National Concrete Bridge Council promotes key speed, strength and durability advantages of HPC to legislators, designers to improve condition of nation's bridges

Group Promotes Benefits Of High Performance Concrete Bridges

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With the fate of the nation's infrastructure at stake, the National Concrete Bridge Council (NCBC) has implemented a program designed to increase the educational information available to legislators and designers about the benefits available through High Performance Concrete (HPC) structures. They hope to generate more research and application funding to take advantage of the potential, which can speed construction while providing longer life and lower costs.

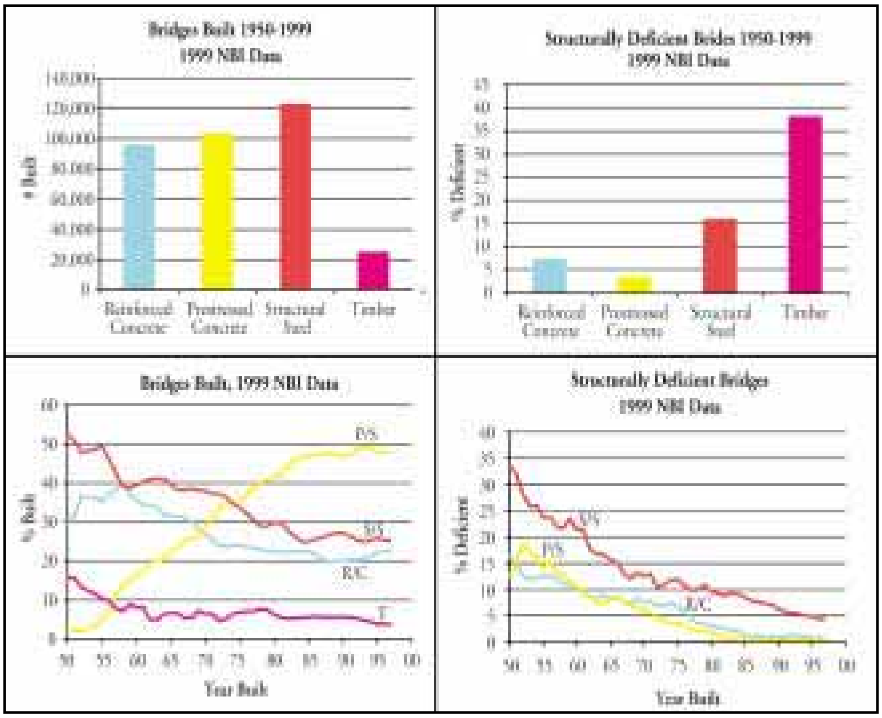
High performance concrete bridges include two key elements: total precast bridge systems that can dramatically improve construction speed and high performance concrete that can improve durability and structural efficiency. In HPC bridges, these improvements are achieved at no cost premium and often at a reduced initial cost.

NCBC's new initiative focuses on expanding the use of HPC bridges by federal, state, city and local jurisdictions and on gaining federal funding to enhance technology transfer, research and creation of additional high-performance concrete bridges. Work is beginning with a strategic plan and blueprint currently being developed. This program will be used to work with various legislative, funding and design groups to advance applications of high-performance concrete bridges.

SPEED IS CRITICAL BENEFIT

The rapid speed of construction that can be achieved with HPC is a vital benefit for using the material. This not only cuts labor costs but it greatly enhances productivity and can even save lives. A recent FHWA study (Meeting the Customers' Needs for Mobility and Safety During Constrution and Maintenance Operations, HPQ-98-1) calculated that road-user delays on urban-freeway reconstruction projects mount up to more than $50,000 per day. Even more critical, work-zone fatalities in construction zones continue to be an urgent concern. In recent years, Congress has placed additional emphasis on finding ways to improve worker safety on roadway construction projects. Their particular focus has been on finding ways to minimize construction interference with traffic and reducing worker and motorist exposure.

