



# Wind Simulation in Robot Structural Analysis Professional

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## SE5789

This class will review the new wind simulation technology available in Robot Structural Analysis Professional 2015 software. We will review the current landscape of code-based wind design (specifically ASCE 7) and we'll discuss the challenges of applying these methods to different structure types. We'll then examine Robot Structural Analysis Professional software's unique computational fluid dynamic (CFD) wind simulation tools, and we'll discuss how they compare to the code-based approaches. Using sample wind simulation models, we will review the wind simulation analysis parameters and the analysis process, and we'll discuss the simulation results. Finally, we'll review the benefits of wind simulation, we'll discuss the ways it can be used to supplement and/or validate code-based approaches, and we'll cover the benefits of wind simulation on workflows and projects.

## Learning Objectives

At the end of this class, you will be able to:

- Recognize the applicability and limitations of code-based wind design approaches
- Understand the wind simulation capabilities in Robot Structural Analysis software
- Learn how to perform a wind simulation on a structure in Robot Structural Analysis software
- Discover the potential applications and benefits of wind simulation in project workflows

## About the Speaker

Lin is an Associate at Souza, True and Partners, a structural engineering firm based in Waltham, MA. As a professional engineer, he has a wide range of project experience that spans many industries and project types. As the technology leader at his firm, Lin researches and implements new technologies and design software, including Revit and Robot Structural Analysis Professional (RSA), aligned with the firm's workflows and business strategy. Over the last year, he has been a consultant for Autodesk's Design, Lifecycle, and Simulation group, providing technical guidance and user experience feedback for new and enhanced features in RSA and Structural Analysis for Revit. Lin recently collaborated with Autodesk's AEC group on their Strategic ROI for BIM webinar series, presenting his firm's experience with BIM and measuring ROI. Lin obtained his bachelor's and master's degrees from UMass Amherst, where he focused on structural engineering, technology, and management.

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## Introduction

Accurately capturing wind load effects on tall buildings and complex structures presents structural engineers with difficult design challenges. The approach engineers use to account for wind loading will have impacts on design decisions, workflow, project economics, and schedule.

## Code based wind design

In the United States, most building codes require designers adhere to the wind load provisions of ASCE 7, with most states currently referencing either ASCE 7-05 or ASCE 7-10. While there are significant differences between the two versions, mostly related to employing strength design level loads and altering risk levels, each code offers three wind load analysis methods. Of these three, two are two analytical methods, one simplified and one more complex, which allow engineers to calculate design wind pressures using tables, figures, and equations. However, the analytical methods can only be used if the structure meets the following limitations:

### Simplified (Envelope) Procedure:

1. Simple diaphragms – no building separations
  2. Low-rise Building – mean roof height  $\leq 60$  ft & mean roof height  $\leq$  least horizontal dimension
  3. Building is enclosed – All buildings that don't meet the following criteria:
    - a. Open ( $A_o \leq 0.8A_g$ )
    - b. Partially enclosed
      - i.  $A_o > 1.10 A_{oi}$
      - ii.  $A_o > 4$  sq ft or  $0.01A_g$  (whichever is smaller)  
&  
 $A_{oi}/A_{gi} \leq 0.02$
- where:
- $A_o$  = total open areas receiving positive pressure ( $\text{ft}^2$ )
  - $A_g$  = gross wall area in which  $A_o$  is located ( $\text{ft}^2$ )
  - $A_{oi}$  = sum of the total open areas not included in  $A_o$  ( $\text{ft}^2$ )
  - $A_{gi}$  = sum of the total surfaces not including  $A_g$  ( $\text{ft}^2$ )
4. Regular shaped – defined by several figures in the codes (Fig 6-6 to 6-17 ASCE7-05)
  5. Building is not flexible – fundamental natural frequency  $< 1$  Hz
  6. Building response is not subject to across wind loading, vortex shedding, galloping or flutter, and site location doesn't have channeling or buffeting effects.
  7. Building approx. symmetric in cross-section with a flat, gable, or hip roof (pitch  $\leq 45^\circ$ )
  8. Building is exempt from torsional load cases or they do not control the design

### Analytical (Directional) Procedure:

1. Regular shaped
2. Building response not subject to across wind loading, vortex shedding, galloping or flutter, and site location doesn't have channeling or buffeting effects.

For buildings and structures that fall outside these limitations, the code allows wind tunnel testing, see below.

## Analytical Methods Examined

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.

