Accelerated Bridge Construction

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Paper prepared for presentation
at the Bridges for the 21st Century session
of the 2006 Annual Conference of the
Transportation Association of Canada
Charlottetown, Prince Edward Island

ABSTRACT

United States' bridges have a median age of 40 years. Today, many of these structures need rehabilitation. Increased traffic and urban congestion demand outside-the-box thinking to accelerate construction. Traffic control is running anywhere from 20 to 40 percent of construction costs. User delays cost thousands of dollars per day in heavy traffic areas. Similar conditions exist in Canada but are often more critical due to our shorter construction season.

In 2001, the AASHTO Technology Implementation Group, chose prefabricated bridge elements and systems as one of the innovative technologies that promised the highest payoff. The FHWA, through its Innovative Bridge Research and Construction program and the Resource Center, champions prefabrication for accelerated construction. Their vision is to solve bridge deterioration with accelerated construction through increased prefabrication.

AASHTO and FHWA are encouraging prefabrication technology because of the many advantages for bridge owners, engineers, builders, and the traveling public. First, use prefabricated elements or systems to minimize traffic impacts. Precast contractors can perform time-consuming formwork assembly, concrete casting, and curing offsite in the controlled environment of a precast plant. Prefabricated bridge designs are more constructible because the offsite work reduces time onsite. Constraints, such as heavy traffic, extreme elevations, and long stretches over water, and tight urban work zones, are overcome through prefabrication. Safety improves because prefabrication reduces the exposure time for workers and the public who travel through construction zones. Precast elements and systems work well to accelerate both rehabilitation and new construction. Shipment of precast components to the job site reduces impacts on the environment. Finally, prefabricating takes elements and systems out of the critical path of a project schedule. Precast fabricators can produce quality components or systems in a controlled plant environment in much less time than is required on site. Improved quality translates to lower life-cycle costs and longer service life.

The paper includes a background on precast concrete bridge construction, an overview of precast concrete deck construction, fabrication transportation and erection, sustainability issues and total precast bridge construction. The benefits of precast prestressed concrete for bridge construction include speed, durability, minimum traffic interruption, assured plant quality, minimum maintenance and attractive designs.

New ideas are required to address the dual needs of faster construction and long service life. Some case studies from the United States and Canada offer new ideas on techniques and construction details to achieve the goal of: "Get in. Get out. Stay out."

1.0 PREFABRICATED BRIDGE ELEMENTS AND SYSTEMS

Advantages

Prefabricated bridge elements and systems offer bridge designers and contractors significant advantages in terms of construction time, safety, environmental impact, constructability, and cost.

Minimize traffic impacts of bridge construction projects

Using prefabricated bridge elements and systems means that time-consuming formwork construction, curing, and other tasks associated with fabrication can be done off-site in a controlled environment without affecting traffic.

Improve construction zone safety

Because prefabrication moves off-site so much of the preparation work for bridge construction, the amount of time that workers are required to operate on-site, frequently in or near traffic or at elevations or over water, is greatly diminished. Job site constraints such as nearby power lines are minimized when contractors can complete most of their construction off-site.

Make construction less disruptive for the environment

Using prefabricated substructure elements reduces the amount of heavy equipment required and the amount of time required on-site for heavy equipment. Keeping equipment out of sensitive environments is less disruptive to those environments.

Make bridge designs more constructible

Many job sites impose difficult constraints on the constructability of bridge designs: heavy traffic on a provincial highway that runs under a neighborhood bridge, difficult elevations, long stretches over water, restricted work areas due to adjacent stores or other facilities. Using prefabricated bridge elements and systems relieves such constructability pressures.

Increase quality and lower life-cycle costs

Prefabricating elements and systems removes them from the critical path of a project schedule: work can be done ahead of time, using as much time as necessary, in a controlled environment. This reduces dependence on weather and increases the control of quality of the resulting elements and systems. All projects that use prefabricated bridge elements and systems increase the quality of their structures; most also lower life-cycle costs.

