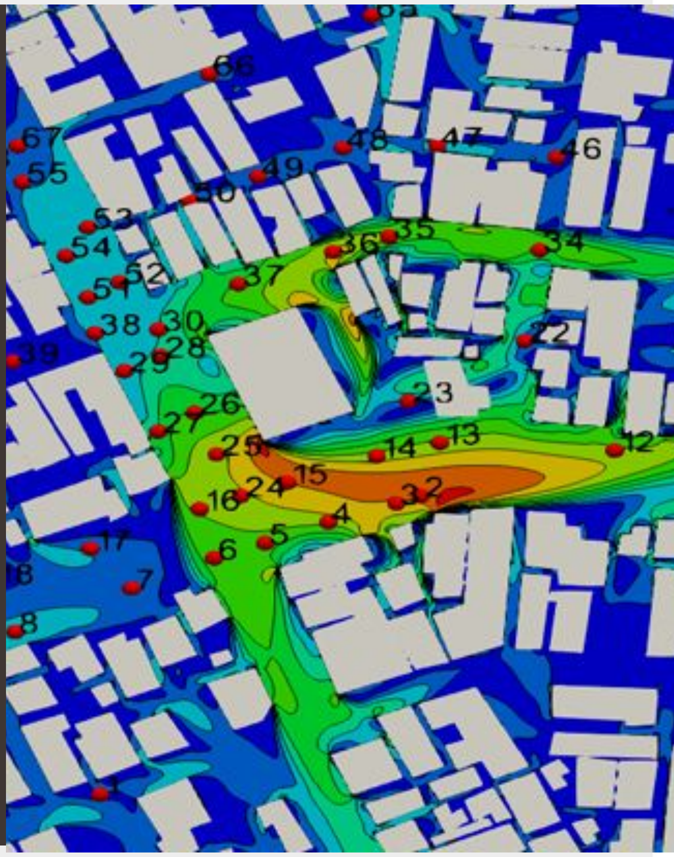
WIND ENGINEERING

GUIDE

This paper addresses significant wind engineering considerations for the architecture, engineering and construction industry today. Topics covered include building design wind load implications, pedestrian wind comfort, natural and ventilation, and pollution mitigation.



Contents



Introduction

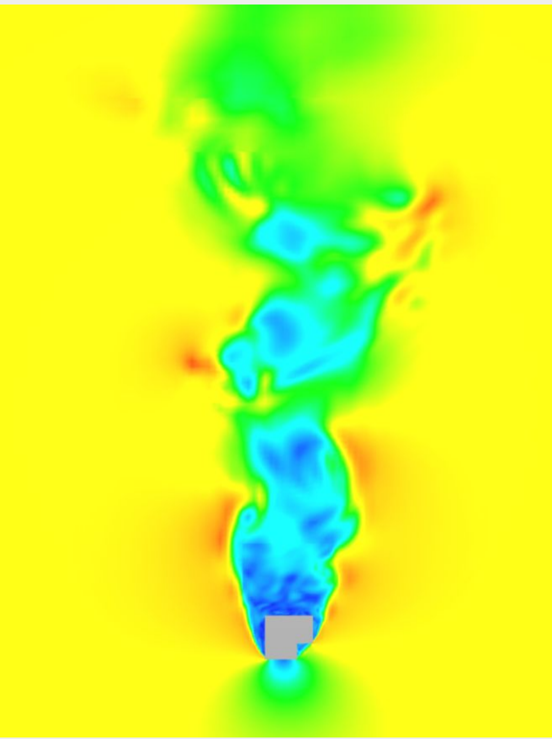
Any building design project is a complicated endeavour that consists of multiple phases and requires contributions from multiple disciplines. Wind engineering exists as one of these disciplines, and is the science behind combining fluid mechanics with wind and thermal comfort to ensure safe and functional living conditions for humans. Designing structures that will last depends on the ability of engineers to understand and predict the behavior of wind.

This specific requirement fuels the centuries-long quest for equations and rules to model fluid flow, a quest that is still relevant today and poised to drive research for many years to come in both meteorology and engineering academias.

This guide explores wind engineering considerations for the initial and planning phases of the building design process including wind load, pedestrian wind comfort, ventilation, and pollution mitigation.

Wind Load Implications

In wind engineering, wind load is essentially wind pressure acting upon buildings and structures. This force is most effective when the surface in question provides a flat face and the torsional directions are greater than zero, when the wind force in the along-wind direction is a maximum. Wind load, in turn, impacts the model or natural frequency of a structure, as well as creates vortex shedding that must be evaluated, or otherwise cause vibrations in the building.