The simplified (envelope) procedure wind pressure calculations use the following simplified equation:

$$P_{net} = \lambda K_{zt} P_{net30}$$

where:

$\lambda$  = an adjustment factor for building height and exposure

$K_{zt}$  = topographic factor, to account for wind speed up

$P_{net30}$  = net design wind pressure for exposure B, at  $h = 30$  ft. These values are tabulated for various building surfaces.

This equation takes the tabulated net wind pressures for various building surfaces and scales them based on the building geometry, topography, and wind exposure.

The analytical (directional) procedure is more involved, but the velocity pressure equation is:

$$q_z = 0.00256 K_z K_{zt} K_d V^2$$

However, to arrive at this value, and then use it to calculate the actual design pressures, many additional factors must be determined:

$K_d$  = directionality factor

$K_z$  = exposure category factor

$K_{zt}$  = topographic factor, to account for wind speed up

$G$  or  $G_f$  = gust factor for rigid or flexible buildings

$GC_{pi}$  = internal pressure coefficient

$C_p$  or  $GC_p$  = external pressure coefficient

After all of these factors are determined, many of which involve interpreting tables or calculating numerous other factors, only then can one calculate the design wind pressures or forces acting on a surface. Not only is this a time consuming process, but in some cases interpreting how to calculate and apply some of these factors can be difficult. →

For both analytical methods, the equations, tables, and figures were derived from test results for simple (rectangular) building



shapes, and represent the upper envelope of coefficient and pressure values for those tests. For buildings that fall outside the intended scope of these methods, the results can vary considerably from reality. This is because these methods do not account many effects including: aerodynamic effects for irregularly shaped structures and building protrusions (balconies, fins, etc.), the influence of adjacent structures and all types topography, aeroelastic interactions between wind flow and the motion of the structure, such as vortex shedding, galloping and flutter, and 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 and more costly 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-wind loading. ASCE 7 recognizes these deficiencies and requires engineers design according to recognized literature or use the results of wind tunnel testing. Unless you are able to find approved published research findings for a building with similar characteristics to the one you're designing, this means wind tunnel testing is your only option.

### Wind Tunnel Testing

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 post-processing 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 which is dependent on the number and type of tests and level of post-processing analysis. The willingness of clients to make this upfront investment is not always an easy proposition. However, the upfront cost of hiring a wind consultant can, and usually is, 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 that arise. 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 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 based on the project schedule. Alternatively, designers can use the analytical procedures from ASCE 7 for preliminary design purposes, but as discussed those results could be unrealistic. What engineers need is a wind analysis and design 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 which could be used in this way, but the software is typically complex, proprietary, and not commercially available. What engineers ideally need is a commercially available structural analysis and design program with wind simulation capabilities.

## Wind Simulation in RSA 2015

With the release of RSA 2015, Autodesk incorporates a power computational fluid dynamics (CFD) solving engine into RSA. With this new tool, you will be able to quickly subject your structure to accurate simulated wind flows. The analysis can be customized and the results can be viewed or used to automatically generate wind loads on the structure. RSA'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 the buildings surfaces. This is very much like having your own simulated wind tunnel. As building parameters change, you can quickly update the wind analysis and see the results of these changes. Preliminary validation testing has revealed that RSA's wind simulation results closely match those from the code-based analytical methods, for regular shaped low-rise structures, and wind tunnel results for taller and more complex structures. Additional validation tests are proposed for a more structure types, so designers can be confident the wind simulation results are accurate for all applications.

### Wind Theory and Convergence:

The basic equation used in RSA for determining the dynamic wind pressures acting on a building surface is the dynamic pressure component of Bernoulli's equation for incompressible fluid flow:

$$q = \frac{1}{2} \rho V^2$$

Where:

$q$  = the dynamic pressure

$\rho$  = the density of air

$V$  = the velocity of air



#### Bernoulli's Principle (Hydrodynamica 1738)

Is a conservation of energy equation that states that the sum of all forms of energy in a fluid along a streamline is the same at all points along the streamline. A result of his experiments showed a linear relationship between pressure and flow speed squared. It is this dynamic pressure component which we seek to calculate and apply to our building surfaces.

The above equation is valid for fluids (gases or liquids) with a constant velocity at subsonic speeds (<610 mph). For most buildings, the variation in air density can assumed to be negligible.