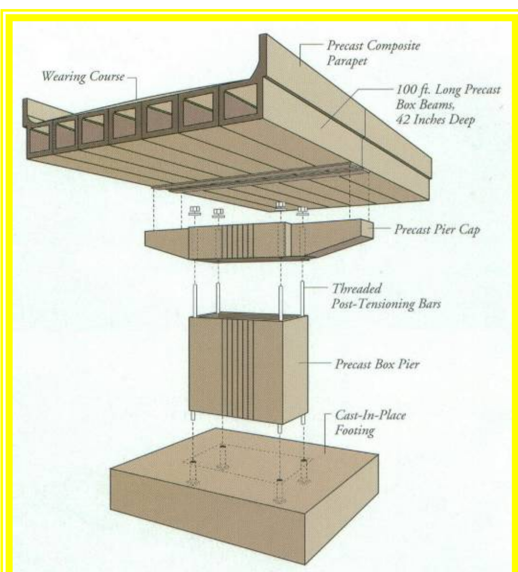
Traffic and environmental impacts are reduced, constructability is increased, and safety is improved because work is moved out of the right-of-way to a remote site, minimizing the need for lane closures, detours, and the use of narrow lanes. Prefabrication of bridge elements and systems can be accomplished in a controlled environment without concern for job-site limitations, that increase quality and can lower costs. Prefabricated bridge elements tend to reduce costs where use of sophisticated techniques would be needed for cast-in-place, such as in long water crossings or higher structures, like multi-level interchanges.

2.0 CASE STUDIES

2.1 Baldorioty Bridges
San Juan, Puerto Rico

- Create Expressway
  - o Separate at-grade intersections
  - o Two intersections, four bridges
- 100,000 Average Daily Traffic

- Design & Build Four Urban Grade Separations
  - o 2 bridges – 900 ft long x 30'- 4" wide
  - o 2 bridges – 700 ft long x 30'- 4" wide
- Maintain continuous traffic
- Complete each bridge in less than 72 hours!



Actual site in dense urban area

Precast pier cap installation

Adjacent box beam installation

Membrane and asphalt wearing surface

Completed bridges with traffic

Baldorioty Bridges Construction Report

- 700-Ft Bridge – January 1992 – open to traffic in 36 hours
- 900-Ft Bridge – March 1992 – open to traffic in 21 hours
- 900-Ft Bridge – May 1992 – open to traffic in 23 hours (rain)
- 700-Ft Bridge – July 1992 – open to traffic in 22 hours

Ahead of its time – little interest since 1992

2.2 Cross Bay Boulevard over the North Channel Jamaica Bay, New York

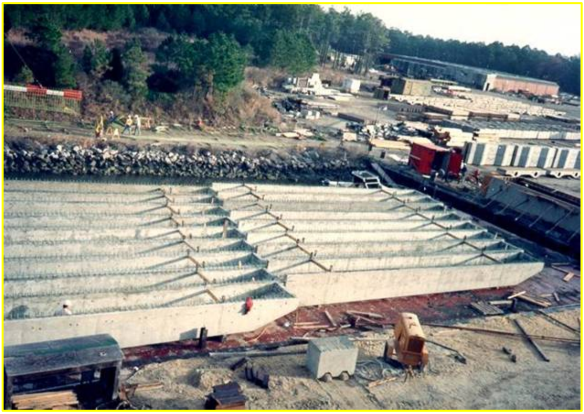
Bridge Description

Bridge length: 2,842 feet, 34 spans, 3 lanes each way plus bicycle lanes, sidewalks and fishing access

Components Used

- Cylinder piles
- Precast pier cap forms
- Prestressed I-Beams
- Precast diaphragm forms
- Prestressed sub-deck panels
- Precast traffic barriers

Precast cylinder piles



Precast pier caps

Precast pier cap

Precast diaphragm

I-girder installation

Precast deck slab placement

Finished structure

2.3 Mitchell Gulch Bridge

Project Description

- Owner – Colorado Department of Transportation – Region 1
- SH 86, South of Denver
- 1,200 vehicles/day
- 40 ft. Long single span bridge
- Redesigned per CDOT value engineering process

