We provide Innovative solutions for Wind Engineering & Vibration Control
BUSINESS

TESOLUTION

- WIND TUNNEL TEST for BUILDINGS & BRIDGES
- COMPUTATIONAL WIND ENGINEERING

VICOSYSTEM

- VIBRATION CONTROL DEVICE for BUILDINGS, BRIDGES & OTHER STRUCTURES
Our company was established in February 2001 with the aim to evaluate the safety and serviceability of structures in order to provide our clients a pleasant life with technique based on our accumulated experiences in the field of Wind Engineering and Vibration Control.

**As to the field of Wind Engineering**, the evaluations of wind resistance stability on buildings and bridges, that of serviceability on wind vibration, and of wind environment are carried out based on the high technical professionals and wind tunnel test facility to provide innovative solutions.

**As to the field of Vibration Control**, vibration control devices and vibration isolation devices are provided in order to reduce or suppress the vibrations occurring due to wind load, seismic load and traffic load on various structures.

Your support and demands paved the way for us to establish our affiliated company, "Vico System Co. Ltd." which specializes in Vibration Control in February 2010. Our new office building and the facility was completed in 2013. With this, TESolution and Vico System now possess office buildings and research/test facilities in each and are now well established professional enterprise with the abilities in both software and hardware.

We promise you to do our best in providing satisfactory results for our clients with differentiated technical services and also in continuous R&D effort.

CEO of TESolution & Vicosystem

Dr. Kim, Yunseok
Structural Laboratory

The structural laboratory at TESolution is well-equipped for performance testing of full-scale vibration control devices, such as Tuned Mass Damper (TMD) and Active Mass Damper (AMD). The fabrication procedures and installation are carefully checked in order to prevent unexpected problems at construction site. Structural laboratory has test reaction floor with 300-ton bearing capacity, OH crane with 5-ton capacity, and 200KW electric power supplier. The 2nd structural laboratory [15m width × 40m length × 20m height] was built at Vico System Co. Ltd. in May, 2013.

Boundary Layer Wind Tunnel

The boundary layer wind tunnel is a facility designed to simulate the field of air flow around structures for variety of aerodynamics studies. This is a closed circuit wind tunnel with the dimension of 8.0m width × 23.0m length × 2.5m height. The wind speed can be continuously adjusted in the range from 0.3m/s through 11.0m/s using suction type blower with 132KW of power for each. Turbulence intensity is less than 0.5% and deviation of wind velocity is ± 1.0% at the location of turntable. This wind tunnel is well suited for model studies of air flow over various structures, full model of long-span bridges, stand-alone pylon, and cable structures, as well as topographic feature.
Wind Tunnel for Section Model Test

Bridge cross-section model test is conducted to investigate the aerodynamic response characteristics of the bridge section. This tunnel has been primarily employed in studies of Aerodynamic stability for long-span bridge, such as vortex-induced vibration, flutter, and galloping phenomena.

The dimension of test section is 1.0m width by 6.0m length by 1.5m height and wind speed can be controlled in the range from 0.3m/s through 21.0m/s. There are additional experimental system, such as spring-support system, active turbulence generator, and forced oscillator.

Test Tower

The test tower is a unique test facility for various control devices. This tower is mainly used in order to conduct performance test of newly developed vibration control devices such as TMD and AMD. In the excitation room, an exciter simulates the vibration of the tower. The control device stationed in the control room detects the vibration to reduce the vibration of the tower. The test tower is 5 stories [20m height] tall steel structure. The tower consists of two rooms - one is control room and the other is excitation room.

Model Workshop

TESolution makes scale models for wind tunnel test using Computer Numerical Control(CNCJ machine and laser engraving system). Wind-tunnel scale and aero- elastic scale models are designed and fabricated with our modelling knowhow and technologies we have accumulated.
Vibration Control System

Vibration Control Device

Structures are becoming sensitive to dynamic loads induced by traffic, machine, equipment and wind, as they become taller, flexible, and become more lightweight with the development of construction material and technology. The serviceability/habitability of structures must be satisfied in order to achieve pleasant living environment for the residents. TESolution continues to take leading role in the field of vibration control of bridges, buildings, and special structures through continuous research activities since its foundation in 2001. TESolution provides optimal vibration control solutions through the following works.

