B R I D G E   D E S I G N

Precast, Prestressed Concrete Bridges – The High Performance Solution

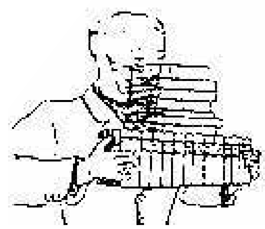
Since its introduction in the United States in 1949, precast, prestressed concrete has rapidly become the preferred composite material for bridge design and construction. Today, it remains the solution of choice for transportation agencies and their bridge designers across the country. This growth came, and will continue to come, from the commitment of precasters to develop, improve, and implement advanced materials, products and technology all aimed at enhancing the performance of these bridges and the options available to the designer.

This publication is intended to provide the designer with an understanding of the precast, prestressed concrete industry and an introduction to the application of this material to bridge design and construction.

Growth of the Industry

The combination of prestressed high strength steel to counteract tensile stresses, and high performance concrete to provide compressive strength, makes this unique composite material adaptable to many situations, especially to the design and construction of bridges.

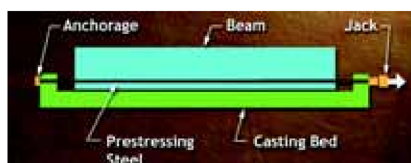
Professor Gustav Magnel, one of the pioneers of prestressed concrete, explained it very simply to his students by using a stack of books. When concrete is precompressed, as the lower row of books are, it can carry not only its own weight but also a significant amount of superimposed loads, represented by the books on top.



There are two ways of introducing prestress into a concrete member:

- Post-tensioning applies to concrete where steel strands or bars are tensioned against the concrete after the concrete has hardened. Cement grout is usually pumped to fill the duct.

- Pretensioning applies to concrete where steel strands are tensioned between abutments before the concrete is placed in the forms. After the concrete has hardened, force in the strands is transferred to the concrete by releasing anchors at the abutments. The transfer of force occurs through the bond between concrete and steel.



Walnut Lane Memorial Bridge
Photo: ©Lawrence S. Williams, Inc.

The single most important event leading to the founding of the precast, prestressed concrete industry in North America was the construction, in 1949 and '50, of the famed Walnut Lane Memorial Bridge in Fairmont Park, Philadelphia, Pennsylvania. From a technical perspective it is innovative, and from an historical perspective, it is fascinating that the Walnut Lane Memorial Bridge was constructed with prestressed concrete. Consider that there was very little published information on the subject and no experience with linear prestressing in this country. The bridge became a reality through a fortunate sequence of events, and the vision, courage and persistence of a few extraordinary individuals.

The 1950s was the decade that saw the introduction of 7-wire prestressing strand, plant pretensioning, long-line steel casting beds, chemical admixtures, high early-strength concrete, steam curing and many other innovations. These developments coupled with the technical and logistical support provided by the Precast/Prestressed Concrete Institute (PCI), chartered in 1954, fostered the rapid growth of the industry. Applications of precast and prestressed concrete designs quickly began to appear in a wide variety of impressive structures. By 1958, there were more than 200 prestressing plants in the United States.

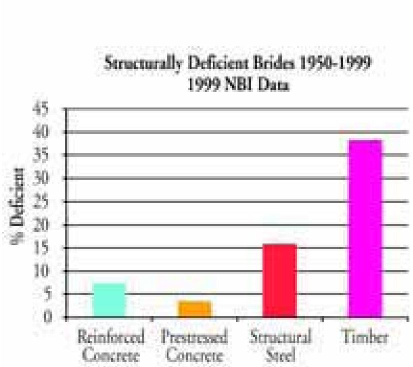
Precast and prestressed concrete products, while designed in accordance with evolving engineering standards, gained an excellent reputation because the industry, early on, recognized the need for quality above all else. PCI's Plant Certification program quickly became an integral part of plant production. PCI Plant Certification assures specifiers that each manufacturing plant has been audited for its processes and its capability to consistently produce quality products.

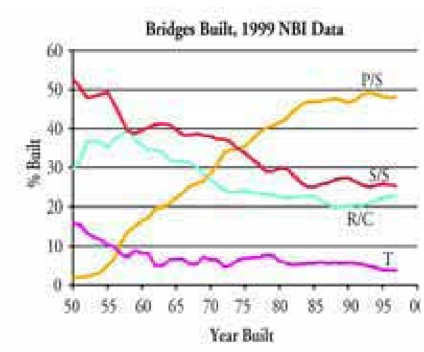
Performance of Prestressed Concrete Bridges

The National Bridge Inventory, maintained by the Federal Highway Administration (FHWA), reveals that of about 475,000 bridges with spans of 20 feet and more, 173,000 are rated as substandard.

The fact that a bridge is "deficient" does not imply that it is unsafe or is likely to collapse. It may be either structurally or functionally deficient. A deficient bridge may need significant maintenance, rehabilitation or sometimes, even replacement. Proper load posting, restricted use and various other methods of traffic control can allow these bridges to continue to be used.

What is causing the nation's bridge problem? One contributing factor is age – the average age of all bridges is now about 45 years. Another factor is increasing vehicle sizes and weights, as well as traffic volumes, that are well beyond what many structures were designed for when they were put into service. A third major factor was limited corrosion resistance in coastal regions and the increasing use of de-icing salts in cold climates. These salts seep through and under the bridge decks, corroding reinforcing bars in decks, in beams and in substructures. Salts readily attack exposed steel members.