The best ways to achieve those goals, according to a 1998 FHWA report, are to use longer-lasting materials and place more emphasis on life-cycle costing. This focus ensures that fewer bridge repairs and replacement projects will be needed, reducing the frequency with which work zones are established. Precast concrete components, which are manufactured as site work is performed, can drastically reduce the time that work zones are in place, another critical element to reducing exposure. (For more on the speed with which precast HPC components can be erected, see the sidebar on page 20.)

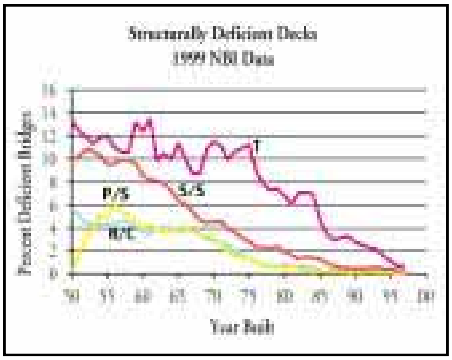


Source: National Bridge Inventory Data

FHWA's report notes that "traditional bidding procedures do not reward or encourage contractors to produce higher quality work and/or expedite the completion of the work." To change that and enhance worker safety, FHWA is encouraging transportation agencies to make several changes, including:

- Revise prescriptive-type specifications to performance-based specifications.
- Adopt specs that reward contractors for innovation, quality and exceeding expectations.
- Insist on quality work and timely completion.
- Standardize design details to encourage a greater use of precast materials.

All of these practices are leading officials to take a long, close look at the advantages that are developing from working with HPC components.



BRIDGES ARE DETERIORATING

The potential for HPC structures and their economy of construction is being given greater weight due to rising concerns over the general condition of bridges nationwide. The most recent report of the Secretary of Transportation to Congress makes it clear that the nation is falling far behind in maintaining and replacing its outdated bridges. It is paramount that more funding be established to improve the country's infrastructure, and HPC offers an ideal way to design the needed bridges cost effectively with both short- and long-term savings available.

One driver behind this goal of building more cost-effective and longer-life bridges is the federal government itself. Kenneth R. Wykle, former chief of the Federal Highway Administration (FHWA) challenged industry and academia to design and build bridges that can provide 100-year useful lives. He sees the advances that have been made in HPC technology as one of the ways to achieve that. And indeed, the techniques now available with HPC make such a goal entirely practical.

The need to speed construction and make it more cost efficient is apparent in the latest Report of the Secretary of Transportation to Congress. Its 1999 data indicates that 29.6 percent of the nation's 583,000 bridges are deficient and need attention. Current FHWA statistics show that while the number of deficient bridges has declined in recent years, the decline is minimal when compared to what is needed. In 1994, more than 187,000 bridges were in need of repair or replacement. By 1998, that number had dropped by only 15,000 — leaving a staggering 172,000-plus still in need (see the chart).

Funding also lags badly, with the report to Congress showing that while $6 billion had been allocated for bridge work, this barely covered the amount required to maintain existing deteriorating bridges. An additional $10 billion was needed annually over the next 20 years to improve those bridges on the brink. Clearly, the more cost efficiently bridges can be repaired or replaced, the more that can be improved for the same funding.

