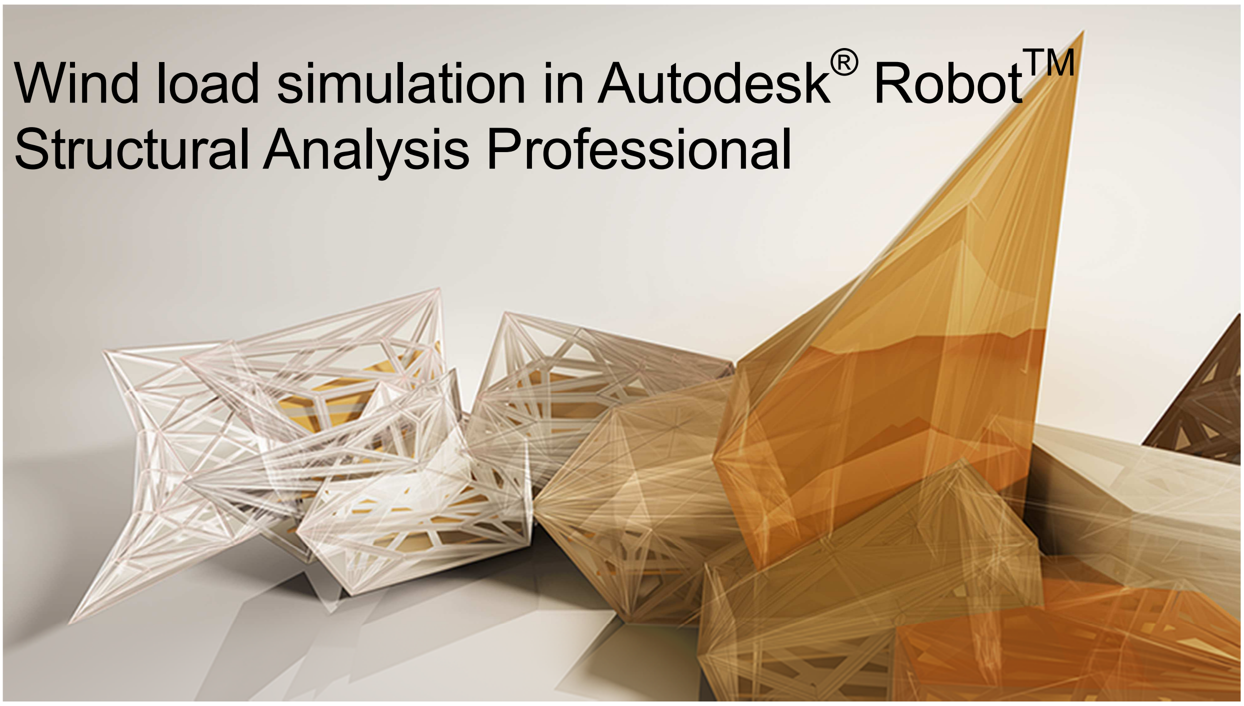
**Autodesk® Robot™ Structural Analysis Professional** 2015




**Souza, True and Partners:**

Souza and True was founded in 1959 by Edward K. True and Richard W. Souza, with the goal to provide superior structural engineering advice and design services to architects, owners, and contractors. We work closely with our clients to provide them the most efficient and optimum results while staying on schedule and on budget. Our design experience spans a long history of both publicly and privately funded projects, from new construction to historic renovations. While we design all types of structures, our specialty is designing structures in the following industries: health care, research, museum, theatre, academic, housing, laboratory, commercial, municipal, parking, residential, and industrial. We use the latest analysis, design, and documentation tools, including FEA, BIM, and LEED, and have extensive experience with various project delivery methods, such as IPD. We offer a full range of structural engineering services, including:

- Analysis and design
- Construction administration
- Comparative studies and feasibility studies
- Structural evaluations
- Peer reviews
- Expert witness

**Lin Gallant:**

Lin Gallant is an associate at Souza, True and Partners, with more than eight years of experience in structural engineering design. As a registered professional structural engineer in Massachusetts, Lin is focused on providing structural engineering solutions to clients in the building industry. Lin's design experience spans all industries and building types, from hospitals and research facilities to intermodal transportation centers. With a strong background in IT, Lin is the technology leader at his firm, responsible for researching and implementing new technology aligned to his company's business strategy and client demands. Prior to joining Souza and True, Lin has worked at both large and small multidisciplinary engineering firms and in the public sector at a regional planning agency. Lin's college education focused on structural engineering and technology at UMass Amherst, where he obtained his bachelor's and master's degrees in civil engineering.