Source: National Bridge Inventory Data

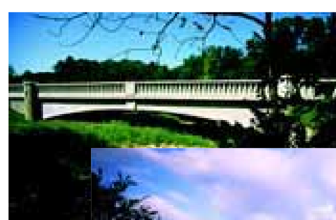
Studies of the National Bridge Inventory data clearly indicate the superior performance of prestressed concrete bridges when compared to the performance of other materials of an equal age.

In addition, owners and designers have long recognized the low initial cost, low maintenance requirements and extended life expectancy of prestressed concrete bridges. This is reflected in the increasing market share of prestressed concrete, which has grown from zero percent in 1950 to about 50 percent now. It's the only structural material to have experienced continuous growth during this period.

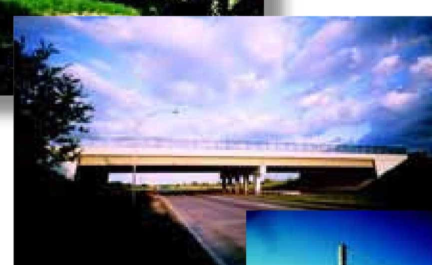
This growth is not only reflected in short-span bridges, but is also now occurring for spans over 150 feet. These spans have been the exclusive domain of structural steel for many years.

Precast concrete bridges have also been shown to be highly durable and fire resistant, and they have excellent riding characteristics. Precast concrete bridges can be installed during all seasons and opened to traffic more rapidly than any other permanent type of bridge. In addition, very slender bridges can be achieved with solid slabs, box beams, multi stemmed units and I-beams. The clean, attractive lines of concrete beams help bridge designers meet the most demanding aesthetic requirements.

Since 1950, tens of thousands of prestressed bridges have been built and many are under construction in all parts of the United States. They range in



size from short spans



to medium spans

to some of the largest bridge projects in the world.

Advantages of Prestressed Concrete Bridges

There are several good reasons why precast, prestressed concrete bridges have gained such wide acceptance. Some bridge designers are surprised to learn that precast, prestressed concrete bridges are usually lower in first cost than other types of bridges. Coupled with savings in maintenance, precast bridges offer maximum economy. Case-after-case can be cited at locations throughout the United States, and these bridges are attractive as well as economical.

Low Initial Cost

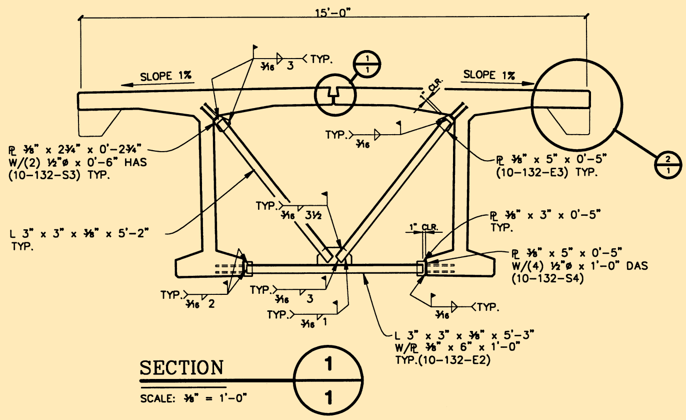
The state of Minnesota saved more than 16% – half a million dollars – by planning for a prestressed alternate to a steel bridge. The 700-foot-long bridge is jointless up to the abutments and is the longest continuous bridge in the state. It also contained the state's longest single concrete span. A Minnesota transportation official stated, "Originally, we didn't think concrete was suited to this…bridge. However, the fabricator showed us it was a viable alternative. Everything went smoothly…we're well satisfied…"

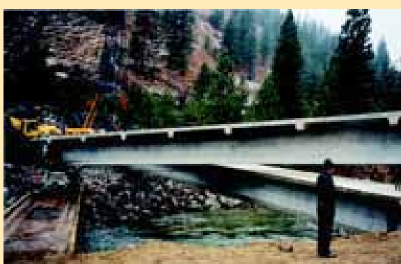
The overall economy of a structure is measured in terms of its life-cycle costs. This includes the initial cost of the structure plus the total operating costs. For stationary bridges, the operating cost is the maintenance cost. Precast, prestressed concrete bridges designed and built in accordance with AASHTO or AREMA specifications should require little, if any, maintenance. Because of the high quality of materials used, prestressed members are particularly durable. Fatigue problems are nonexistent because traffic loads induce only minor net stresses.

Minimal Maintenance

On the Illinois Toll Highway System, during 1957 and 1958, the superstructures of more than 250 bridges were built with precast prestressed concrete I-beams. They span up to 90 feet and some of them have precast stay-in-place deck panels, precast diaphragms, and 94 use spun-cast, hollow cylinder pile column bents. They have withstood heavy traffic, severe weathering and very high salt applications. Yet, these bridges have required very little maintenance. Other projects in all parts of North America have exhibited similar experience – little or no maintenance has been required on precast prestressed concrete bridges.

Of course, no painting is needed. Some bridge engineers estimate the life-cycle cost of re-painting steel bridges to be 15 to 25% of the initial cost. Painting bridges is environmentally unfriendly and can be especially expensive when accomplished over busy highways, streams and railroad rights-of-way, or in rugged terrain.