Pile driving in advance

Demolition begins

Install substructure units

Weld substructure units together

First abutment in place

Flow-filling behind abutments

Stream work begins

Grading and riprap under bridge

Install precast superstructure slabs

Placing edge girder - integral curb & rail

Backfilling & road approach work

Grouting the deck joints

Final paving

The completed structure

New bridge is open for traffic

Schedule

- Single weekend
- Started construction Friday at 7 PM
- Opened for Traffic Sunday at 5 PM
- Less than 48 hours to complete

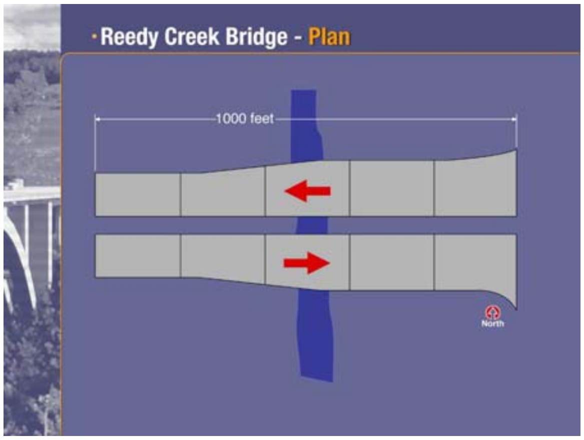
2.4 Reedy Creek Bridge
Disney World, Orlando, Florida

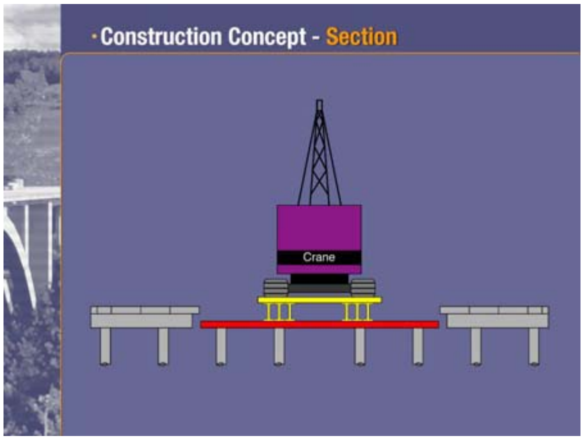
The Environment
- Reedy Creek Wetlands

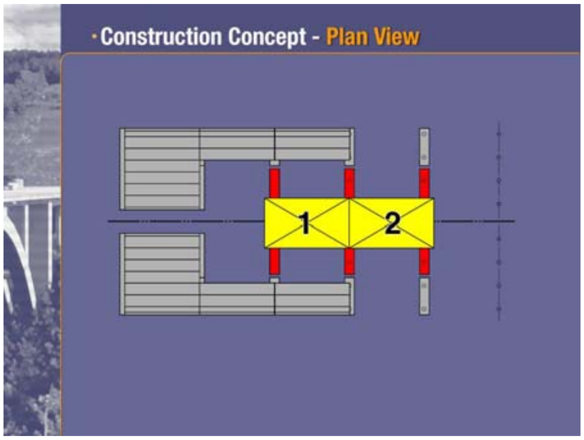
The Need
- Provide vehicular access to the new Animal Kingdom theme park

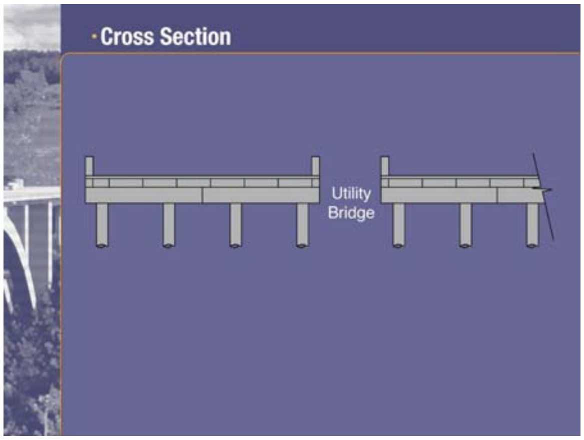
The Solution
- A precast prestressed concrete slab bridge constructed using top down construction