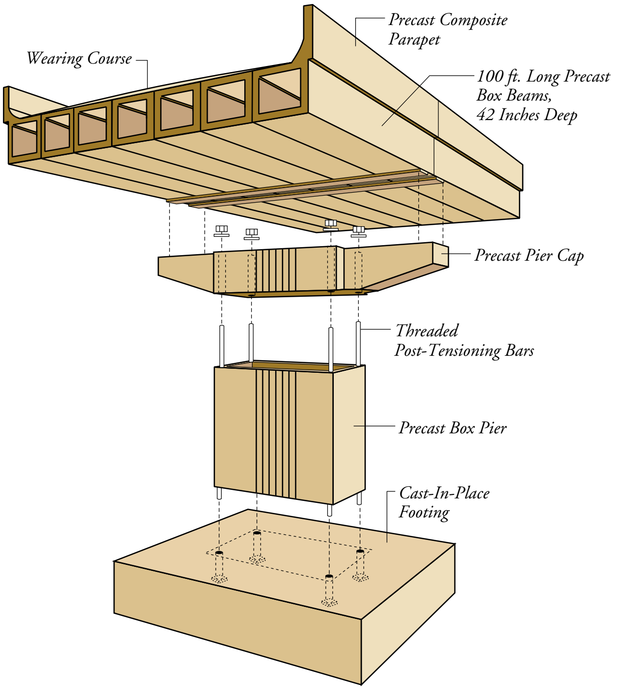
An evaluation of the 1999 NBI data also points to one solution to this dilemma. It shows that in the period 1950-1999, prestressed concrete bridges have become a dominant alternative to steel and timber bridges. In the same period, the data indicates, steel and timber bridges have been the most structurally deficient, while prestressed concrete bridges have had by far the fewest deficiencies. Further, decks supported on prestressed concrete girders outperform decks supported on steel girders. Prestressed concrete's growth since its introduction in 1950 shows that it has even more potential when combined with the technology available using high performance concrete.

Deficient Bridges

Year	# Deficient	% of Total
1992	199,352	34.6
1994	187,515	32.5
1996	182,726	31.4
1998	172,572	29.6

Source: National Bridge Inventory, report to Congress, 1999

Artist rendering of Baldority de Castro Avenue
Photo: Aerial/Architectural photography



This cross-section of the pier elevation shows the main components of the Puerto Rico bridge system.

WHAT ARE HPC BRIDGES?

Designing with HPC components can drastically reduce construction time because various precast components can be combined to allow a truck-to-structure systems approach — without waiting for site forming and curing. Full depth precast decks are being used on both new and rehabilitated bridges. The cost for this approach can result in overall savings due to more efficient designs that permit longer spans or fewer girders and/or piers. HPC can be used effectively in virtually all bridge components to aid in minimizing construction and future maintenance. HPC components can include piles and pile caps, piers and column bents, abutments, decks, and rails and barriers.

HPC uses the same materials as typical concrete but is engineered to provide higher strength and better durability. These attributes can be varied to align with the design's needs. They will be affected by environmental and geographic conditions and the specific bridge components (that is, substructure, beams or deck).

To be sure, the desirability of higher strength and durability must be balanced with the needs for constructability and cost control. But it also must be stressed that the longer life spans possible with HPC designs will dramatically cut maintenance and even replacement needs over the entire life of the HPC bridge. This means that it is critical to examine maintenance and repair costs in relation to the bridge's entire lifespan when considering various construction options and not limit the considerations simply to the initial construction costs.

To ensure all designers and suppliers understand the term, the FHWA has proposed a definition of HPC that consists of four durability and four strength parameters. The eight criteria are:

- freeze/thaw durability
- scaling resistance
- abrasion resistance
- chloride penetration
- strength
- modulus of elasticity
- shrinkage
- creep

'Instant' Bridge Keeps Traffic On The Move

The rapid construction available with HPC precast bridge components can be seen in four overpasses built in San Juan, Puerto Rico, along the Baldority de Castro Avenue. The structures, consisting of two 700-foot-long overpasses and two 900-foot-long ones, were each constructed in 36 hours or less using precast prestressed HPC components.

Two overpasses were provided at each of two intersections to alleviate congestion on the busy road, which carries more than 100,000 vehicles per day. But because of this traffic, officials had to minimize disruptions. The accepted design proposal not only allowed for ultra-fast construction but was priced approximately $2 million lower than the next lowest bid. Behar-Ybarra & Associates served as the engineering firm on the project, Las Piedras Construction Corp. was the general contractor, and precast components were supplied by Caribbean Prestressed S.E.

The project was built in two stages. First piles were driven and footings were cast to prepare the site, causing little traffic disruption. The footings were cast with special forms to allow for fast connections. Then with the clock running, the precast concrete components were erected and post-tensioned. Box piers were positioned and post-tensioned to the footings, then caps were placed and the piers were vertically post-tensioned. Precast abutments and retaining walls were also used.