Since this problem is dynamic, the wind simulation does not result in a stable static solution after one iteration. Instead, RSA employs the use of a convergence tolerance on the resultant wind forces in the three global axis directions:

1.  $F_{x_{wind}}$  - in the direction of the wind
2.  $F_{y_{wind}}$  - horizontal and perpendicular to the wind direction
3.  $F_{z_{wind}}$  - vertical direction

Since these resultant forces depend on the model size, RSA scales these forces by multiplying the dynamic pressure  $q$  by the total surface areas in the model normal to each wind direction:  $S_{x_{wind}}$ ,  $S_{y_{wind}}$ , and  $S_{z_{wind}}$ . These surface areas correspond to the total meshed surface areas that lie on a plane

perpendicular to each global axis direction. This approach neutralizes disproportions of the model in the wind directions x, y and z.

To measure the total forces convergence over a specific time period, the resultant forces  $F_{x_{wind}}$ ,  $F_{y_{wind}}$ , and  $F_{z_{wind}}$  are calculated and stored for a number of steps  $n$ , and then the maximum change for a given moment is calculated as follows:

$$\Delta F_{x_{wind}} = \max(|F_{x_{wind}} - F_{ix_{wind}}|)$$

$$\Delta F_{y_{wind}} = \max(|F_{y_{wind}} - F_{iy_{wind}}|)$$

$$\Delta F_{z_{wind}} = \max(|F_{z_{wind}} - F_{iz_{wind}}|)$$

Where:

$F_{i_{wind}}$  represents the stored values of  $F_{wind}$  for a given step, for  $i = 1$  to  $n$ . These maximum changes in resultants forces are then scaled by the values of  $F_{x_{wind}}$ ,  $F_{y_{wind}}$ , and  $F_{z_{wind}}$ , and are displayed as percentage values during the simulation in real-time. When the maximum of these three percentages falls below the convergence tolerance (set to 0.5% by default) automatic load generation can occur. However, the simulation must complete a minimum number of step, 10 steps by default, before the convergence results can be accepted and loads generated.

## Wind Simulation Walkthrough:

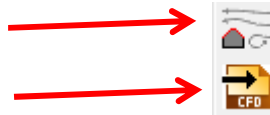
The following section takes you through the numerous wind simulation parameters used to customize your wind simulation analysis.

To begin a wind simulation analysis, you have two options:

From the text menu select **Loads > Wind loads simulation > Generate wind loads...**

In the Loads layout mode:

The top button will open the RSA wind simulation window.



The bottom button will export the RSA model to Autodesk CFD (if installed). Please note, the results from Autodesk CFD cannot be imported back into RSA.



### Wind Simulation Window:

Once the wind simulation command has been invoked, the wind simulation window will open. This is where all of the wind simulation parameters are defined and where the wind simulation analysis is started, observed, and terminated.