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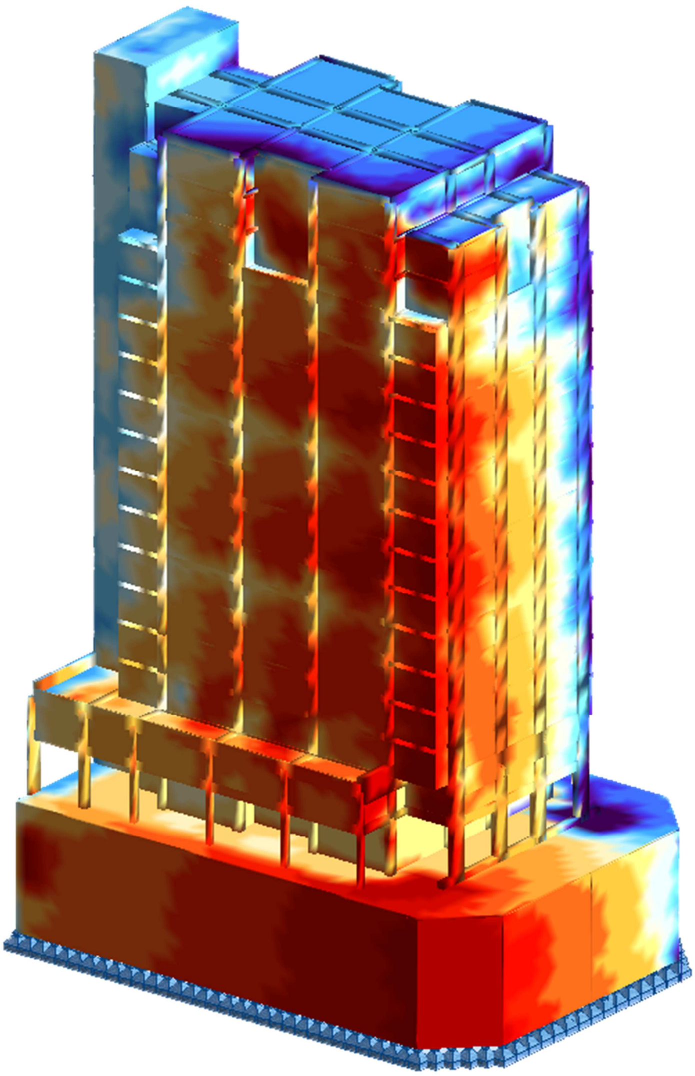
# Introduction

Accurately capturing wind load effects on tall buildings and complex structures presents structural engineers with difficult design challenges. In the United States, most building codes require that designers adhere to the wind load provisions of ASCE 7, with most states currently referencing either ASCE 7-05 or ASCE 7-10. Other counties have similar codes, or reference ASCE 7 for wind design. While there are significant differences between the two versions, they each offer three wind load analysis methods for engineers to use: two analytical methods and one testing method. The two analytical methods, one simplified and one more detailed, allow engineers to calculate wind pressures quickly using tables, figures, and equations. However, the use of the analytical methods is limited to structures with specific geometric and response characteristics. For buildings and structures that fall outside these limitations, the code allows wind tunnel testing, which requires engaging the services of a wind consultant. Choosing which of these methods to implement is a decision that should be made early in the design process. For tall structures and complex structures, this decision requires engineers to balance design accuracy, safety, and efficiency with impacts to workflow.