When the first two piers were in place (starting from the center of the bridge), the 100-foot-long superstructure box beams, seven per span, were set in place. Using two crews, the overpass then was erected simultaneously from the center span toward each end. Each span then was post-tensioned transversely as it was completed.

The construction method minimized the time traffic had to be diverted, with the first bridge erected in 36 hours and the others taking as little as 21 hours. The project was so distinctive in its solution to a growing problem that it was awarded a Harry H. Edwards Industry Advancement Award.

Council Establishes Goals

Nine construction industry associations comprise the National Concrete Bridge Council, with four key objectives. The groups' goals include:

- Promoting quality in concrete bridge construction.
- Gathering and disseminating information on design, construction and condition of concrete bridges.
- Establishing communication with federal and state departments of transportation, city and county public works departments and consulting engineers.
- Providing information on behalf of the concrete industry to codes and standards groups.

The nine organizations of the NCBC (and their Web sites for further information) consist of:

- American Segmental Bridge Institute (www. asbi-assoc.org)
- Concrete Reinforcing Steel Institute (www.crsi.org)
- Expanded Shale Clay & Slate Institute (www.escsi.org)
- National Ready Mixed Concrete Association (www.nrmca.org)
- Portland Cement Association (www.portcement.org)
- Post-Tensioning Institute (www.post-tensioning.org)
- Precast/Prestressed Concrete Institute (www.pci.org)
- Silica Fume Association (www.silicafume.org)
- Wire Reinforcement Institute (www.bright.net/~wwri/)

Additional information about NCBC can be gained on its Web site, www.nationalconcretebridge.org or by contacting any of these organizations or from the group's spokesman, Basile G. Rabbat, at 847/966-6200 or basile_rabbat@portcement.org

For more on high performance concrete in relation to the Federal Highway Administration, go to the HPC section of FHWA's Web site at http://hpc.fhwa.dot.gov.

For its definition, the Precast/Prestressed Concrete Institute's High Performance Concrete Committee states that HPC offers a 28-day compressive strength above 8,000 psi. But defining the material by its compressive strength focuses the connotation solely on the strength parameter, which is not the only factor that makes HPC such an ideal candidate for bridge design. Indeed, precasters have systematically been improving their compressive strength for many years, with many offering higher-strength concrete than is called for in current specs. This high early strength offers a win-win situation, as it provides better design capabilities while allowing casting beds to be cycled more quickly.

In fact, while much attention has been drawn to HPC's strength characteristics, the material's durability performance creates as strong an argument for its use even where long spans or other strength capabilities are not required. This durability reduces costs over the life span, just as its strength can reduce material costs by eliminating a line of girders or piers. This

Two Tennessee Projects Show HPC's Potential

Two High Performance Concrete bridge projects recently completed in Tennessee will give local officials an opportunity to study and promote this technology. One involves the reconstruction of a bridge in Nashville while the other features construction of two new two-span, continuous HPC structures.

Tennessee bridges most often are constructed with precast, prestressed concrete beams and cast-in-place reinforced concrete decks, explains Mark Holloran of the Tennessee Department of Transportation. "The dominance of this type of construction can be attributed to the lower initial costs and lower long-term maintenance costs compared to other bridge systems," he says.

The state now is testing HPC to see if it can improve on these qualities. "With improved durability and strength characteristics, HPC can provide initial and long-term benefits with a reduced number of beams or piers, shallower superstructures and superior resistance to chloride penetration."

The reconstruction project involves a 660-foot, six-span bridge carrying SR 1 over the CSX Railroad in Nashville. It uses 63-inch-deep bulb tees spanning up to 115 feet. Using HPC on this bridge, which was opened to traffic last summer, reduced the number of beam lines from 11 to nine with no increase in deck-slab thickness.

The second project consists of a section of SR 840 in Dickson County, with one of the decks completed in January 2000 and the other opening last summer. Both bridges feature 72-inch-deep bulb tees spanning up to 159 feet, the longest single-piece bulb-tee girders ever used in the state.