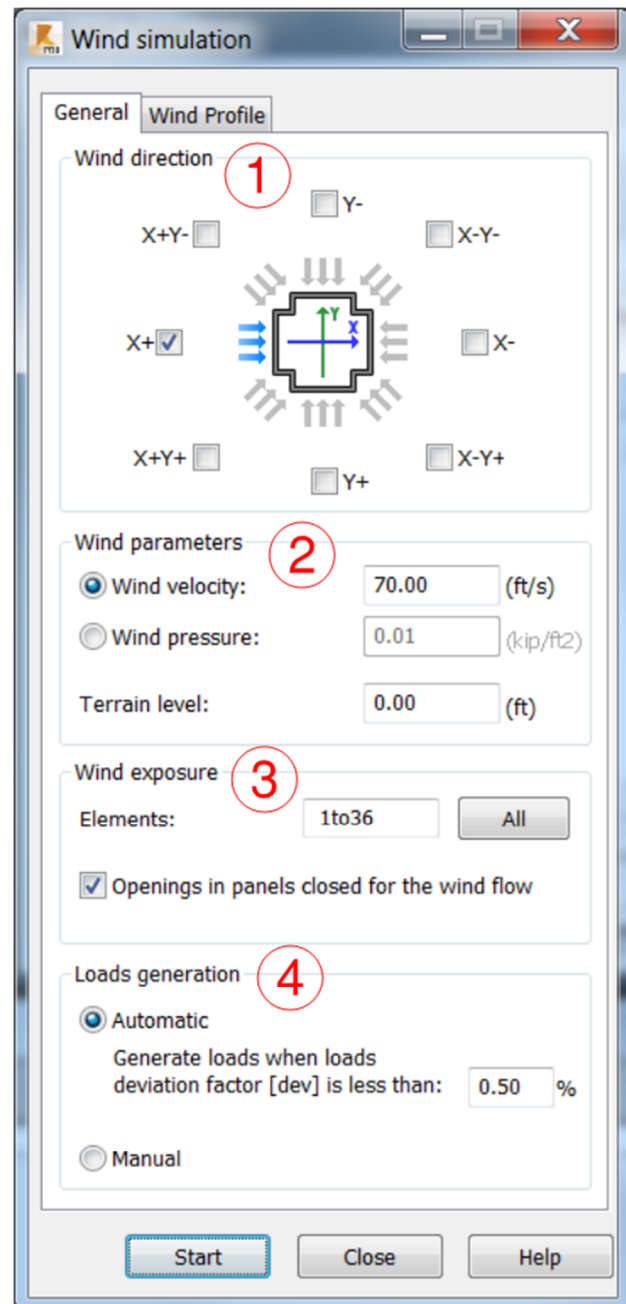
#### General Tab

1. **Wind direction** - Users can specify up to 8 directions (based on global coordinate system) for wind load simulation. RSA will conduct one wind simulation run for each check box selected. The order of wind simulations runs starts with the X direction and proceeds with each direction selected in a counterclockwise manner. Should you wish to investigate additional wind directions, you can rotate your model about the principal axis to the desired alignment.
2. **Wind parameters** – The wind pressure applied to the structure can be specified using either a constant wind velocity or pressure. The units for each option change depending on the units specified in the **Job Preferences > Units and Formats > Forces** options window.

There are two ways to specify the ground (terrain) level:

**Manually** - you can manually type in a Z coordinate. The default value is set to the lowest level coordinate in the model, so be certain to check this number if you have subterranean elements.

**Graphically** - by clicking the text box (which will turn green), you now have the ability to click a point in the model window to set the terrain level. Graphically, you will see a blue square, with four quadrants, at your cursor location as you move the cursor in the model window. In an elevation view, the square will appear as a thin blue line.





3. **Wind exposure** – The wind exposure options allow you to specify which surfaces you want RSA to mesh and consider for wind exposure. Elements not selected will not be meshed and accounted for in the wind simulation. The user has the option of selecting elements either graphically, entering the elements manually, or by clicking the **All** button all elements will be selected.

There is also a check box to set how openings in panels will be handled. If the box is checked, openings in panels will be assumed closed (solid) for wind simulation purposes. With the box checked, you will see that openings have been meshed and the pressure maps will display where the panel openings once were. If this box is not checked, openings will not be meshed and wind will be allowed to flow through the panel openings.

Choosing which elements which will be exposed to wind loading will have a significant impact on the results and the calculation time. RSA will mesh every surface of each element selected for wind exposure, so care should be taken when choosing which surfaces to mesh. Generally, for enclosed buildings you'll want to limit the exposed elements to panels and claddings, unless you have some exterior elements, such as canopies, which you wish to analyze for wind loading.

For models with narrow exposure surfaces along one of the global axis directions, you may notice that the wind simulation may not converge to the tolerance specified for the resultant force in that direction. It may be that the model will never converge in this direction, but that doesn't necessarily invalidate the results in the other directions. Try clicking the **Generate load now** button once the resultant forces in the other directions have met the convergence tolerance setting. If careful review of the results reveals pressures in the primary directions of investigation are valid, you'll simply have to manually tell the simulation to generate loads instead of relying on the automatic method.

4. **Load generation** – There are two options for deciding when RSA will generate the wind load on members:

**Automatic** – this option will automatically generate wind loads on elements once the convergence tolerance for all three resultant forces fall below the specified threshold. Once this is occurs, RSA will generate the wind loads and move onto the next wind simulation in the queue.

**Manual** – this option requires the user to click the **Generate load now** button on the wind simulation window (which appears once a simulation has started). This is a very handy feature, particularly for your first few uses of the tool, when trying to observe the behavior of the simulation as it attempts to converge, or if you want to change the pressure map display during the simulation. This last feature is rather handy as you cannot change the pressure map display after the simulation has been completed, only the default pressure map display can be shown after the analysis completes.