- Basic/Detail design: Determination of dimension, types, and specifications of tuned mass dampers, drawing works
- Fabrication/Performance test at TESolution: Friction/vibration tests
- Installation/Performance test at construction site:
  Frequency tuning and verification of required control performance
- Maintenance: Confirmation of control performance and main components

HMD, Incheon International Airport
TMD, Alpensia Ski JumpTower
TMD, Centumcity
AMD, Ulsan Lotte Hotel
TMD, POSCO E&C Headquarters
TMD, Yangyang International Airport
Applications

Buildings

Wind-induced vibrations on high-rise residential and office buildings have a highly negative impact on habitability and serviceability. International organization for standardization (ISO) and building codes in many countries (such as AIJ2004) recommend structures meet specific criteria of vibration control by classification of vibration’s magnitude considering the types of vibration and human perception level. The objective of vibration control device is to improve damping efficiency and habitability of building by installing vibration control device such as tuned mass damper on the structures.
Long-span bridges, such as suspension or cable-stayed bridges are structurally highly vulnerable to wind load due to small bending / momentum stiffness and damping ratio. In the case of footbridge, vibration serviceability may not be satisfied due to the excessive vertical vibration through pedestrian movement even if the structural safety is satisfied. When the excessive vertical vibration is occurred on the foot bridge, pedestrians may experience unpleasant feeling. Furthermore, if these vibrations are repeatedly occurred on the footbridge, structural damage due to fatigue may be intensified.

Vibration control devices for bridges are not only to increase the wind resistant performance under construction and in-service stages but also to improve serviceability of footbridges.

Vibration Control System

Yoido Setgang FootBridge(2011)

Ulleungdo Footbridge(2011)

Jinindo Bridge(2012)

Pylon of 4th Songdo Bridge
+ **Special Structures**

Flexible structures, such as chimney, steel tower, and cable cars are highly vulnerable to wind load because of their long period and low damping characteristics. Vibration control devices are installed to these structures to increase structural damping.

+ **Isolation table system**

Isolation table system protects manufacturing equipments and servers from an earthquake by isolating it from the ground. Structures with valuable contents or operations such as data centers, communications facilities, and museums need isolation table system to protect earthquake-induced damages. Isolation table system (ITS) of Vico System provides structural safety against overturning and damage from an earthquake.
Wind Tunnel Tests for Buildings

As buildings become taller and more lightweight, they become more sensitive to wind-induced vibration. Especially, dynamic responses of the tall building for the structural safety and occupant comfort should be evaluated with proper measuring procedure. Wind tunnel test is one of the measures to evaluate the wind response of structures and offers specific information about structural design.

TESolution is a group of experts in wind engineering and vibration control and provides total engineering solutions for the wind-induced vibration such as structural safety, assessment of human comfort against building vibration and pedestrian level wind environment. TESolution has been involved in many of domestic / international projects and continues to play a leading role in the field of wind engineering.

High Frequency Force Balance Test

High frequency force Balance [HFFB] test is conducted to evaluate the overall wind load and the response for structural design and serviceability. In HFFB test, a rigid model is used to measure the wind loads [shear and moment of each structural axis] with six component force balance. Wind force coefficients are computed through analysis of time-dependent forces and the response of the model is evaluated by spectral modal analysis.

- Shear, overturning moment, and torsional load at the base.
- Story wind load and combined design story load.
- Wind-induced acceleration and serviceability evaluation
- Countermeasure of vibrational control
- Shape Optimization
- Structural Monitoring

Wind Tunnel Test for Buildings
**Aeroelastic Model Test**

Aeroelastic model test is suitable for slender, flexible, and dynamically sensitive structures. The objective of aeroelastic model test is to investigate the vortex-induced vibration and aeroelastic instability vibration within the range of target wind speed. The aeroelastic model is designed with precisely scaled dynamic properties of the full-scale building (stiffness, mass, natural frequency, and damping properties of the structural system). Responses are directly measured in wind tunnel by using non-contact displacement meters (optical sensor type or laser sensor type) or accelerometers.

- Shear, overturning moment, and torsional load at the base
- Story load at each wind direction, combined design story load
- Displacement
- Acceleration for various return periods (1, 5, and 10 years)
- Study of vortex shedding and aeroelastic instability
- Study of vibration mitigation

**Pedestrian Level Wind Test**

Pedestrian Level wind test is conducted to evaluate the comfort and safety of pedestrian near the building. If tall building is constructed in the high-density building area, the flow pattern near the construction site may be changed due to surroundings of the buildings. Generally speaking, the pedestrian level wind environment is evaluated with the wind speed ratios and the probabilities of occurrence of wind speed/direction near the target area.

