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Smart bridge Project:
Modeling and Design of Wind Tunnel Tests

S. Shravan K. Sajja

Professor : *Alcherio Martinoli*
Assistant(s) : *Pascal Gilbert*

Bridges or structures can be termed '*smart*' by virtue of their capability to respond to incumbent threats like wind and earthquakes. The degree of smartness depends on our understanding of the structural response, interaction of the structure with other physical phenomenon (fluid), its interpretation and control.

Long-span bridges are particularly vulnerable to wind loads, owing to their inherently low structural damping, lower natural frequencies and adjacent fundamental torsional and vertical mode frequencies. This leads to wind induced instabilities causing potential damage to the whole structure.

Control strategies to mitigate such instabilities can be classified into two methods: structural and aerodynamic methods. Structural methods include increasing the structural stiffness and mass of the girders. Torsional stiffness of a girder can be increased by increasing the bridge cross section; however, increased cross sections suffer with larger drag forces, which further demand higher structural strength leading to increased cost of construction. Flat box girders designed to overcome these problems are prone to coupled flutter and need supplementary suppression techniques. Such contradicting requirements set an upper limit on the bridge span length.

Aerodynamic methods are based on the manipulation of aerodynamic forces acting on the structure. As aerodynamic forces depend on the shape of the girder, manipulation of the bridge section by adding flaps or fairings can stabilize the girder. Triangular wind fairings installed along both sides of Bronx-Whitestone Bridge and Deer Isle Bridge, perform the function of a passive aerodynamic control system reducing wind induced vibrations. Active aerodynamic control, using small moving flaps installed along both edges of the bridge girder, was proposed by Ostenfeld. Advantage of active aerodynamic control over other active schemes such as tendons or active tuned mass dampers is that the control forces are generated by the aerodynamic forces exerted on the flaps and/or the flaps actively modify the flow pattern around the bridge to stabilize the structure. This reduces the actuator forces, as the stabilizing forces are drawn from the airflow. This approach also provides a convenient method of applying the control force at the center of the span.

The smart bridge project aims to further this study for a full bridge model with an array of such control flaps on both sides of the girder. An underlying sensor network is used to measure the local wind field and the structural displacements. Each individual flap is controlled locally based on the information from the sensor network and the neighboring flap control units. Such distributed control systems increase the system reliability. The distribution of these flaps and real time coordination among them in order to control the global aerodynamic profile of the bridge poses an interesting research problem. This method would provide the means to increase the critical flutter wind velocity of a long span bridge without using a large, inexpedient and expensive torsionally stiff bridge girder and also improve the serviceability state of the bridge.

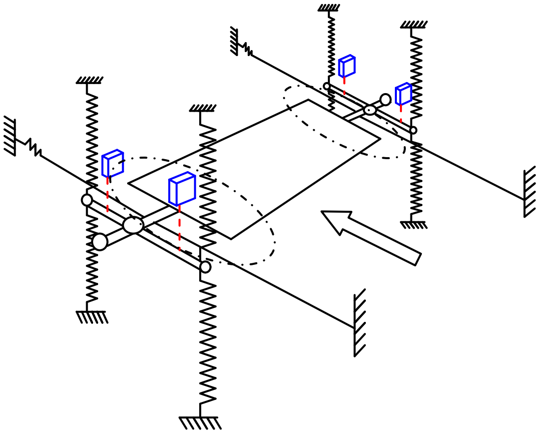

Fig. Schematic of experimental set up without flaps

The first phase of the smart bridge project aims to experimentally implement the active deck flap system with only two flaps (leading edge and trailing edge flaps). This is followed by a numerical simulation of the bridge deck with multiple flaps leading to its experimental verification in the second phase of the project.