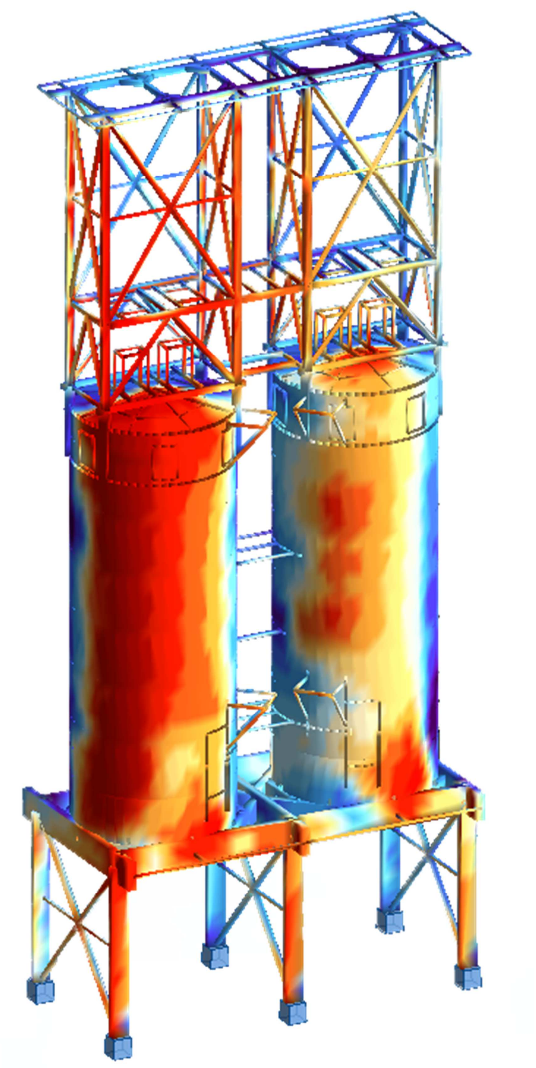
# Present solutions: analytical methods and wind tunnel testing

The analytical methods presented in ASCE 7 are suitable for capturing against-wind load effects for low-rise and mid-rise buildings with standard shapes, surroundings, and response characteristics, and in these cases are relatively easy to implement. However, for buildings that fall outside these parameters, it can be difficult to apply either analytical method, and the results can vary considerably from reality. This is because the equations, tables, and figures used by each method were derived from test results for simple (rectangular) building shapes, and represent the upper envelope of values for those tests. These methods do not account for: aerodynamic effects for irregular-shaped structures and building protrusions (balconies, fins, etc.); the influence of adjacent structures and topography; or aeroelastic interactions between wind flow and the motion of the structure, such as vortex shedding, galloping, and flutter. In addition, they offer limited guidance on torsional loading effects. Compared to testing results, analytical results for tall and complex structures have been generally shown to produce higher along-wind loading pressures on the overall structure, which can lead to overly conservative designs. Analytical results have also been shown to underestimate along-wind loading pressures on localized regions and components, which can lead to unconservative designs of cladding and supporting elements. Furthermore, the analytical methods don't account for aeroelastic interactions, which can induce larger building responses than against-wing loading. For complex structures, ASCE 7 recognizes these deficiencies and requires that engineers design according to recognized literature or use the results of wind tunnel testing.

**Figure 1.** Wind tunnel and model—view from northwest.

In a wind tunnel test, direct measurements of wind pressures on a structure are obtained by subjecting a geometrically scaled model of a structure, and its surroundings, to a simulated wind environment. Wind consultants are able to use wind tunnel data and postprocessing to account for aerodynamic effects of the actual building shape, the influence of nearby structures and topography, the local wind climate, and aeroelastic building response. Results obtained from instrumented full-sized structures, subject to design-level wind speeds, have shown wind tunnel test results are more accurate than analytical method results. These results can be more refined and focus on project-specific concerns, which allows for the potential of safer, better performing, and more cost-effective designs. Wind studies can also investigate other design concerns, such as occupant comfort, the outdoor wind comfort of pedestrians, air-quality impacts of building exhaust, and more. However, hiring a wind consultant does have both an upfront cost and workflow impacts that must be considered.

Generally, hiring a wind consultant to conduct wind tunnel tests is expensive (tens of thousands of dollars), a cost that is dependent on the number and type of tests and level of postprocessing analysis. The willingness of clients to make this upfront investment is not always an easy proposition. The upfront cost of hiring a wind consultant can be offset by cost savings from design efficiencies achieved from the results, and can be further rationalized by increases in safety and occupant comfort. For the design team, there are also workflow challenges. The design team must be aware of the complexities that arise from adding another consultant to the project team, in determining their scope of work and in weaving their testing schedule into the overall project schedule. Since many of the most important form and function decisions occur early in the design process, it is advantageous to determine what impact wind design is going to have on the structure as early as possible. Engaging a wind consultant early in the process is clearly desirable from a results standpoint, but has cost implications (additional testing) and might not be feasible within the project schedule. Alternatively, designers can use the analytical procedures from ASCE 7 for preliminary design purposes, but, as discussed previously, those results could be unrealistic. What engineers need is a wind simulation tool that considers all wind load effects and is easy and cost-effective to use in the early stages of design. Companies that specialize in wind analysis use computer analysis tools, but the software is typically complex, proprietary, and not commercially available. What engineers need is a commercially available structural analysis and design program with wind simulation capabilities.