- Occurrence of wind speed and direction
- Wind speed ratio
- Assessment of pedestrian level wind load
Wind Pressure Test

Wind pressure test is conducted to evaluate the design wind loads on claddings and components of a building. Pressure on the surfaces of a rigid model are measured by multi point pressure measurement system. The pressure tabs are evenly distributed to ensure sufficient coverage to provide information on the surface of the building. External pressure coefficients (mean, RMS and peak values) are used in predicting cladding design pressures.

- Cladding design pressure.
- Roof structural design pressure
- Differential pressure
- Overall wind loads and responses by pressure integral method

Topography Model Test

Topography model test is conducted to evaluate the characteristics of wind direction and wind speed over areas having complex terrain and topographical features. Wind speed and turbulence intensity over scaled-topographical model are measured by using an anemometer system.

- Distribution of wind speed [horizontal and vertical directions]
- Distribution of turbulence Intensity [horizontal and vertical directions]
- Topographic effects
Wind Tunnel Test for Bridges

Wind Tunnel Tests for Bridges

Bridge structures have higher probability of suffering from wind-induced vibration due to the characteristics of flexible structures. As the span of the bridge gets longer, wind load becomes dominant design factor in the bridge design. The Aerodynamic stability of bridge is mainly conducted for the deck, pylon, and cable of the bridge. We also investigate the Aerodynamic stability of barrier, guarded fence or road sign on the bridge. TESolution gained experience in the field of wind engineering through numerous domestic and international projects from all over the world, such as Japan, Turkey, Vietnam, Indonesia, China, and Uganda.

Section Model Test

The Section Model Test is conducted to evaluate wind-resistance stability of the bridge. It is the basic, yet one of the most important tests that is also cost efficient.

A rigid model with representation of a section of the bridge, including girders, barriers, and railings for inspection car is used in the tests, which is evaluated through the spring support system, wind force measurement system, and forced oscillator in the wind tunnel. The spring support system allows motion of the model for vibration test, and the wind forces acting on the model are measured by two three-component load cells. Our patented forced oscillator shakes the model in sinusoidal motion with heaving, sway and pitching mode, respectively, to measure flutter derivatives. The test results show the main issues regarding wind stability of the bridge, and with further analysis of these results, our engineers are able to provide suggestions on aerodynamic or structural vibration control systems.

- Aerodynamic stability: vortex-induced vibration, flutter, galloping
- Aerodynamic force drag, lift, moment coefficients
- Steady aerodynamic force: drag, lift, moment coefficients.
- Aerodynamic optimization of the shape for unstable aerodynamic behavior of bridge
Wind Tunnel Test for Bridges

Pylon Model Test

Pylons for cable-stayed bridge and suspension bridge generally are in slender figure, which are vulnerable to the wind load. The pylons are especially vulnerable when stood alone in the erection stage, prior to the installation of cables, due to their low structural damping properties.

Wind tunnel tests of pylon include aeroelastic model tests and wind force tests under various construction stages. Aeroelastic model tests are conducted to evaluate aerodynamic stability of free standing pylon. Wind force tests are conducted to provide wind force coefficients of pylon legs or whole pylon.

- Aerodynamic stability: vortex-induced vibration, flutter, galloping
- Base shear force, base overturning moment, base torsional moment
- Wind force of pylon leg: drag, lift, pitching moment coefficients
- Wind force of whole pylon: drag, lift, torsional moment, overturning moment coefficients
- Aerodynamic optimization of the shape for unstable aerodynamic behavior of pylon

Full Bridge Model Test

Full bridge models offer the possibility of extensive explorations of prototype conditions, such as the effects of the wind at various approach angles, velocity profiles, special effects that may be caused by unusual topography and upwind obstacles, and etc. It is necessary to check three dimensional Aerodynamic stability of the bridge due to changing dynamic properties of the bridge under the erection stage or at completed stage.

Three-dimensional aeroelastic model is used for the vibration test of full-bridge. Aeroelastic model affects not only model geometry of the bridge in detail, but also affects physical properties such as mass distribution, stiffness, and mass moment of inertia.