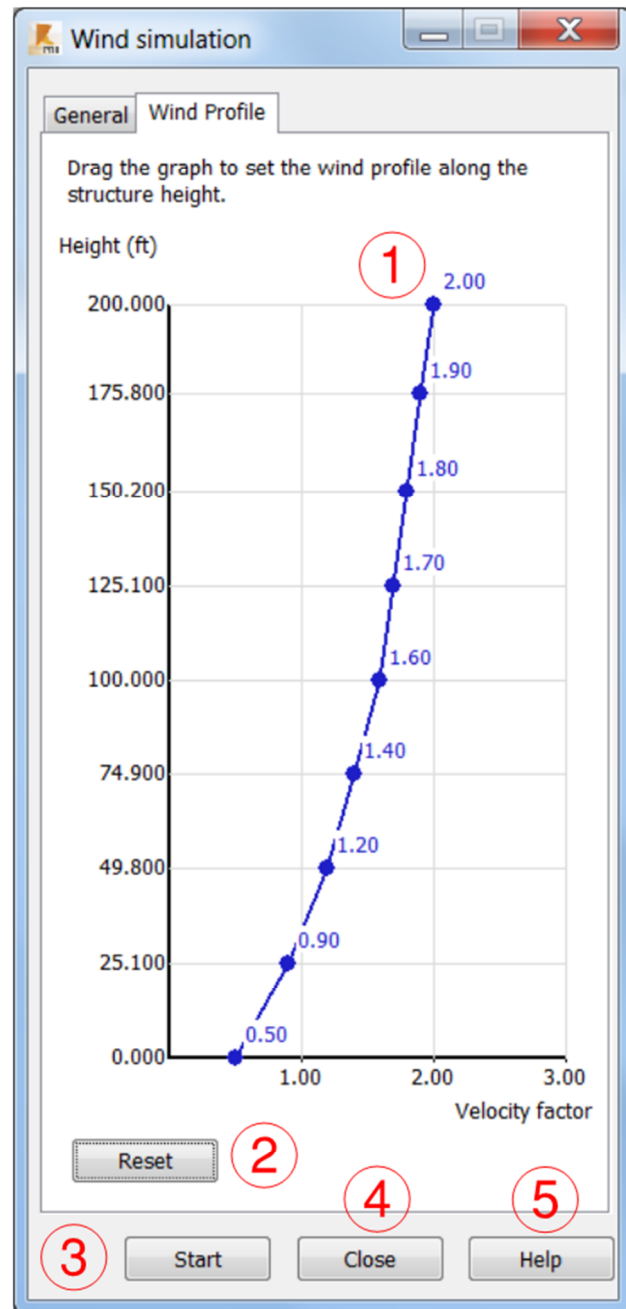
After filling in these four options, click on the Wind Profile tab at the top, to verify and modify the wind velocity profile

## Wind Profile Tab

### 1. Velocity Factor vs. Height Graph –

Using this graph, you can create your own wind profile curve. If you move your cursor over the blue profile line you'll notice a horizontal line and height value will appear along the vertical axis. To modify the curve, move your cursor to the desired height, click on the blue line, and drag your mouse horizontally to the desired velocity factor. The wind profile created will be applied to all wind simulations specified in the general tab. You'll notice the height of the graph will be taller than your structure. This is because the wind simulation needs to define an air boundary layer greater than your structure in order to be accurate. So, make sure to continue the profile curve to the maximum height allowed by the graph.

2. You can **Reset** the curve to a constant velocity factor of 1.0
3. The **Start** button will begin the wind simulation analysis for the directions and parameters selected. Once clicked, the Wind simulation window will change and show the real-time analysis results of the first simulation in the queue.
4. The **Close** button simply closes the window.
5. The **Help** button launches the RSA help page and opens the Wind simulation dialog page. This page describes the various options and parameters, but it also provides useful links to other wind simulation topics, such as convergence and a brief step-by-step guide to running a wind simulation.



## Wind Parameter Tips:

1. Create the profile curve starting from the base elevation and work your way upward in height. If you work from the top down, you'll notice the points above the current point your modifying may