# A new wind simulation solution: Robot Structural Analysis Professional

With the release of Autodesk® Robot™ Structural Analysis Professional 2015 software, Autodesk incorporates a powerful new wind simulation tool into the software that enables users to emulate wind tunnel testing to investigate building performance. By incorporating computational fluid dynamics (CFD) analysis capabilities into Robot Structural Analysis Professional, users will be able to quickly subject their structures to simulated wind flows. The analysis can be customized and the results can be viewed or used to automatically generate wind loads on the structure. Robot Structural Analysis Professional's wind simulation analysis is unique to structural analysis and design software, and is applicable to all structure types. Unlike code-based analytical methods, the program accounts for the actual building geometry and the interaction between wind flow and building response. As building parameters change, such as geometry, mass, or stiffness, the engineer can quickly update the wind analysis and see the results of these changes. Preliminary validation testing has revealed that Robot Structural Analysis Professional's wind simulation results closely match those from the code-based analytical methods, for regular-shaped, low-rise structures, and wind tunnel results for more complex structures. Autodesk has made available a validation study of wind tunnel testing so users can understand the results the simulation will provide for them. Additional validation tests are proposed for a wide variety of structure types, so designers can be confident that the wind simulation results are accurate for all applications.

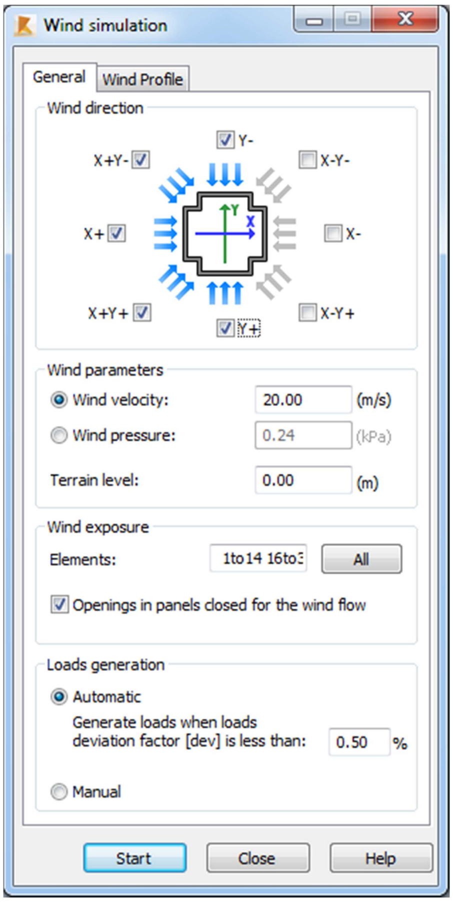



**Figure 2.** Wind parameters in Robot Structural Analysis Professional

Conducting a wind simulation analysis in Robot Structural Analysis Professional is both fast and easy. Once the model has been built, the user simply engages the wind simulation command and begins defining the analysis parameters. The Wind Simulation dialog box enables the user to adjust various wind simulation parameters, including: wind direction; wind velocity (or a uniform pressure); terrain elevation; load generation requirements; and the wind profile along the height of the building, which allows for different wind exposure simulation. These parameters enable the user to customize his or her analysis to fit the building and site characteristics. Once the analysis is started, the user will see the wind pressure results from the wind flow analysis, updated in real time, as the analysis progresses. Once the analysis is complete, either by converging to a set tolerance or as dictated by the user, the user can have the program automatically generate and apply equivalent static loads from the simulation results to the structural members.