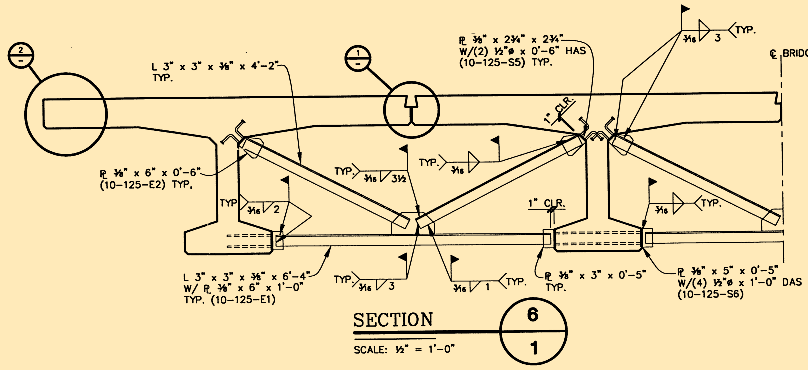


Durable Concrete

One of the reasons for selecting prestressed concrete beams with integral precast decks for this bridge was the durability of prestressed concrete and the resulting low maintenance requirements. As a result of a winter flood, the single lane bridge on a major forest road was washed out, cutting access to a U.S. highway for a half dozen homes…including one with an elderly resident needing continuing medical care. In only 15 days of receiving plans, the precaster had fabricated the two, 135-foot-long spans with 7′-6″-wide integral decks, and the bridge was opened to traffic 3 days later – 18 days in all. The U.S. Forest Service stated that the bridge was least expensive, fastest and the best solution.

Precast, prestressed concrete bridge components are easy to erect, particularly when the tops of the units form the entire deck slab – called an integral deck bridge. Formwork and site-cast concrete are eliminated. Connections between these adjacent units often consist of welding adjoining plates and grouting a continuous keyway. Carefully planned details speed the construction process and result in overall economy.

Simple Solution



Replacing this bridge on US Route 95 in Idaho illustrates another example of the advantages of very fast, yet simple construction:

New Year's Day: Rains and melting snow washed out this bridge over the Little Salmon River linking the northern and southern parts of the state.

January 4: The Idaho Department of Transportation contacted the precaster to investigate solutions. They determined that the fastest way to replace the three spans was to use a single 80-foot span comprised of bulb-tees with an integral deck. The top flange would be 8-inches thick and 8'-6" wide. The diaphragms would also be precast onto the ends of the girders.

January 8: Engineers in the Bridge Section approved shop drawings and tensioning calculations.

January 18: Bulb-tees were shipped 240 miles and set in place…just 17 days after the flood! Included in the shipment were intermediate steel diaphragms, guardrail posts and guardrail…all the components to complete the structure.

January 25: The project was completed. The bridge was in service just 24 days after the flood!

Integral deck bridges can be set on precast or other abutments and erected through practically any weather. They can be opened to traffic very rapidly.

All Weather Construction

In Ketchikan, Alaska, a bridge on the only highway to the north was washed out when an old dam gave way on October 26. Integral deck girders were selected for the 85-ft span. The 12 girders were designed and precast in the state of Washington, then shipped by rail and barge to Alaska. The girders were installed and the bridge was completed and opened to traffic on December 19 - only 54 days after the washout - despite the problems of design, remote location, great distances, and adverse weather conditions during the onset of an Alaskan winter!

The planned replacement of substandard bridges can be accomplished easily with precast prestressed sections. In some cases, existing abutments can be used, but in others, it is easier and more economical to build new ones, or to utilize precast abutments and wing walls supported on cast-in-place footings.

Fast Construction

Mitchell Gulch Bridge, southeast of Denver, was scheduled for replacement with three, 10 ft by 6 ft cast-in-place box culverts. This would require three months of traffic detour on a key commuter route carrying 12,000 vehicles per day. A contractor-suggested alternate resulted in the replacement of the bridge in less than 48 hours – requiring traffic interruption only from Friday night until Sunday.

The project required driving H-piles in advance of closure, dismantling the old bridge, then installing a precast wingwall and abutment system. Next, prestressed voided slabs were installed and grouted along the joints. Fill was placed over the slabs and compacted. Finally, asphalt paving was laid and the bridge opened to traffic. Commuters on Monday morning weren't any the wiser – exactly as planned!

The replacement of bridges may not always be easy to plan in advance. Fires, floods and accidents are but a few reasons for emergency replacements or repairs. Precast concrete and industry manufacturers have consistently demonstrated response to disasters large and small.

Emergency Response

In1996, the bridge over Salt Creek on I-75 near Venice, Florida, was damaged beyond repair when a tanker loaded with diesel fuel crashed and rolled underneath. The five-span, 330-foot-long bridge required 25 AASHTO beams, 65 ft, 3-1/2 in. long. Exposed precast piles were salvaged by cutting them just below ground line, then splicing on precast extensions. The extensions arrived on-site just two days after they were ordered. The first five beams were delivered and erected four days after production began, and all 25 beams arrived within seven days. The new bridge was reopened to traffic just 18 days after the accident.

In May 2002, two barges hit and collapsed four spans of the I-40 bridge over the Arkansas River near Webber Falls, Oklahoma. Fourteen people were lost. Originally steel, three spans were replaced with 36, 72-in.-deep precast bulb-tee beams, 130-feet long. After a spectacular effort by the entire design and construction team, the bridge was opened to traffic in just 65 days. State officials stated that, "…precast concrete offered us a speed advantage over replacing the entire bridge with steel."

Interstate 65 in Birmingham, Alabama was brought to a standstill on a Saturday morning in January 2002, when a tanker load of gasoline crashed and burned under a steel bridge. The state quickly designed a replacement bridge and construction began only 16 days after the accident. Prestressed concrete bulb-tee beams, 54-in. deep and 140-ft long, were used in the new bridge, which was both wider and some 20-ft longer to provide for additional future lanes. Using high strength concrete that achieved 8,500 psi in 14 days, the span-to-depth ratio is an impressive 31:1. Fabrication of the beams required only 15 days. The new bridge was opened to traffic just 65 days after the accident and 36 days after construction began. A state designer said that precast concrete "…could be cast and delivered to the jobsite before steel fabricators could even procure material and start fabrication." The general contractor said, "There was no way we could have gone with steel girders because the lead time was prohibitive. The precast was on site within a very short period of time."