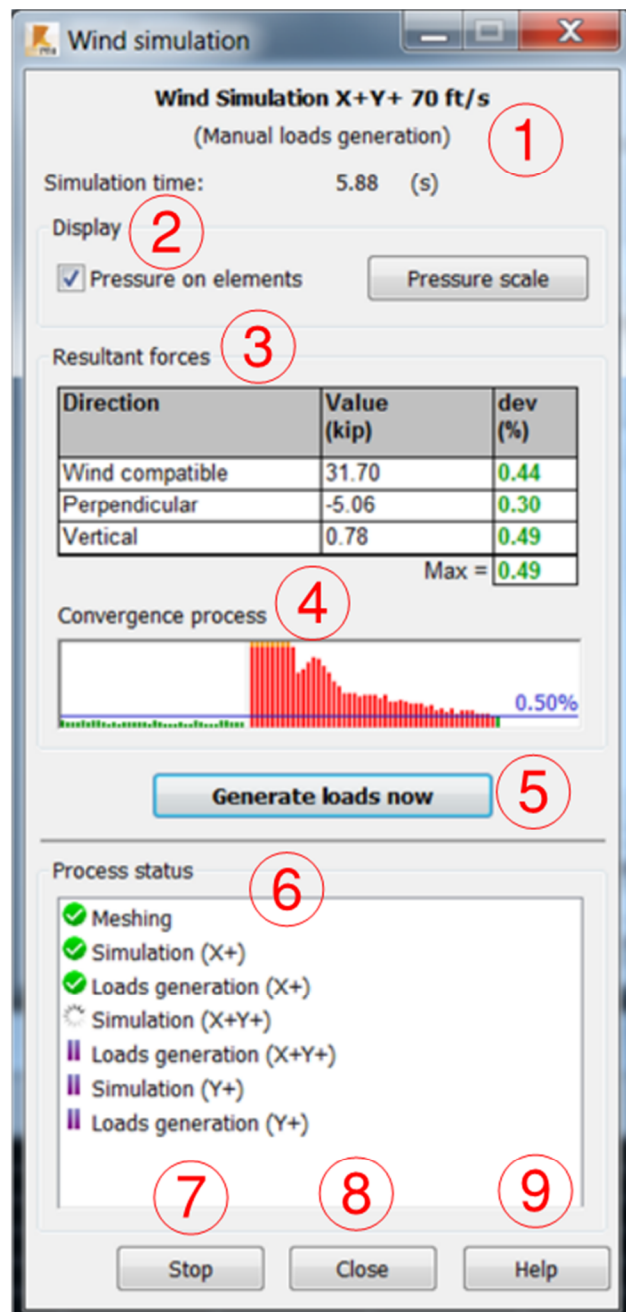
shift depending on how much of a kink the next point makes in the curve.

- The previous wind profile used will be temporarily stored and will appear the next time you open the Wind simulation window. However, there is no way to save a wind profile more permanently, nor is there a way to view the profile used after the analysis is complete. If you wish to investigate multiple profiles, it is recommended that you save a screenshot of the profile used for reference. To take a screenshot, on your keyboard, hold the **ALT** key and press the **Print Screen** key. This will take a screenshot of the currently active window (make sure the wind simulation window is active by clicking on it) and copy it to the clipboard. You can then paste this image to any image editor or word processing program to save for record keeping.
- Sharp changes in the wind profile curve and factors close to the upper limit of 3.0 can sometimes create convergence issues with the resultant forces. If possible, try to use smoother velocity factor profile and scale the wind speed/pressure up manually in the general tab to avoid using velocity factors near 3.0.

### Wind Simulation – Live Analysis Window:

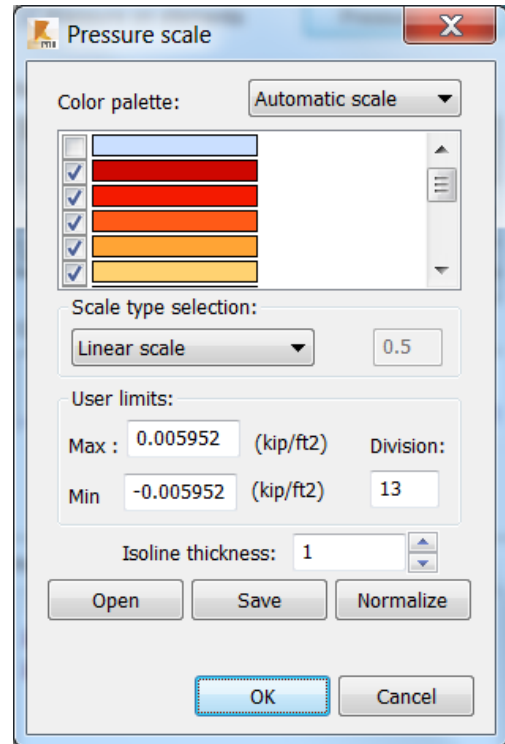
After clicking the **Start** button, the Wind simulation window will change to provide real-time information about the current wind simulation analysis:

- At the top of the window, the analysis direction, wind speed, load generation type, and simulation time are displayed. This information will change to reflect the current simulation being run.
- Display** – The **Pressure on elements** check box allows you to control whether or not you wish to see the pressure maps displayed on the meshed model elements in the project window. The display updates in real-time and only displays pressure maps on elements selected for wind exposure. The **Pressure scale** button opens up a new window where you can customize the pressure map display. This window and its options behave just like the **Stress Analysis – Structure layout**. Here you can change



the color mapping, scale, limits, divisions, etc. You can normalize the limits based on the current (real-time) analysis results. You can even save the pressure scale template for use later. One thing to note is that while this window is open the model window will not update the visual pressure display, and the modifications made in the **Pressure scale** window will not apply until clicking the **OK** button.