"HPC made this structure type more economical compared to other alternatives," Holloran says. The bridges used 10,000 psi concrete with a cementitious-materials content of 996 lbs./cu. yd., a water-cementitious materials ratio of 0.25, and a permeability that averaged approximately 800 coulombs at 56 days, considered highly resistant to chloride penetration.

With these long spans, lateral stability was of some concern during delivery, so the precaster, CPI Concrete Products Inc. in Memphis, worked closely with the trucking company to provide safe delivery. "The partnership that developed between all of the parties involved in these projects is an essential success factor in Tennessee's HPC construction," Holloran adds.

The Admiral Clarey Bridge at Pearl Harbor
Photo: Williams Photography, Honolulu

HPC Durability, Economy Aids Innovative Hawaii Bridge

The PCI Award-winning Admiral Clarey Bridge in Hawaii not only features an innovative design, it took advantage of high performance precast concrete materials to enhance its durability and economy.

The project, which won a 1999 Design Award, consists of a 3,628-foot-long, pile-supported fixed bridge section incorporating 29 spans and a 1,045-foot-long movable span at the center.

The movable portion includes three prestressed concrete pontoon sections equipped with watertight access hatches, water sensors and piping to permit pumping. Its bottom slab was cast in place, the longitudinal and transverse walls were precast, and the top deck was formed with precast prestressed panels used as stay-in-place forms.

The pontoons support two transitional spans, weighing 16,500 tons, which are raised and lowered hydraulically to allow the pontoon to be withdrawn or extended.

"Given the aggressive marine environment, the Navy's requirement for a durable structure included the use of HPC throughout the project," explains Michael J. Abrahams of Parsons Brinckerhoff Quade & Douglas Inc. Specifications included the requirement that all concrete contain a minimum of 5 percent silica fume by weight of cementitious materials and to have a maximum water/cementitious material ratio of 0.38.

Other ways the team improved durability included increased concrete cover to the reinforcement, zero tensile stress in all prestressed concrete, a pipeline-type epoxy for coasting reinforcing bars and a maximum tricaclium aluminate content for the cement of 8 percent to improve sulfate resistance.

A key challenge came in needing to produce the various components at different sites, with the precast pontoons and beams being delivered from Tacoma, Wash., the precast piles and deck panels produced in Hawaii and the cast-in-place concrete made locally. All components matched perfectly in color, producing a bridge that is aesthetically pleasing, functionally innovative and highly durable for the long term.

resistance to the ravages of the environment makes HPC a popular choice for those designers creating bridges in harsh climates or places where it is difficult to maintain bridges. The current problem is that this universe of informed designers must be increased to ensure all localities are aware of the opportunities available.

Overall, the advantages accruing from higher durability and/or additional strength include a variety of benefits:

- Longer service life thanks to higher durability and lower chloride penetration. When needed, bridge life can extend to 100 years or even more.
- Lower maintenance and inspection requirements, especially since the bridge requires no painting or rust protection. This savings grows with the bridge's longer service life.
- Longer spans, which can reduce costs by eliminating piers or allowing the use of concrete beams instead of steel beams.
- Wider beam spacings, reducing the number and cost of beams.
- Shallower beams due to higher concrete strength.
- Improved mechanical properties such as greater tensile strength.
- Rapid construction due to the ability to factory-cast components while site work is underway and the ability to erect pieces upon delivery. These benefits cut the time necessary for disruptions to local traffic.
- Predictable performance and close tolerances for precast members due to the high quality achieved through PCI certification and casting under controlled conditions in the plant.

In general, HPC components can produce lighter, longer precast pieces and smaller-diameter columns that creep less. This means span lengths can be lengthened and underclearances can be maximized.

Tom Music Bridge, Randall, Wash.