A common requirement of bridges is that the superstructure be as shallow as possible in order to provide maximum clearance with minimum approach grades. Through the technique of prestressing, the designer is able to utilize the maximum possible span-to-depth ratio. Span-to-depth ratios as high as 35:1, or even more, can be achieved with solid slabs, voided slabs, box beams, multi-stemmed units, I-beams or bulb-tee sections, each within their respective span ranges. Even though deeper sections will require less prestressing steel, the overall economy of a project may dictate the shallowest available section.

Slender Bridges

The Sedley Bridge provides a crossing for county Rt. 475W over the Norfolk Southern/CSX Railroad tracks in Porter County, Indiana. Faced with severe clearance and approach embankment constraints, the designer chose a unique through-girder solution that resulted in a 112-foot span having an effective structure depth of just 14 inches.

The Yale Avenue Bridge carries Interstate 25 over Yale Avenue, a busy urban arterial in Denver, Colorado. The structure was Colorado's entry in the Federal Highway Administration's High Performance Concrete Showcase program. It is designed for traditional Interstate highway loading. The adjacent, single-cell box beams measure 67 in. wide by 30 inches deep and use 10,000 psi concrete (at 56 days). The bridge has two continuous spans (for live load) of 100 and 114 ft and is 138-ft wide. Composite topping has a minimum thickness of 5 in. for a total structure depth of 35 in. and a span-to-depth ratio of 39:1.

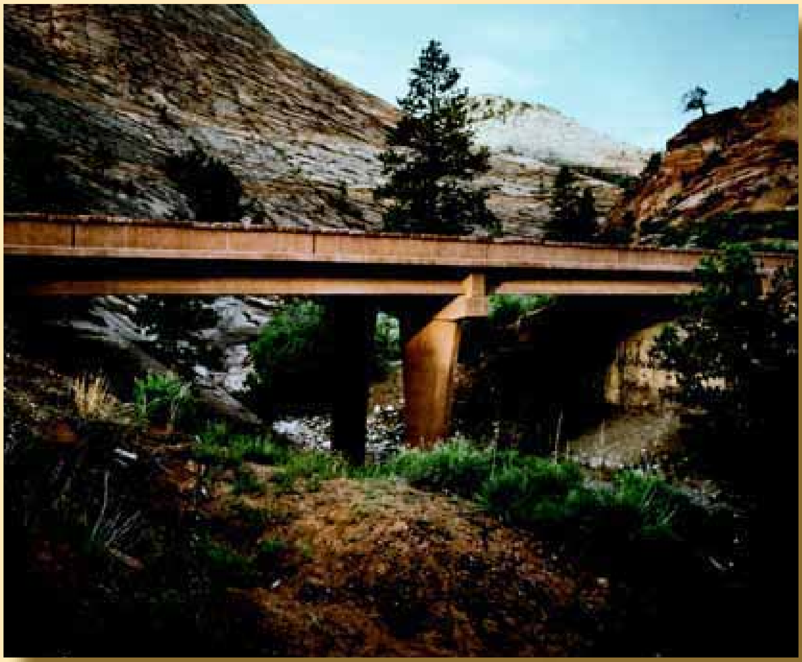
The San Angelo (Texas) Bridges, carrying U.S. 87 over the North Concho River and South Orient Railroad, are parallel, eight- and nine-span structures. One bridge used primarily conventional concrete and the other, high performance concrete as part of the Federal Highway Administration's HPC Showcase program. Designed as simple spans, one used 0.6-in.-diameter strands with 13,500 psi concrete to achieve a length of 157-ft with 54-in.-deep beams plus 3-1/2-in.-thick precast concrete deck panels plus 4-1/2-in. cast-in-place composite concrete topping to achieve a 30.4:1 span-to-depth ratio.

The Clarks Viaduct located in Omaha, is a four-span bridge over U.S. Highway 30 and the Union Pacific Railroad. It has a 52-degree skew and spans of 100, 151, 148 and 128.5 ft. The superstructure is a modified Nebraska 1100 beam, 50-in. deep, using 8,500 psi concrete. The beams sit on unique, individual cast-in-place pier tables to extend their spans. The beams are made fully continuous for superimposed dead loads and live load by splicing high-strength reinforcement extended from the ends of the beams through the cast-in-place tables between the ends of the beams. Including the 7-1/2-in. deck, the span-to-depth ratio is 31.5:1.

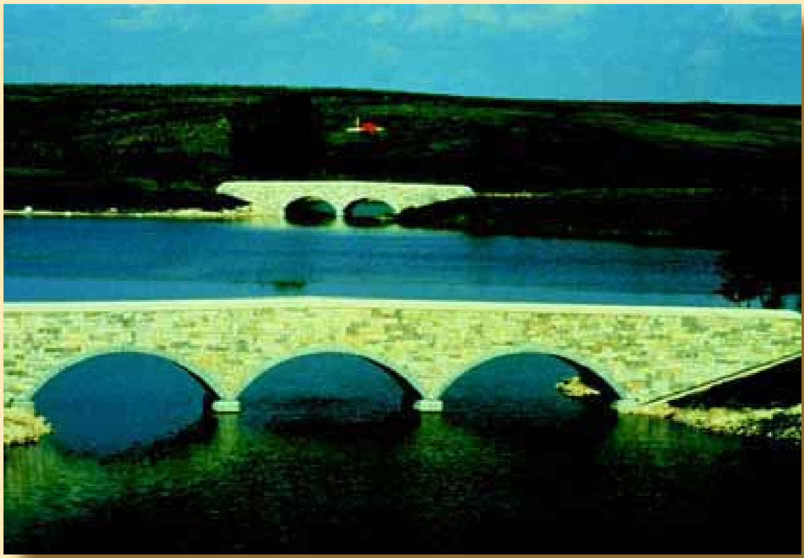
Beams that include integral decks, such as this one, can achieve exceptionally high span-depth ratios. In addition, they can be installed very quickly while requiring little site-cast concrete.