3. **Resultant forces** – the resultant wind forces in the three primary axis directions are displayed in real-time. The convergence deviation for each resultant force is displayed and is color coded: **red** for above the limit and **green** for below the limit.
4. **Convergence Process** – for a more visual display of how well the model is converging, a bar graph displays the maximum convergence deviation for each step and is updated in real-time during the analysis. The graph continues to update through each simulation direction, without clearing the results from the previous simulation direction.
5. **Generate loads now** – this button will generate wind loads on elements based on the current solution step and will prompt RSA to proceed to the next simulation direction, if another is specified. If the current direction is the only direction being analyzed, or it is the last direction in the queue, a dialog box will pop up and indicate the load cases created during this simulation run. This button will function the same way regardless of whether manual and automatic load generation is selected.
6. **Process status** – this text box displays the current status and progress of each step in the wind simulation. As each step is completed the pause symbol is changed to a green circle with a white checkmark.
7. **Stop** – this button will cause a dialog box to pop up with the following two options:
  - Yes** – Stop the simulation process at the current step.
  - No** – Back to the simulation process and continue loads generation.



The dialog can be expanded to show the wind directions still awaiting analysis and load generation, and those which have been completed. Clicking **Yes** will stop the simulation for the current direction being processed. No load data from the current and awaiting directions will be stored. However, directions already analyzed will have their load cases created and stored for use. Clicking **No** simply resumes the current analysis direction.

8. **Close** – will close the wind simulation tool if no current simulations are being analyzed. If an analysis is underway, clicking **Close** will function in the same manner as the **Stop** button.
9. **Help** – clicking this help button opens the main help screen for RSA in your default browser.

### Post-analysis Items:

1. After the wind simulation analysis completes, you can now view the generated loads and load cases. To do so, use the **load case selector** on the **Selection Toolbar**. When you click the dropdown list, you'll notice all of the load cases and combinations in the model. By default wind load cases will be named: **Wind Simulation + Direction + Velocity**. Note that the direction and velocity parameters will vary between load cases, but even if you elect to specify a wind pressure the load case will include the wind velocity in the load case name. After the load case has been generated it behaves like any other static load case. For example, you can edit the load case number, label, nature, and name from the Load Types window (**Loads > Load types...**). You can also add to or delete any of the load definitions within the wind load case, just as if you had created them manually.
2. Once the wind load simulation completes, the pressure maps will no longer be displayed. To display the pressure maps again, you'll need to adjust your display settings to show load symbols. You can click on **load symbol** button on the quick access display toggles of the bottom left corner of the project view window:



If you're using default setting in RSA, you should now see the pressure maps and load symbols for the wind simulation load case selected. If it does not show, or you wish to hide some of the other load symbols, you need to turn the pressure maps displays on in the display options. To do this, click **View > Display**, then select the **Loads** category. You'll find the **Pressure maps** display option under the subcategory **Load symbols**.

This covers all of the windows, options, dialogs, etc. need to understand and run a wind simulation. Now, here is a basic workflow for using the tool in practice.

### General Building Design Workflow for Wind Simulation:

1. Create and define the geometry of your building
  - a. Define all member types, materials, sections, supports, etc.
2. In our office, we generally like to design the structure for gravity loads first. There are several benefits to this approach:
  - a. The majority of members in the building are likely controlled by gravity load combinations.