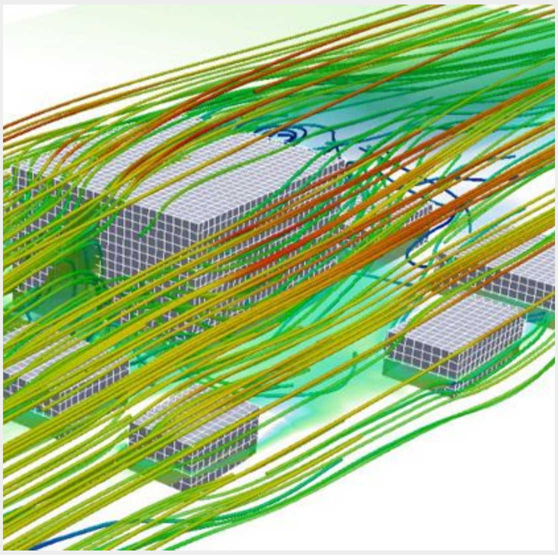


As tall buildings and skyscrapers become increasingly complex in overall design and scale, they are placed at a greater risk of being affected by the wind. In certain regions with high wind velocity (such as coastal areas), even typical building designs have to take wind loads into account. It is the task of architects and design engineers to ensure a safe, sustainable, and cost-efficient design by utilizing wind engineering studies. These studies are now an industry standard and are conducted to first evaluate the dynamic effect of the wind on the structure, and then to optimize the design to mitigate these effects.

In most cases, the two main concerns for designers and engineers are:

1. Pressure loads on the structure and facade. This mainly involves steady state analysis to identify areas of high-low peak pressures that would experience larger forces and could require reinforcement to ensure safety. While it is often possible to derive pressure loads for simple designs via basic code methodology, it is necessary to use detailed wind tunnel testing or numerical analysis to get accurate results for complex shapes.

2. Determining and mitigating the dynamic effects of the wind load. For tall structures with high aspect-ratio, the analysis of unsteady vortex shedding is vital because this induces oscillating crosswind forces with a certain frequency. If these oscillations coincide with the natural frequency of the structure, the motion could be enhanced leading to either damage or destruction.

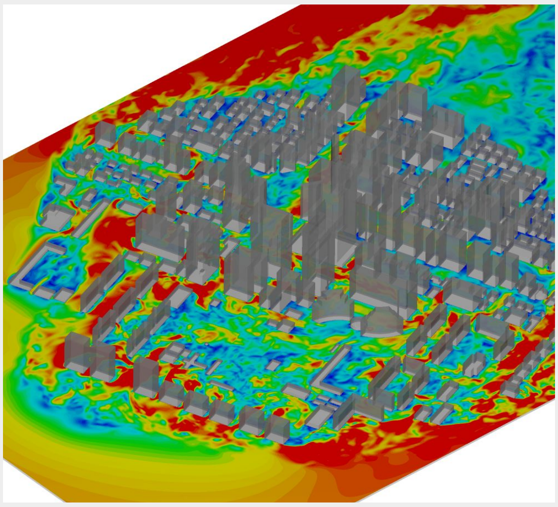


Some of the main design modification strategies that could be undertaken to reduce or suppress vortices include:

- Vortex shedding techniques in building design
- Creating flow spoilers or disturbance
- Corner softening
- Tapering the height or varying the cross-section shape
- Adding porosity, open floors/sections or bleed slots

These modifications can be studied during the design cycle and can alone reduce and mitigate wind-induced forces.

Pedestrian Wind Comfort

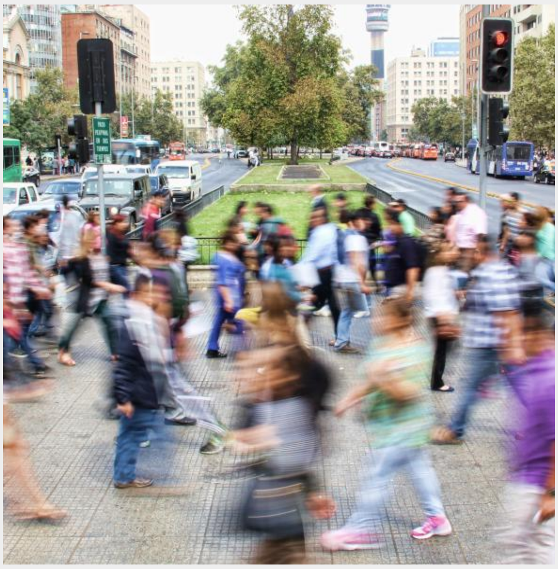


Wind comfort, also known as pedestrian wind comfort, is the evaluation of wind effect at a passerby level. Factors included in this assessment range from wind direction and speed to air pollution. Comfort is tested by investigating outdoor climate changes caused by the presence of a building, which has a lasting impact on its surroundings.