| height [m] | TC1.5 Wind Speed [m/s] | TC1.5 Fraction of Max. Speed |
|---|---|---|
| 0.020 | 14.418 | 0.609 |
| 10.000 | 15.626 | 0.660 |
| 20.000 | 16.620 | 0.701 |
| 30.000 | 17.438 | 0.736 |
| 40.000 | 18.113 | 0.765 |
| 50.000 | 18.679 | 0.788 |
| 60.000 | 19.160 | 0.809 |
| 70.000 | 19.583 | 0.827 |
| 80.000 | 19.966 | 0.843 |
| 90.000 | 20.326 | 0.858 |
| 100.000 | 20.676 | 0.873 |
| 110.000 | 21.023 | 0.887 |
| 120.000 | 21.375 | 0.902 |
| 130.000 | 21.731 | 0.917 |
| 140.000 | 22.090 | 0.932 |
| 150.000 | 22.445 | 0.947 |
| 160.000 | 22.786 | 0.962 |
| 170.000 | 23.101 | 0.975 |
| 180.000 | 23.372 | 0.986 |
| 190.000 | 23.577 | 0.995 |
| 200.000 | 23.692 | 1.000 |

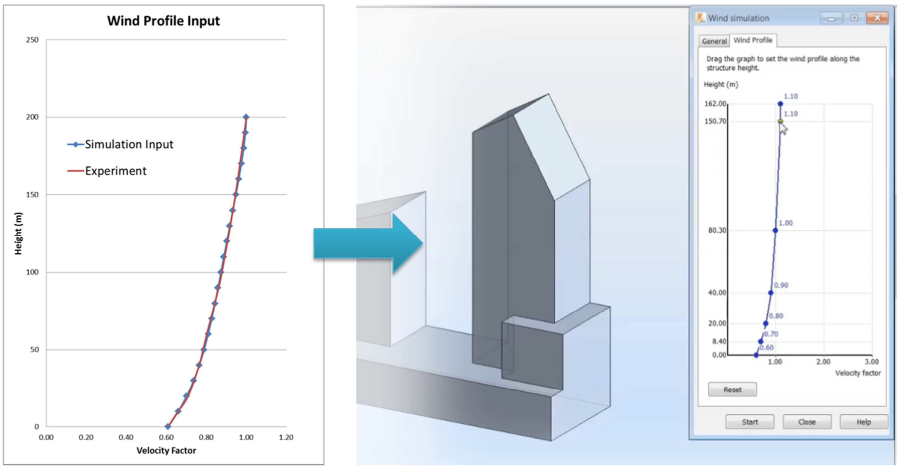
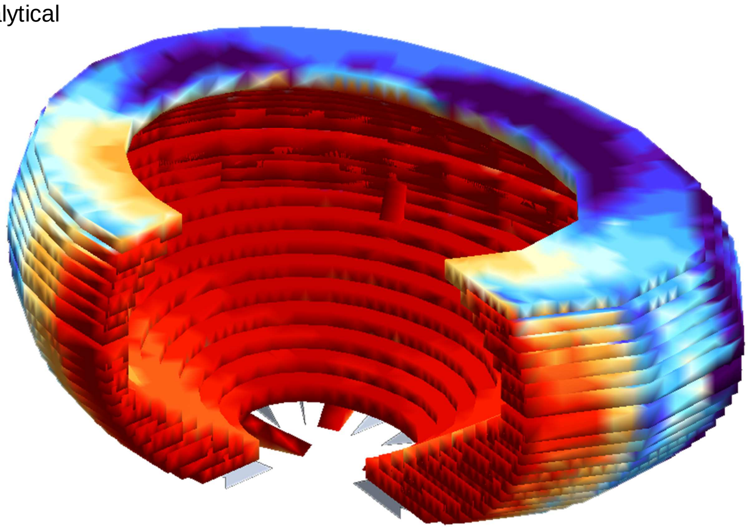



**Figure 3.** The terrain category wind profile was translated into several points used to input a velocity profile into the Robot Structural Analysis Professional wind simulation tool.

A typical wind simulation takes only a few minutes to complete, which is a significant time savings over either the analytical or wind tunnel testing methods. Because of this speed and ease of implementation, Robot Structural Analysis Professional's wind simulation will enable engineers to determine wind load effects earlier in the design process, without compromising accuracy or waiting for results from an outside consultant. Predicting wind load effects early in design can reveal detrimental wind-induced building responses—before structural system changes become a surprising and costly redesign issue. This provides the design team with the ability to quickly investigate the impact of design decisions, creating a unique and iterative approach to wind design. Robot Structural Analysis Professional's wind simulation capabilities can help augment analytical methods and physical testing early in the design process—prior to the application of code-recognized methods for wind design—offering significant advantages when it comes to project understanding and fast project iteration.



