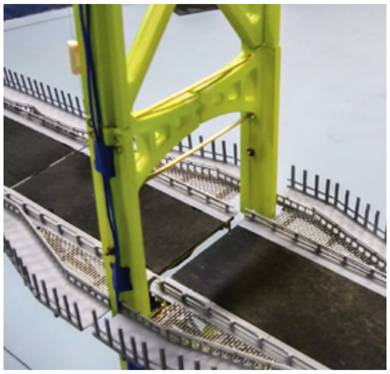
BRIDGE AERODYNAMICS

Optimizing bridge performance and safety through comprehensive analyses, modeling and testing presented in simple, design-ready results



Cable-supported, arch-and-truss bridges are expressions of elegance and functionality. However, they tend to react dynamically to the wind.

Gusting winds may buffet the bridge, causing it to move. In some cases, instability results from the bridge's design. These interactions are highly complex. Left unaddressed, some responses could cause anything from discomfort in users to catastrophic failure of the structure. However, with the correct aerodynamic design, these bridges can become lasting landmarks.

Our Service

We help you arrive at a bridge design that is safe, optimized, cost-efficient, aerodynamically sound—and highly functional. Our exceptional staff is uniquely qualified to help you understand—and adjust—how your structure will respond to the wind. We use state-of-the-art methodology, experimental and numerical tools to conduct the most accurate studies in the industry.

In wind tunnel studies at our facilities, we employ precise modeling and simulation techniques. These studies are designed to correctly capture the effects of geometric details and structural motion. Detailed models are then subjected to realistic atmospheric conditions. We use these tests to assess how the structure would perform aerodynamically in any windstorm.

We distill the test results into critical stability conditions and simplified wind load cases that capture the essential behavior of this wind–bridge interaction. These load cases include specified wind pressures, distributed across the structure, that can be used directly for design. Our wind loads are unmatched in the industry for simplicity and accuracy. All solutions we develop to improve aerodynamic stability and user comfort are project-specific, simple and efficient.

We use advanced,custom modeling tools to quickly and efficiently evaluate design adjustments and address your project's needs. We can also draw on the exceptionally deep resources of RWDI to incorporate environment-related issues into the wind analysis. These broader reviews might include making micro-local adjustments for wind direction, evaluating aerodynamic risks associated with ice accretion and identifying loads from accumulated snow and ice.

RWDI is a valuable partner to clients seeking to...

Explore Innovations

- Understand and compensate for unanticipated aerodynamic behavior in visionary designs
- Safely undertake lighter, material-efficient and more flexible designs

Create Opportunities

- Get design-ready insights quickly
- Spend capital where it matters by choosing correct thresholds for tolerable motion
- Save money by making optimized, highly specific adjustments to a design

Meet Challenges

- Understand the unique effects created by adjacent bridges
- Adapt a design to challenging prevailing winds

Fulfill Expectations

- Create a positive user experience of safety and comfort

How we work

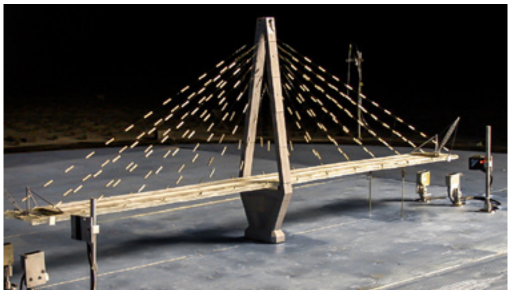
In general, we examine the potential for aerodynamic instabilities in our wind tunnels. We can usually identify the required mitigations quickly, based on experience, and confirm the solution by retesting the modified form in the wind tunnel, when needed. We can then turn to our custom numerical modeling tools to optimize the mitigations.

Sectional model testing

During our detailed testing, we put typical sections of the bridge deck or towers in our wind tunnel. The sectional model test identifies the potential for aerodynamic instability. These models are at relatively large scale to ensure that geometric details are adequately modeled.

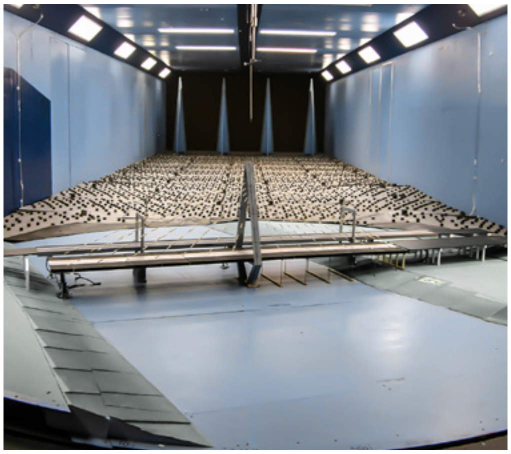
The section model is essentially stiff. Motions are simulated by springs and dampers in a suspension system outside the wind tunnel's walls. These state-of-the-art suspension modules feature air bearings and eddy current dampers; they allow independent adjustment of degrees of freedom. This system ensures consistent and highly adjustable levels of damping at any amplitude of model response. The suspension modules can also be extended to dynamically test multiple bridges in tandem arrangements.

The sectional model testing also allows us to extract static force and moment coefficients. These coefficients quantify the amount of average load the wind will apply to the structure. Furthermore, the self-excited forces can be extracted; these forces describe how the fluid-structure interaction leads to changes in stiffness and damping of the overall system.



Aeroelastic model testing

Aeroelastic models are scaled-down, simplified versions of the full-scale bridges. These models are tested in our state-of-the-art boundary layer wind tunnel. Like the sectional models, aeroelastic models may reveal aerodynamic instabilities. They are also used to find optimal solutions. In these tests, we can also directly measure the wind loads induced by the buffeting action of the turbulent wind.



Numerical modeling

In addition to wind tunnel tests, we construct full-scale numerical models of the bridge. These models are validated by the results of the aeroelastic model tests. When we are working with adjustments to the bridge form, we use these numerical models to optimize the solution. For example, it may show that an added fairing on the deck is needed only on 500 feet of a 1000-foot span to meet the exact project requirements.

Wind loading

To derive design wind loads, we use the same numerical models to solve for time-specific wind loads using our custom, time-domain-based non-linear aerodynamic response solver. Unlike frequency-domain-based codes, our approach provides a snapshot solution at each time step. Thus, we use fewer simplifications about how the modes couple within the structure. Our time-domain response analysis techniques have been validated repeatedly by two decades of studies.

The design wind loads we supply fully account for the interaction of the structure with the gusty action of the wind. We use the results to select the most critical wind loads and provide them to you in a design-ready form.

Complementary analyses

- Overall comfort of bridge users. We can develop realistic scenarios and combine wind loading and aerodynamic excitations with traffic-induced vibrations (due to pedestrians, vehicles or trains, or any combination of these) to determine perceived user comfort.
- Development of realistic wind speed criteria for actual wind climate. We assess the wind climate, including wind direction, to determine correct criteria for aerodynamic stability.
- Multi-hazard assessments. We combine the effects of wind with those of snow/ice to determine wind loads and aerodynamic stability.
- Operational recommendations. We can evaluate operational risks for vehicles to blow over and provide guidance to bridge operators about wind conditions under which the traffic should be restricted or stopped.
- Assessment of cable vibration. We are leaders in research on cable vibrations and are uniquely positioned to translate recent testing and simulation of non-linear aerodynamics into practical design guidance.
- Real-time notification on ice accretion risk. We can monitor and forecast in real time the risk of ice accretion on cables, its release and the projected debris field; we can notify bridge operators of approaching storms and provide guidance about bridge lane restrictions and closures.