Wind flow disruption is one of the many possible impacts. Especially in urban areas, wind effects such as tunnel throttling or vorticity can be created. If not planned beforehand, these effects can even be harmful or dangerous to people using or nearby the affected facilities.

By assessing pedestrian wind comfort, urban master planners can predict the behavior of wind flow around proposed buildings while they are in the design phase. Wind speeds and other parameters can be calculated at pedestrian levels, and a comfort assessment can be made using specific criteria such as the one shown in the following graphic. This allows for improvements to be directly implemented into the design and assessed in cycles until a satisfactory construction plan is achieved.

The chart on the following page gives additional information regarding wind speeds.

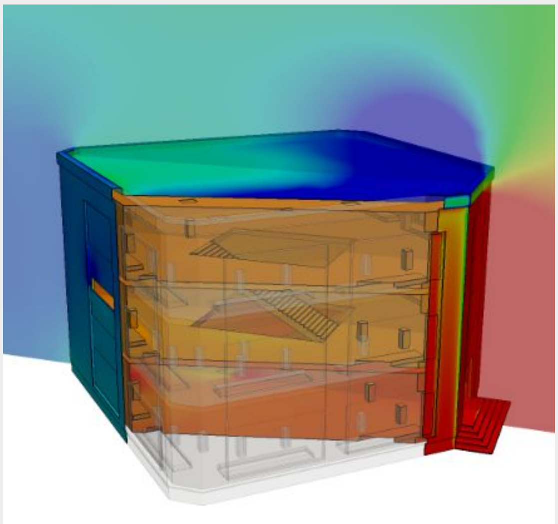


Strength (Bf)	Description	Wind speed at 1.75m above ground (m/s)	Effects
0 - 1	Quiet, very light breeze	0 - 1	Quiet, no sensible wind.
2	Light breeze	2.4 - 3.8	The wind is felt on the face, leaves rustle.
3	Gentle breeze	3.9 - 5.5	The hair is shaken, leaves and twigs are in constant motion; light flags extended.
4	Moderate breeze	5.6 - 7.5	Raises dust and loose paper; small branches moved.
5	Fresh breeze	7.6 - 9.7	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	Strong breeze	9.8 - 12	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	High wind, moderate/near gale,	12.1 - 14.5	Whole trees in motion; inconvenience felt when walking against the wind.
8	Gale, fresh gale	14.6 - 17.1	Twigs break off trees; generally impedes progress.

(Source: https://en.wikipedia.org/wiki/Beaufort_scale)

Wind Engineering for Natural Ventilation

Mainly used for commercial buildings such as offices, restaurants, sports halls or supermarkets, natural ventilation can reduce energy costs and environmental impact while maintaining good indoor air quality and ensuring a higher level of comfort for occupants, especially when compared to mechanical air conditioning.