Construction
5 continuous segments at 200 ft = 1000 ft
Each segment = 5 spans at 40 ft





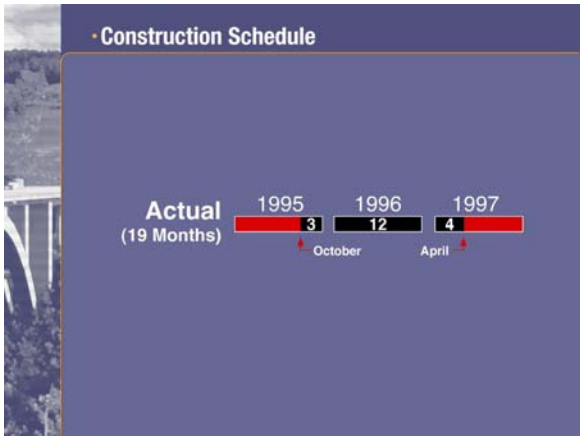


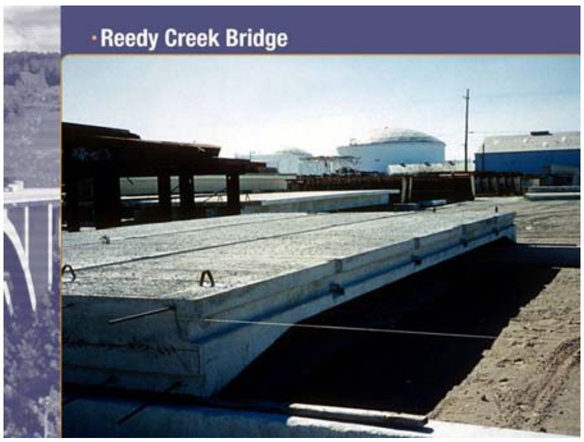


Original Design
- Cast-in-place construction

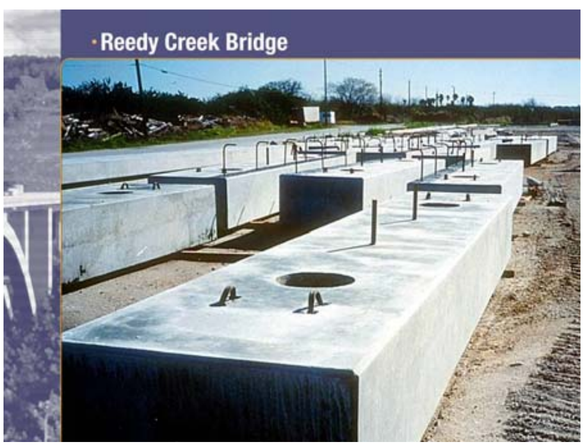
Value Engineering proposal
- Use precast components in the same configuration

Conclusion
The precast alternate saved both cost and time.