Regardless of how they are viewed, prestressed concrete bridges are attractive from above, below, and from the side because of the simple and clean shapes of the members used. The high span-to-depth ratios made possible with prestressing, result in strong, tough, durable and yet graceful bridges.

Aesthetic Bridges



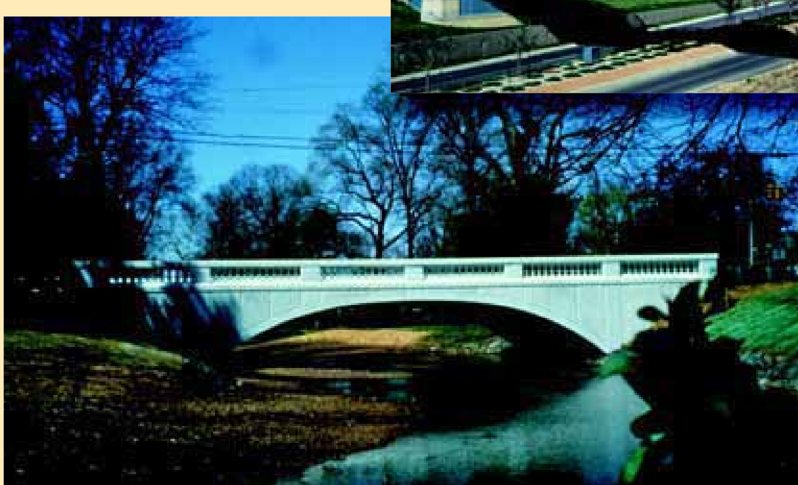
Two very different parks use precast concrete in special ways. The Bridge over Clear Creek, Zion National Park, Utah, uses colored aggregate, sandblasting and pigments to match the bridge to the surrounding native stone. Costing just $60/SF, the project was considerably less than either steel or CIP.