# Conclusions

Wind load effects on tall or geometrically complicated buildings and complex structures such as masts, truss towers, and industrial platforms can be challenging to account for accurately and can create complex workflows for the design team. The code-based wind design methods offer designers three approaches to capture these effects, but each method has limitations and trade-offs between accuracy and cost. The analytical methods suffer from limitations on applicability and accuracy, and wind tunnel testing comes at a cost and with impacts to workflow. Robot Structural Analysis Professional's wind simulation can supplement each method and address some of their shortcomings, even before the application of code-recognized methods for wind design. Engineers can use this software to validate or supplement analytical method results, and to identify potential wind design issues that require special consideration earlier in the design process. Robot Structural Analysis Professional can replace wind tunnel testing during the early design stages, providing meaningful results much more quickly and at a much lower cost. The software can't replace all wind tunnel test types, such as occupant comfort or outdoor pedestrian comfort; however, it can be used to supplement, validate, and investigate wind tunnel test results, and perhaps to reduce the number of tests required. This can help save engineering time, reduce wind consultant costs, and shrink overall project costs. The software provides a unique approach to wind simulation and load generation that cannot be found in other structural analysis and design software. Robot Structural Analysis Professional's wind load simulation is a robust tool that improves a firm's wind design capabilities, at a cost much lower than a single wind tunnel test, and provides many other useful analysis and design features.

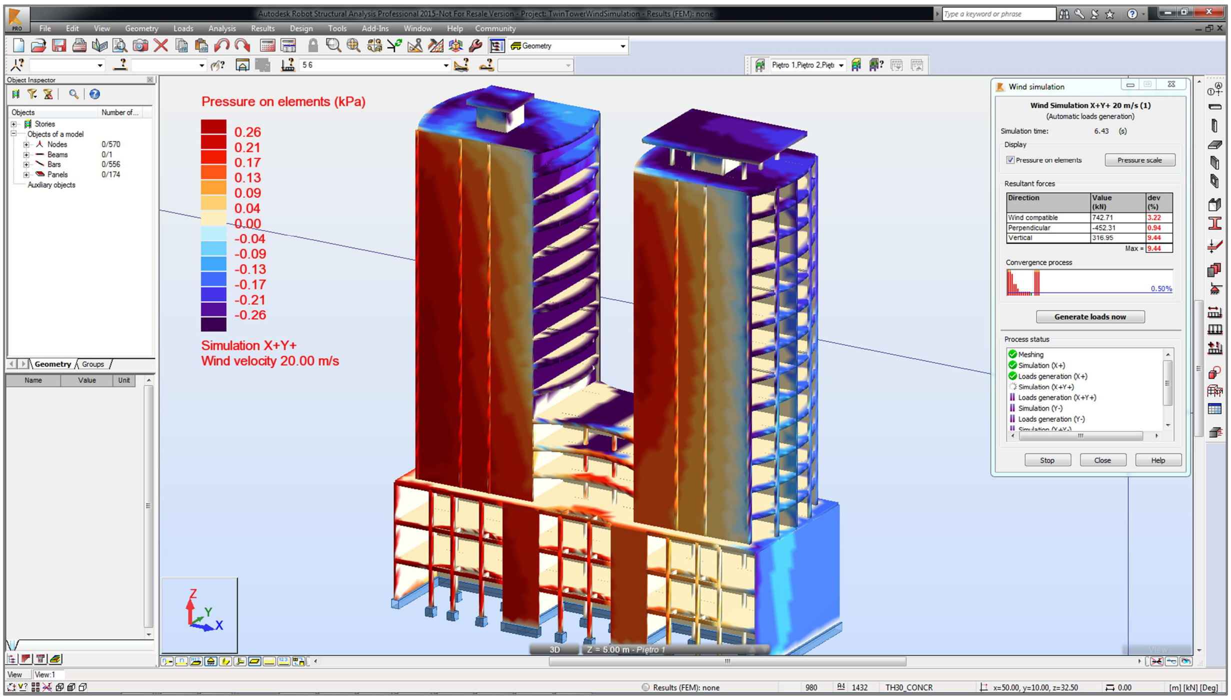



**Figure 4.** Wind load simulation tool in action in Robot Structural Analysis Professional.