- Aerodynamic stability: vortex-induced vibration, flutter, galloping
- Aerodynamic stability of full-bridge during the erection/ at completed stages
- Aerodynamic stability of full-bridge considering topography effect
- Aerodynamic stability of full-bridge considering construction facilities
  - [derrick crane, etc]
- Aerodynamic optimization of the shape for unstable aerodynamic behavior of full-bridge
Buffeting Analysis

Buffeting responses are random vibrations by turbulent components of approaching flow. Static deformation by mean wind speed and buffeting response by fluctuating wind speed are computed in the erection stage and in-service stage. Eigenvalue analysis results such as natural frequency and mode shapes are used for the buffeting analysis

- Buffeting response of girder and pylon during the construction and in-service stages
- Suggestion countermeasure for unstable aerodynamic behavior of full bridge

<table>
<thead>
<tr>
<th>Bridge deck</th>
<th>Pylon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>In-plane</td>
</tr>
<tr>
<td>Vertical</td>
<td>Out-of-plane</td>
</tr>
<tr>
<td>Torsion</td>
<td></td>
</tr>
</tbody>
</table>

Flutter Analysis

Flutter is an aeroelastic instability involving coupling of Vibration modes. In other words, flutter occurs at certain range of wind speeds where energy exerted by wind flow interacts with the bridge causing oscillation.

Multi-mode flutter analysis method is generally used as an analytical method to calculate the critical wind speed of flutter. Flutter derivatives, natural frequency and mode shapes from eigenvalue analysis are used as input data. Flutter derivatives from forced vibration test are required for flutter analysis.

- Flutter onset speeds of a bridge in the erection and completed stage
- Various combination of bridge modes should be considered
Computational Wind Engineering

Computational Wind Engineering (CWE) uses Computational Fluid Dynamics (CFD) method to solve problems encountered in wind engineering. Numerical modeling with CFD can be a powerful alternative as it can avoid limitations of on-site measurements and wind tunnel tests. CFD can provide detailed information on the relevant flow variables in the whole calculation domain under well-controlled conditions. Typical application examples are the prediction of wind comfort, pollution dispersion, natural ventilation of buildings, wind load on buildings, static aerodynamic force and flutter analysis of a bridge.

Wind Environment

High-rise buildings can form street canyon and induce high wind speed at pedestrian level, which can lead to uncomfortable or even dangerous conditions on the street. Construction of new building can worsen the situation. Numerical simulations conducted on wind environment makes optimized urban planning or placing windbreak forest possible.

Stack Effect

Stack effect is caused by buoyancy due to the difference in temperature between the air inside a building and the ambient conditions outside. It is particularly a problem for high-rise buildings with continuous lift shafts and stairwells. Numerical simulation is used to predict pressure distribution and natural ventilation, which are caused by stack effect in high-rise building.
Air pollution/Diffusion

Outdoor air pollution is a main concern of building engineers who design the ventilation inlets and outlets on building facades or roofs. The major sources of outdoor pollutant are the re-ingestion of the contaminated exhaust air by the same building or by the intake of exhaust gas from other sources such as nearby buildings, street traffic, parking lots, and etc. The precise prediction of pollution distributions around and near the building is important for building design and evaluation.

Indoor Ventilation

Indoor thermal equilibrium state and indoor ventilation of factory facility with heat sources or office building is investigated with numerical simulation. The airflow, thermal, and humidity patterns at the height levels of human activity are simulated. These analyses are helpful for designing comfortable working environment in early design step.

Typhoon Simulation

TMCS (Typhoon Monte Carlo Simulation) is widely used to estimate extreme wind velocity. TMCS method is based on the analysis of characteristics of historical typhoons passed in the target site. To calculate wind environmental condition, wind speed and direction for each return period are estimated using computer simulations for the target site.

Aerodynamic Analysis

Numerical simulation is used to investigate static aerodynamic forces, wind velocity, vortex, and pressure distributions near the bridge. Also, flutter derivative and velocity are estimated with unsteady numerical simulation.
Total Engineering Solution in Wind Engineering and Vibration Control

TESolution Co. Ltd.
142 Seungjin-gil, Gongdo-eup,
Anseong-si, Gyeonggi-do, 17563, Korea

TEL +82-31-658-2906
FAX +82-31-658-2908

General Inquiries : tesolution@tesolution.com