- b. Gravity analysis and design optimization can establish member sizes quickly, as the analysis and design parameters are easier and faster to specify. This will quickly establish a baseline of members sizes to be checked for lateral load resistance.
3. Save a separate copy of the gravity analysis model for reference and disaster recovery purposes.
4. Define preliminary lateral load resisting system components for the structure (add braces, shear walls, moment frames, etc.)
5. Create exterior panels and cladding elements, as necessary, to enclose the building.
  - a. Cladding elements are great for wind load distribution as they are simple planar elements whose sole purpose is for load distribution. Take care when specifying the span direction so that the loads generated are applied to the appropriate elements. Remember, cladding elements span directions are based on their local coordinate system orientation, not the global axis.
6. Run the wind simulation tool
  - a. Set the appropriate parameters for your building and wind environment.
  - b. Pick two primary wind directions to investigate first, picking directions orthogonal to each other (say +X and +Y) which represent the primary directions of the main lateral force resisting system elements.
  - c. For wind exposure, pick elements which will actually distribute the wind pressures. Accidentally picking columns, girders, etc. will mesh those elements and apply wind loading if they are picked. This not only increases the complexity and calculation time required, but it will also change how the wind flows over the surface of the building and the resulting pressure magnitudes and layout.
  - d. Choose the **manual load generation** mode to allow you to have more time viewing the pressure mapping as the analysis runs. This will also give you time to customize the pressure mapping scales and patterns to your liking, which you should save for use later.
  - e. When each direction converges, generate the loads on elements. Letting the simulation run for additional time can reduce conservative pressures for leeward and areas subject to turbulent flow, so it can be worthwhile to investigate this behavior. You can either reduce the convergence tolerance to 0.3% (from 0.5%) or simply double the analysis time required to reach convergence prior to generating loads. After you are comfortable with the results, you can switch to automatic load generation for convenience.
  - f. Review the pressure maps and element loads generated for each load case.
  - g. Run the analysis calculations for the new wind load cases and review analysis results.
  - h. A quick check of the total load applied for each wind load case via the reactions table and against estimated or baseline values (hand calculations, other analysis results, etc.) is recommended to ensure the model is behaving properly. The resultant forces in the convergence portion of the Wind simulation window during analysis should match the results you find in the reactions table, but it is worth checking both. Checking nodal displacements is also recommended, to ensure the model appears stable and is behaving as expected.
  - i. Run design checks with the two wind load cases added to your design combinations and run design checks to see if the trial lateral elements are reasonably sized. Iterate the

above steps until you achieve satisfactory performance from the two primary wind directions, checking both strength and serviceability.

7. Re-run the wind simulation tool for all directions desired for investigation, adjusting the input parameters from step 6 as necessary based on the initial analysis review, convergence issues, etc.
  - a. Generate the load cases for the desired directions and delete all unnecessary/irrelevant wind load cases created from step 6.
  - b. Create load combinations with the new wind load cases created.
  - c. Complete design/optimization calculations for all members and iterate the above steps as required until an optimum design is obtained.

During the presentation we'll work through many of these steps in using an example model. The resulting modeled will be shared with you after the conference so you can revisit and experiment at your leisure.

### Benefits of Wind Simulation

Designing buildings for wind load is a daunting task regardless of which method or set of tools you use. While learning the nuances of using RSA's wind simulation tool may seem formidable at first, the key to a successful analysis is proper model definition and wind simulation parameter specification. Once you become familiar with the process, the above steps become extremely easy to implement and you'll be obtaining accurate results much faster than if you had tried to implement one of the current code based methods.

Now that we know how to use this great tool, what are the benefits?

1. The wind simulation tool can be applied to any structure type and configuration. There are no limitations on model size or complexity.
2. The simulation analysis is very fast. This allows designers to tackle the daunting task of wind design challenges earlier on in a project, and quickly analyze the impact of changes at any stage in the design process.
3. This tool allows designer to identify areas of concern which can inform geometry, cladding, and wind force resisting system choices earlier in the process than other methods.
4. Validation testing indicates RSA's wind simulation results are accurate and comparable to wind tunnel test results. Where there are differences, the results RSA results are typically slightly more conservative, therefore the results can be used reliably for design purposes.
5. While RSA isn't currently a code recognized approved wind design method, RSA can be used to validate and augment other wind design approaches, including wind tunnel testing.
  - a. The speed and accuracy of wind simulation can help shape the scope and focus of the wind consultant's efforts. Different building configurations can be tested prior to spending costly wind tunnel testing time, only to find out changes are required and therefore more testing.
  - b. For buildings that may be on the edge of wind tunnel testing consideration, RSA's wind simulation tool can help determine if wind tunnel testing is warranted.
  - c. Wind tunnel test results can assist in validating the wind simulation results from RSA, and can guide tweaks to the wind simulation parameters to get the two results into



- agreement. The calibrated analysis can provide a baseline to investigate building changes without necessarily needing to conduct additional wind tunnel testing.
- d. Simulation results can also be used to validate analytical methods and possibly identify areas not specifically addressed by the code approaches.
6. Using computational fluid dynamics shifts most of the complex and time-consuming wind analysis calculation burden away from the engineer, allowing more time to focus on other priorities and endeavors.
  7. The wind simulation tool can be a learning and experimentation tool for testing out new wind design concepts and ideas.
  8. The cost of RSA is significantly less than a single wind tunnel test, so in addition to excellent wind design capabilities, you're also getting a fully featured analysis and design platform.
  9. Having a wind simulation tool will expand/improve your company's wind design capabilities. Increasing your technical capabilities can increase your firm's appeal to clients that design complex and tall building structures.