GETTING OUT THE WORD

HPC bridges have shown, clearly and loudly, that they provide excellent durability and cost efficiency throughout their lives. Now it is the job of the concrete industry to ensure that designers and transportation department officials at the federal, state and local levels — along with legislators — are aware of these benefits. In order to reduce the backlog of deficient bridges, it is vital for Congress to help fund additional technology transfer, research and applications on projects to show the extent of these many advantages across various regions.

SR18/SR15 Interchange, Covington, Wash.

With many states committed to putting HPC to the test in applications, much has been learned about the material in the past few years. But as with any new technique, designers are reluctant to risk their design and budget assurances by extending specifications beyond their own comfort level.

NCBC hopes that its blueprint provides a document that FHWA and Congress, among others, can use as a starting point for providing this option in a more comfortable form that designers will use. The group's goal is to help these decision makers better understand the material, the construction systems and their advantages and help push funding that speeds the process of replacing our deteriorating bridges.

The NCBC goal will take a major effort. But it is a process that is growing in need as more bridges reach the end of their useful service life and find no funds available for repair or replacement. These projects can be accomplished. But they will happen only with a concerted effort among all organizations, acceptance by designers and a commitment of funding from budgeting agencies. It is our hope that designers will embrace these new concepts as they learn about their proven potential and will incorporate them into their designs to improve service life and create lower-cost structures. ■

'Super Girders' Aid HPC Designs In Washington State

Since 1997, state and local agencies in Washington State have constructed or begun work on 26 bridges using HPC components. "Environmental requirements to keep piers out of waterways and the necessity of providing for future widening to accommodate increasing traffic demands are creating an ever-growing need for longer spans," says Jerry Weigel of the state's Department of Transportation. "The use of HPC improves construction economy by providing for longer spans, increased girder spacings and shallower girders."

The state's designers have found that a specified release strength of 7,500 psi and a specified design compressive strength of 8,500 psi result in an optimum design economy for the region. Although 10,000-psi levels can be achieved, the additional benefits don't offset the added curing time and design mix complexities, Weigel says.

Partnering with the precast industry, the state's engineers have developed two deep precast prestressed concrete I-girder sections called "Super Girders." These sections use HPC and 0.6-inch prestressing strands to span up to 225 feet. A number of projects have been completed using these girders, including the Twisp River Bridge, the first to be completed, which features a span of 197 feet.

The girder concrete has a specified release compressive strength of 5,000 psi and a design compressive strength of 8,000 psi. Because of their weight, the girders were fabricated in three sections for transportation to the site and were post-tensioned after erection.

"We have learned a great deal and are convinced that the future of high performance concrete is very bright," says Weigel. "This learning experience has confirmed that we can build bridges that are durable, cost effective and low maintenance."

Maryland Looks To HPC For New Bridges

A dozen new bridges will be built in Prince George's County in Maryland in the next three years, with a number of those featuring high performance concrete in an effort to reduce long-term maintenance costs as well as overall construction expense.

"Decreasing the life-cycle costs associated with each bridge became a priority," explains Edward Binseel of the county's transportation department. "We believe HPC will give us durability and longevity at a lower overall cost." He added that the lack of familiarity with the material within the local design community was seen as a potential barrier to using HPC. "It's one thing to specify the use of HPC, and it's another to build with it. These barriers had to be overcome by recognizing the education and resources of the consulting engineers with which we work."

The county was prepared to pay higher initial costs to achieve the long-term savings offered by HPC, he notes. But in fact bid prices have come in at comparable levels to those where HPC was not specified. "We have also seen fewer construction-related problems than were expected using the stiffer mix, and there have not been any change orders as a result of surprises or any difficulties encountered."

HPC offers additional economic advantages because it results in greater strength and requires fewer structural members, he adds. "We will be exploring this benefit as we become more familiar with the material. With dwindling resources, we are determined to achieve the best value for our construction dollar."

Free HPC Bridge Views

Updates on current activities and case histories focusing on high performance concrete are available from the bimonthly *HPC Bridge Views* publication, which provided some of the material for the case histories in this article. To receive a free subscription to the publication, contact:

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