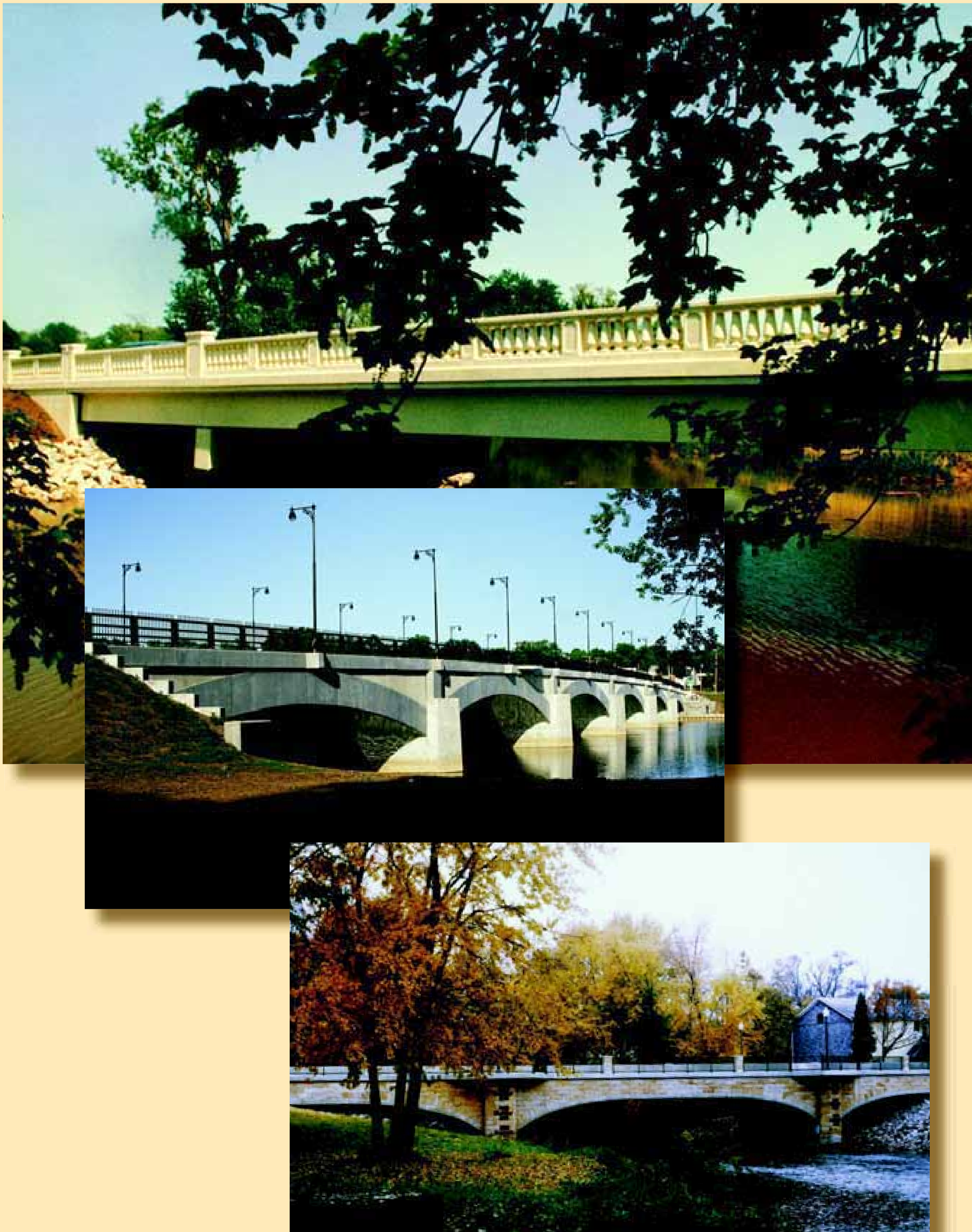


Two bridges in Kil-Cona Park in Winnipeg provide an attractive compliment to these family recreational surroundings.

Attractive Bridges

More and more often, designers are adding architectural and aesthetic treatments to precast bridges. These include panels that create an arch appearance or decorative railings. Some solutions are shown in the accompanying photos.





Bridges are subjected to a hostile environment as well as repeated impact loadings. Some must endure intense sun, high temperatures and brackish water. Others must withstand not only the freezing and thawing provided by nature but also the potential for damage induced with the use of de-icing chemicals. High strength prestressed concrete has excellent freeze-thaw and chemical resistance. Also, prestressed concrete bridges are not easily damaged by fire.

Fire Performance

The Washington State Route 509 Bridge over the Puyallup River near Tacoma was damaged in December, 2002, when a railroad car containing 30,000 gallons of methanol burned beneath span number 8. The span is 146 ft in length and uses 15 lines of 74-in.-deep bulb-tee beams. An investigation revealed that the fire reached temperatures of 3,000 degrees F. The study showed that no significant amount of prestress was lost. A plan was immediately developed for repairs that would permit the bridge to remain in service.

After this timber deck truss bridge burned, an extremely busy 2-lane link was severed between two major population areas.

It was replaced by a safe, low maintenance, prestressed concrete bridge with a record span for this area of 141 ft. It was erected without falsework over an environmentally sensitive, salmon-bearing river. It opened seven months after bid.

Steel girder bridges frequently exhibit disturbing vibrations. The natural frequency of vibration of these bridges can coincide with the frequencies of traffic and then resonance occurs. There are documented cases that show that light bulbs in fixtures installed on steel bridges burn out more rapidly because of such vibrations. There are indications that concrete decks on steel bridges need replacement significantly sooner then concrete decks cast on concrete girders. The natural frequency of vibration of prestressed girder bridges, because of their mass and stiffness, does not coincide with vehicle frequencies. The public will feel safe, secure and comfortable when riding on prestressed concrete bridges. Owners report that decks are less likely to crack prematurely when built on stiff concrete bridges.

Excellent Riding Characteristics

The public will not only be safe but they will feel more secure and comfortable on a concrete bridge that holds traffic vibrations to an absolute minimum. Long continuous spans and integral abutments eliminate or reduce expansion joints for a smoother ride and reduced maintenance.

Quality Assurance

Prestressed concrete is economical because it is an efficient composite of high-strength steel and high performance concrete. To take advantage of this efficiency, precasting plants have developed sophisticated quality control programs that assure the customer that products meet exacting specifications.

Precast prestressed concrete products are rigorously inspected and quality is controlled at the precasting plant. In fact, each operation in the manufacturing process provides for a point of scheduled inspection and control.

During fabrication and handling, portions of prestressed concrete beams are subjected to some of the highest stresses they will ever encounter as structural members. So, in a sense, prestressed members are load-tested during fabrication, handling and installation.

Engineers put their professional reputation on the line whenever they specify a structural material. This requires that they work with the most reputable and qualified sources.

A plant that is PCI Certified tells the engineer several important things:

- The facility has demonstrated production and quality control procedures that meet national industry standards.
- A nationally recognized, independent consulting engineering firm conducts at least two unannounced annual audits. The auditors are accredited engineers. The firm is engaged by PCI for all audits nation-wide.
- Each plant must maintain a comprehensive Quality System Manual (QSM) based on national standards and approved by PCI. The QSM is available for review by owner agencies.

The rigid audits cover more than 150 items. Standards are based on the Manual for Quality Control for Plants and Production of Structural Precast Concrete, PCI manual MNL-116. The audits evaluate concrete materials and stockpiles, concrete mixing, transporting, placing, consolidation and finishing. Procedures are inspected for tensioning of strands and transfer of prestress; concrete curing and temperature controls; product stripping, handling and storage. In-house QC procedures are reviewed thoroughly. In addition, engineering, shop drawings, record keeping and many other practices related to quality production are examined.

- QC personnel must be PCI-Certified, attained by passing written and practical examinations.
- The designer will know that the producer has PCI confirmed capabilities and that the producer stands behind their products.

Failure to maintain acceptable standards makes loss of certification mandatory.

Totally Precast Concrete Bridges

Work zones and detours are difficult problems faced by highway agencies. Using precast concrete and with techniques such as integral deck bridges, traffic interruptions can be minimized because of the availability of plant-produced sections and the speed of erecting and completing the bridge.

The versatility of the precast, prestressed concrete industry provides the designer with many options. Can one use precast bridge components to build an "Instant Bridge"? Almost! There are many ways to put a bridge together with precast concrete products.

In addition to the well known superstructure elements – girders and deck slabs – substructure components can be precast.