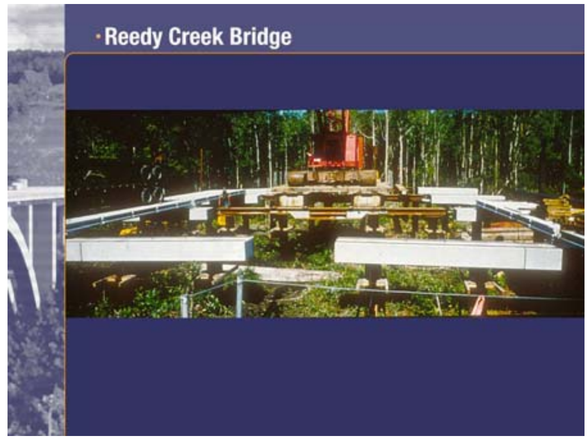


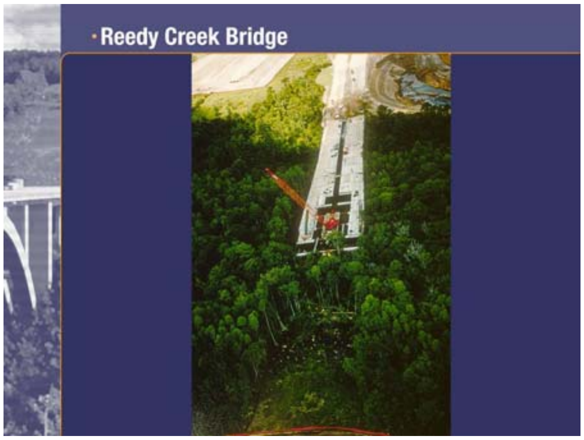


The deck construction used 405 haunched slabs in two sizes

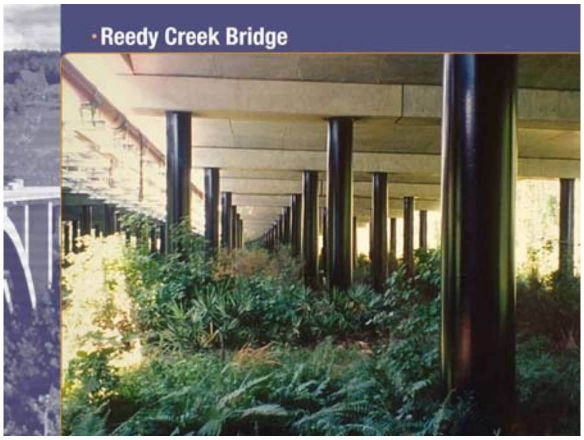


Precast pile caps





The finished bridge



2.5 Robert Moses Causeway over Great South Bay Long Island, NY

South Bound Bridge Description
Bridge Length: Approximately 2 miles, 2 lanes wide, 153 spans

Components Used
Original Contract:

- Rehabilitate Superstructure girder and truss spans.
- Replace 122 stringer spans with spread P/S Box Beams.
- Replace deck.

Value Engineering Proposal:

- Substitute full-width quad-Tee span segments for spread box-girder spans.

The finished bridge

2.6 MOOSE CREEK BRIDGE
Total Precast Concrete Bridge Structure near Timmins, Ontario

Precast Elements
The Moose Creek project was commissioned by the Ministry of Transportation of Ontario (MTO) and engineered by Stantec Consulting to try out several new precast construction concepts that could be used to speed up bridge construction in Ontario. This bridge has a single span of 22 m, an overall width of 14.64 m and a roadway of 13.5 m. The bridge is supported on steel piles and has integral abutments.

The Faster the Better
The Moose Creek Bridge project is part of a North American initiative - looking at ways to speed up bridge construction to minimize costs and inconvenience to the public.

This project used a total of 10 precast concrete substructure/abutment elements (3 stem units + 2 wingwall units per abutment). The precast concrete superstructure consisted of 6 girder/deck units consisting of CPCI 1200 girders precast with monolithic decks.

Project Specification Highlights

- Use of High Performance Concrete (HPC)
- Casting of Concrete Trial Batches
- Temperature Monitoring
- Temperature Restrictions
- Seven Day Wet Cure

Concrete Trial Batch

The final concrete mix developed for each precast unit was cast and tested prior to production of the units. Test results were submitted for 28 day strength, rapid chloride permeability and hardened air void tests. A comparably thick test unit was cast to monitor the core heat generated by the stem units during curing

Abutment and Wingwall Production

Abutment and wingwall units were cast at Pre-Con's Brampton precast plant. Units were cast with the exposed face on the down side of form. All units were cast with conventional reinforcing steel.