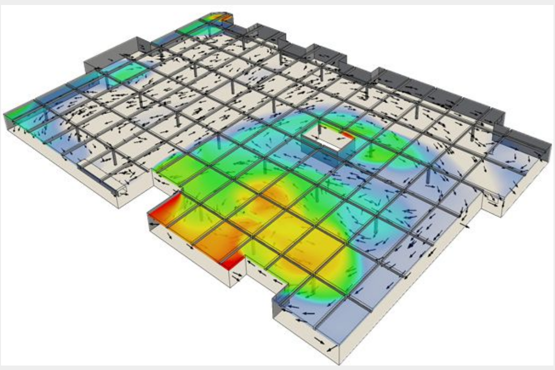


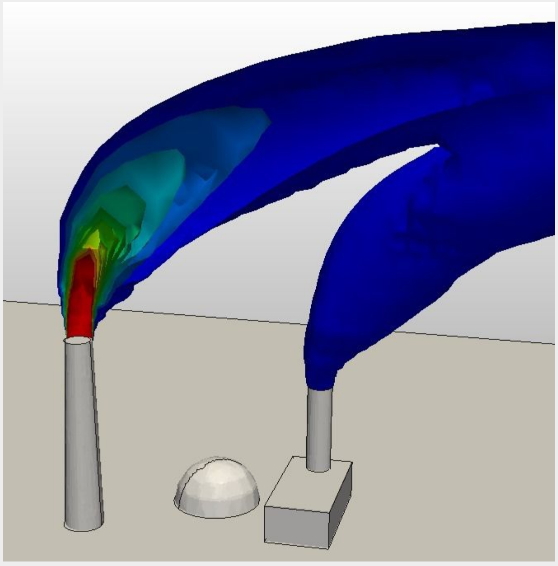
Natural ventilation is possible through harnessing the power of air pressure differences from natural forces defined by two varieties: buoyancy-driven and wind-driven. Buoyancy-driven ventilation is a result of temperature differences between the internal and external space of the structure. Although more energy efficient and safe, natural ventilation can be unreliable in removing and introducing fresh air to an indoor space due to the nature of the natural forces (including wind) it replies upon.

The uncertain driving forces alongside difficulties in overall control of airflow can deem natural ventilation not efficient enough in some cases due to certain climates.

Wind Engineering for Pollution Mitigation

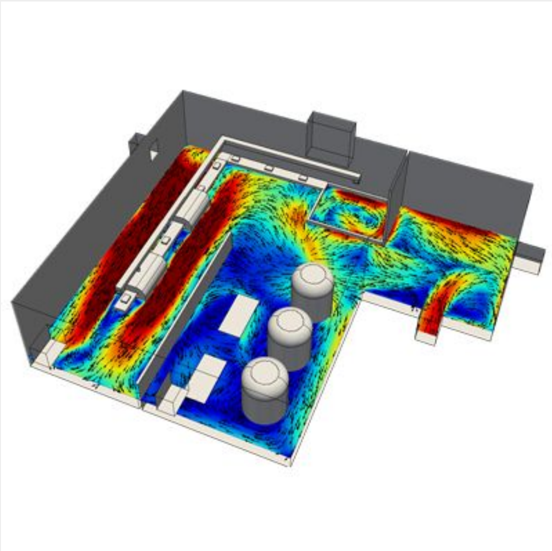
Air pollution remains a great threat within the built environment. Ventilation prevents this, and wind force is especially powerful in natural ventilation systems. In wind engineering, wind simulation can be used to determine the best method of pollution extraction. If artificial wind is created through ducted ventilation systems, extract fans and jet fan ventilation systems are also needed. For example, in an underground car park gases such as carbon monoxide (CO), nitrogen oxides (NOx) and sulphur oxides (SOx) cause poor air quality and need to be extracted. In less dangerous pollution cases, natural ventilation harnessing wind energy provides a great alternative to mechanical ventilation.





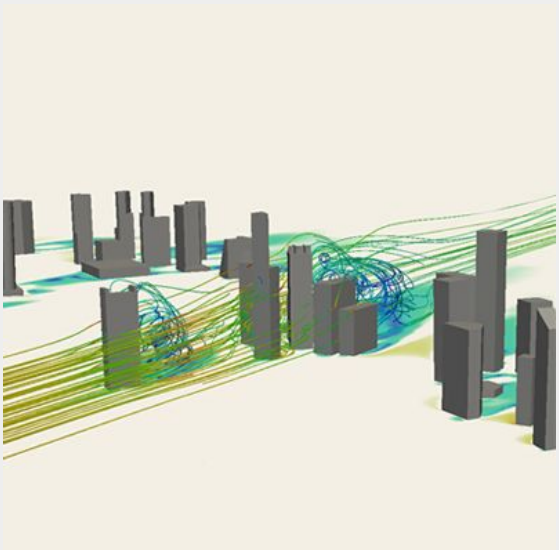
Indoor pollution can cause adverse effects on the occupants, including sick building syndrome (SBS), allergic rhinitis, and hypersensitivity pneumonitis. Studies have shown that exposure to pollutants such as carbon dioxide is linked to significant decrements to decision-making. It directly impacts the productivity of the occupants and exposure to cold drafts or overheating can easily result in a health hazard. The World Health Organization estimates that 12.7% of deaths could be avoided by improving the indoor environment and ambient air quality around the world.