Precast concrete piles are quite popular in many parts of the country. They come in different sizes and shapes, ranging from 10-inch-square piles to 66-inch-diameter cylindrical piles such as this 172-ft-long unit.

In addition, pile caps can be precast.

Piers and abutments can also be made of precast concrete pieces quickly assembled in the field.

There are many benefits to using precast concrete elements to construct prefabricated bridges. They include:

- A single contractor working with only one familiar material can control the schedule for erection of the entire bridge.
- Precast concrete structural elements are made in manufacturing plants under controlled conditions in advance of need and stockpiled for "just-in-time" delivery and erection.
- No need for curing cast-in-place concrete: precast bridge piers can be erected in one working day and beams can be erected immediately following the piers.
- Corrosion resistance and excellent concrete quality is provided through in-plant manufacture of all of the structural elements.
- Fully cured precast concrete structural elements can be delivered to the site. These elements contain little potential for additional shrinkage or creep.
- Owner agencies complete more work in a shorter period of time, resulting in:
  - Reduced cost of handling traffic
  - Reduced accident exposure
  - Reduced inconvenience to the traveling public
  - Fewer motorist complaints
- Contractors benefit from:
  - Reduced exposure of personnel to traffic hazards
  - Greater dollar volume of work accomplished in a shorter period
  - Fewer delays due to weather conditions
  - Less dependence on remote delivery of ready-mixed concrete
- Lower costs for:
  - Forms
  - Cranes
  - Skilled field labor
  - Scaffolding and shoring
- The same crane already needed on the job site for erecting beams and girders may be used for erecting bridge piers and other elements.

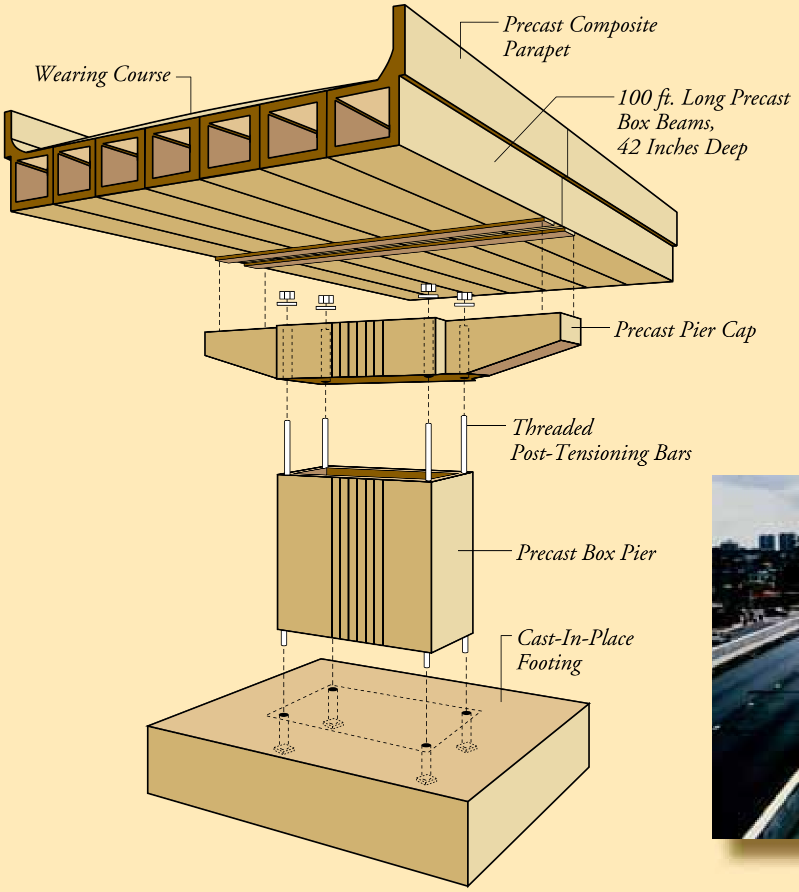
- Reduction of motorist delays, complaints and accidents. According to a report by the Texas Transportation Institute, costs incurred by drivers passing through a work zone, along with engineering costs, can be $10,000 to $20,000 per day. In urban areas, a federal report states that the cost of work zones can reach $50,000 per day.

Minimal Traffic Disruption

In San Juan, Puerto Rico, the four, totally precast concrete Baldorioty de Castro Avenue bridges were built in record-setting time, attractively and economically.

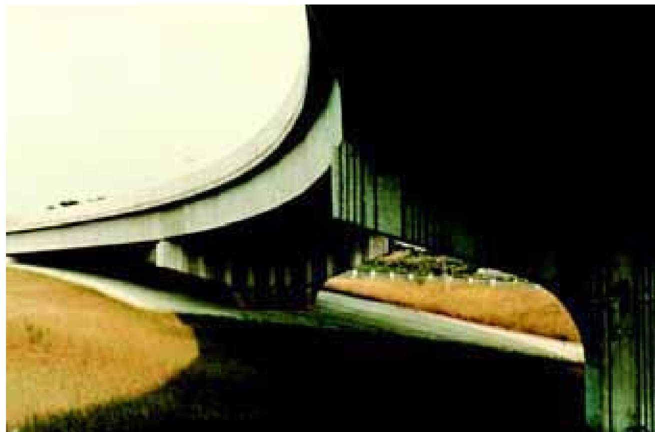
Each of four bridges, ranging in length from 700 to 900 feet, was erected in less than 36 hours – that's from the time traffic was re-routed on Friday night until traffic resumed over the new bridge on Saturday or Sunday! This included the piers, the superstructure, the overlay and lighting. It was well within the owner's construction allowance of 72 hours per bridge; a condition established to minimize disruption to one of the city's most highly traveled corridors.

