tial for dramatically modifying the technology of bridge engineering in the future. An intelligent bridge system includes sensors, which receive information about the bridge's behavior or the external action being applied to it; a controller, which determines the counteractions to be applied; and actuators, which apply counteractions to the bridge. An analogy can be made to living creatures, with the sensors being comparable to sense organs; the controller being comparable to the nervous system; and the actuators being comparable, for example, to the muscles executing a countermeasure.

An example related to bridge aerodynamics is offered by the Danish firm of COWIConsult, which has recently patented an actively controlled aerodynamic surface that it is believed will allow unlimited span length with regard to aerodynamic stability. The system is, to borrow from the wing flaps of aircraft technology, a controllable airfoil bridge deck.

A series of accelerometers mounted in the deck monitors vertical movements and sends a signal to an on-board mounted computer. The computer in turn responds by instructing a hydraulic servo mechanism to change the pitch of the flaps, creating either a positive or a negative lift to counteract the effect measured by the accelerometer.

Concluding Remarks

New materials and structural concepts are emerging that will extend the boundaries of technology limitations. As promising as emerging materials are in providing increased strength and durability and reduced weight, however, there is a price to be paid for these advantages in the form of reduced stiffness. Designers must be aware of the potential for global and local instabilities resulting from decreased stiffness. Undoubtedly it will be impractical at some point to realize the full advantages of increased strength and reduced weight because of resulting inherent instability or because service limit states are exceeded. It may be necessary to deal with new limit states, such as user sensitivity to vibration or claustrophobic reaction to long tubular structures or tunnels, and to partner with the medical profession for solutions. The result will in turn be the need for innovative structural solutions to overcome the problems that emerge with the use of new technologies.

Reference

1. Simonsén, B., J. Sulkiewicz, and J. Virola. Sillanrakennuksen Tulevaissuudennäkymiä [Future Aspects of Bridge Construction]. *Rakennustekniikka.* Helsinki, 1972.

High-Performance Concrete: A Superior Solution

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As part of the implementation of Strategic Highway Research Program high-performance concrete (HPC) products, several states have started to use HPC for bridge construction. Applications include all bridge components: decks, superstructures, and substructures.

HPC meets performance requirements that cannot always be met with conventional constituents and normal mixing, placing, and curing practices. These requirements may involve the enhancement of ease of placement and compaction, long-term mechanical properties, early-age strength, and durability and service life.

Because of its lower water-to-cementitious-materials ratio (w/cm), HPC is typically stronger than conventional-strength concrete. However, high strength is not always the primary requirement. HPC is valuable where any of the following properties are required: high strength, high early strength, low permeability, resistance to freeze-thaw damage, resistance to chemical (e.g., sulfate) attach, abrasion resistance, low absorption, high resistivity, high modulus of elasticity, and volume stability.

Given its improved material characteristics, bridge decks built with HPC can be expected to last much longer than those built with conventional concrete. High-strength concrete girders can span longer distances and be used at wider spacings than conventional concrete girders, thus reducing the number of girders required and lowering costs. Alternatively, bridge designers have the option of selecting shallower girders to increase clearances without changing grades. Again, the net result is economy. Therefore, HPC can be used both to reduce the size and to extend the service life of superstructure and substructure elements, particularly in severe environments. It also allows for more graceful structures; aesthetics, although difficult to measure, can represent an important benefit.

Twelve states are participating in the Federal Highway Administration-sponsored HPC Bridge Showcase program. The intent of this program is to give the states an opportunity to see how they can benefit from the use of HPC. So far, the program appears to be a success. Virginia, for example, has completed two additional HPC bridges on its own; it has another under construction and five in design. A number of other states, including New York and Delaware, are not participating in the FHWA program, but are using HPC, particularly in their decks.

In summary, HPC is an improvement over previous formulations of high-quality concrete, made possible by the use of modern admixtures and supplementary cementitious materials. In almost all forms of construction, HPC offers a superior solution that should have lower service-life costs than conventional concrete. The superior qualities of HPC will result in its increased acceptance on the basis of reduced life-cycle costs. In some instances, initial economies will result even though the material itself may be slightly more expensive. Information about the use of HPC can be found at FHWA's HPC Web site: http://hpc.fhwa.dot.gov.

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