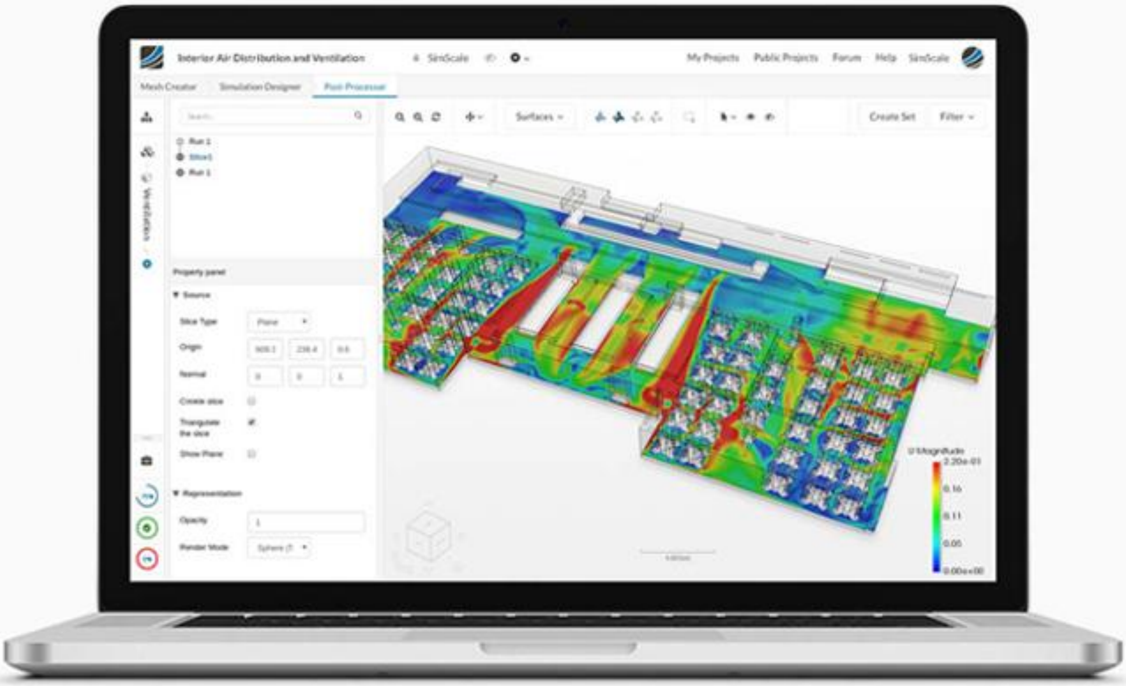
CFD for Wind Engineering



Wind loads, pedestrian wind comfort, pollution control, and ventilation are just some examples of the many simulations possible with our CFD software. CFD's power resides in the ability to apply physical fluid models to almost any geometry, through leveraging the use of numerical methods and digital computers. Its application power has grown hand-in-hand with the growth in computing power. CFD used to be limited by workstation computers lacking memory and processing speed to run viable models, however this problem has been overcome with cloud-computing capabilities.

Today, the widespread availability of computing power means that full-scale simulations on complex environments can be done. SimScale exists as a prime example of this, where the availability of up to 96 computing cores and the ability to run simulations in parallel is of incredible benefit to anyone wishing to perform full-scale complex computational wind engineering simulations. The availability of such computing power in the cloud that can be accessed with a simple web browser further reduces the need to invest in costly infrastructure for fluid dynamics analysis.





About SimScale

SimScale is a cloud-based simulation platform that gives instant access to **FEA**, **CFD**, and **thermal simulation** technology for quick and reliable testing and optimization of building designs.

By harnessing the power of the cloud, SimScale is revolutionizing the simulation industry, allowing every engineer and designer to virtually test and optimize their designs online.

With SimScale, you can run complex fluid dynamics, solid mechanics, and thermostructural simulations in parallel, without leaving the web browser.

Why SimScale?

Collaborative: Get instant access to a premium cloud-based CAE tool that enables you to collaborate with others in testing and optimizing designs end-to-end in a web browser—from anywhere, anytime.

Cost-efficient: As a SaaS application, SimScale requires zero investment in high-performance hardware, licenses or maintenance. The yearly subscription is a fraction of the cost of on-premises CAE software.

For everyone: Having access to dedicated support, learning resources, and consulting services, you get reliable simulation results fast, with no need to hire an expert.

For information and webinars:
www.simscale.com

+49 89 809 1327 70
contact@simscale.com

SIMSCALE