In addition to speed, the bridges also met the city's budgetary needs. The four box-beam bridges were constructed for $2 million less than the next lowest bid for another material. In addition, the bridges will prove durable and maintenance-free, adding value to this investment.



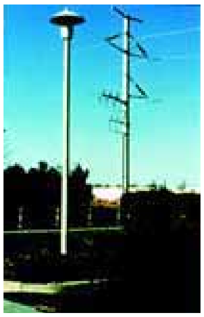
The Future

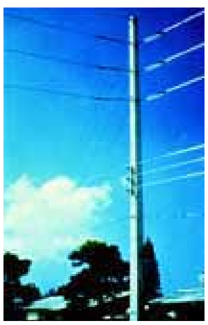
Innovation in bridge construction has been, and will continue to be the ongoing focus in the precast concrete industry. The development of horizontally curved precast concrete bridges is one such example out of the past.



Another development was the use of precast deck panels. Used as stay-in-place forms, the panels improve safety on the jobsite, reduce field placement of reinforcing steel and concrete for bridge decks, resulting in considerable savings. The panels become composite for live loads with the field-placed concrete and are now common in many states.

Material properties, such as corrosion resistance, fire resistance and durability have been improved in a process of continuous evolution. These inherent qualities of precast, prestressed concrete together with a high degree of design flexibility also make it ideal for a wide variety of other applications such as poles, storage tanks, retaining walls, railroad sleepers and sound barriers. All have benefited from plant standardization and the production repetitions achieved from it.





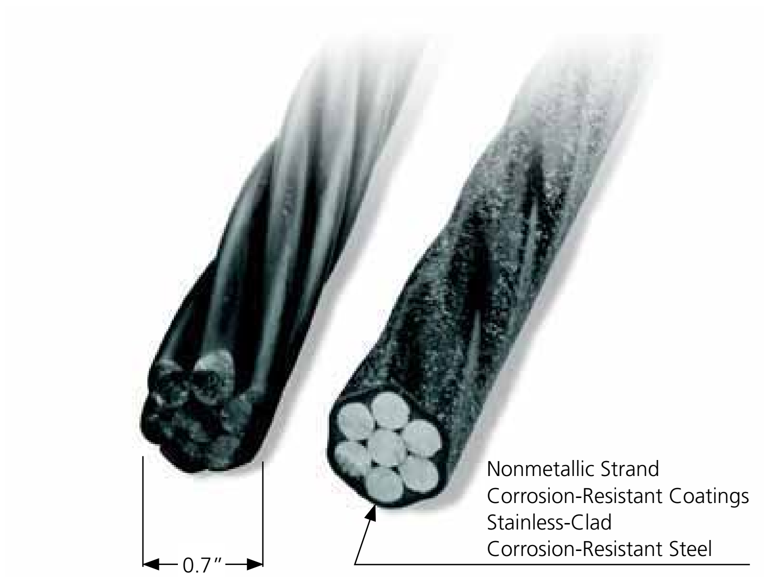
Concrete in the 12,000 to 14,000 psi range is already commercially available. The Louetta Road Bridge in Houston, Texas and the 120th Street and Giles Road Bridge in Sarpy County, Nebraska, both completed in 1996, are examples of bridges with 12,000 to 14,000 psi concrete girders and 5,000 to 8,000 psi concrete decks. Further, the Louetta Road Bridge utilizes high strength precast concrete hollow segmental piers. The Federal Highway Administration, jointly with PCI and numerous states, has consistently promoted the use of High Performance Concrete in bridge applications. High Performance Concrete often involves higher than average compressive strength. But other factors, such as stiffness, permeability and abrasion resistance, in addition to strength, may be requirements of High Performance Concrete. This often depends on the geographic location of the bridge and the component for which it is used.

The benefits of High Performance Concrete include: 1) reduced initial construction costs resulting from wider beam spacing and, 2) longer spans and reduced long-term costs that result because of fewer replacements and fewer repairs.

Lightweight aggregate concrete with strengths in the 7,000 to 10,000 psi range is possible. Lightweight concrete reduces dead loads and results in lower seismic forces.

Synthetic, organic and steel fibers have been shown to improve toughness and shrinkage cracking. Recent developments in high performance fiber-reinforced concrete hold promise in terms of performance and cost-effectiveness.

Strands of larger diameters and higher strengths will become more common as higher strength concretes are used and the demand for higher prestress force increases. When 0.6-inch diameter strands are used in conjunction with high strength concrete, in the 10,000 to 12,000 psi range, standard I-beams and other products have significantly increased span capabilities. Standard products can be stretched to spans never thought possible before. Epoxy-coated and enhanced strands will further increase product versatility.



Nonmetallic reinforcement such as glass, carbon and aramid fiber composites will be increasingly used for special applications. A recent demonstration project has shown the compatibility of carbon fiber strands for prestressing a double-tee bridge. Both internally bonded pretensioning and external unbonded prestressing systems were used.

Prestressed concrete got its start as a unique composite material. Further developments by the industry and its suppliers have continued to refine the performance of the product for a wide range of bridge applications.

Today, it gives the public extraordinarily good value for their money.

The reputation of the precast, prestressed concrete industry has been built on the strength, imagination, consistency and integrity of its people and products alike. These attributes will continue to make prestressed concrete the solution of choice for the nation’s bridges... not only today, but far into the future.

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CONCRETE INSTITUTE
209 W. Jackson Blvd., Chicago IL 60606
Tel: 312/786-0300 • Fax: 312/786-0353 • Email: info@pci.org • www.pci.org