All units were cast with High Performance Concrete (HPC). Special curing requirements were carried out in conformance with the specifications.

The concrete temperature was monitored and controlled. Thermocouple wires were placed at the centre and the surface of the units. Wires were cast at 3 locations per unit to monitor the temperature. Thermocouple wires were connected to dataloggers for recording and downloaded daily. Temperatures were recorded every 30 minutes for 7 days. Manual temperature readings were taken at specified intervals during the 7 day curing period.

Temperature Restrictions
To prevent shrinkage and micro-cracking, the concrete temperature was maintained between 10^0C and 70^0C and the temperature difference between any one set of the centre and the surface thermocouples could not exceed 20^0C. If the limits were neared or exceeded, the surface temperature was raised or lowered through use of hot or cold water as necessary. The core temperature could not be influenced.

All units were wet cured with burlap or filter cloth for a 7 day period. Soaker hoses were used to keep units continuously wet during the 7 day curing period. Moisture vapour barrier was used to prevent air flow between layers during the curing period

Girder/Deck Production
One girder/deck unit cast per day was precast at Pre-Con's Woodstock, ON, precast plant using a reusable wood form. Units were prestressed and conventionally reinforced, similar to typical CPCI girder units - but with a monolithically cast deck slab above. The girder deck was formed with a parabolic shape in elevation and cross slope in section to account for girder camber and cross fall.

The deck side form was notched for projecting reinforcing steel - to ensure proper alignment with steel in adjacent units. Focus was placed on the edge detail, girder-to-girder.

High Performance Concrete was required for production of these units, together with similar curing and temperature restrictions/monitoring procedures used for the abutment and wingwall units. Centre and surface thermocouples were cast into unit: 3 wires/deck, 2 wires/girder and 3 locations per deck and girder (15 thermocouples/unit total).

A 7 day wet cure with burlap was maintained, including a layer of plastic vapour barrier. Temporary steel stands were required for stability after the girder/deck units were removed from the wood form.

Girder/Deck Shipping
Temporary steel strands were needed for stability during shipping.

Abutment/Wingwall Installation
The precast units were erected in two mobilizations. First the stems and wingwalls were installed beginning July 28, 2004. Units were shipped flat. The steel pile and HSS knee bracing system was installed by the general contractor. This system also acted as a temporary lateral support for abutment stem units.

For stability, the outer abutment stem units were erected first. Wingwall end reinforcing was threaded through the reinforcing of the stem units. Wingwall units were set on steel piles and connections were made between stem and wingwall units. Installation of the stem and wingwall units took place over two days

Post-Abutment Installation Site Work
Cast-in-place bearing seats and closure strips between stem units were poured by the General Contractor after installation was completed. Lateral bracing was removed when the concrete reached minimum strength.

Girder/Deck Installation
Minimum design strength of the cast-in-place substructure portions was required prior to girder/deck erection. Units were erected on August 19, 2004 - 3 weeks after the stems and wingwalls. Units were shipped over a two day period to reach site at the required time.

Units were erected from a temporary bridge adjacent to the site. The middle units were placed first and braced temporarily to the stem units for stability before adding the permanent steel diaphragms. Adjacent units were then installed and connected to the diaphragm steel before releasing the crane.

Differential camber was monitored in the plant and checked at erection to ensure allowable tolerances were not exceeded. The deck cross slope was checked after each girder was installed to maintain a constant cross fall.

Installation continued outwards until the entire deck was complete. Bracing from the middle unit to stem could then be removed. Installation progressed quickly and was completed within one day.

Post-Girder/Deck Installation Site Work
Cast-in-place concrete was installed in the pour strips between adjacent girder units. The end diaphragms were poured by the general contractor after the precast units were erected - along with the other work performed on a typical bridge structures (approach slabs, barrier walls, etc.).

Moose Creek Bridge Opening
The bridge was opened to traffic on the evening of October 27, 2004.

Owner: Ministry of Transportation of Ontario (MTO)
Precaster: Pre-Con Inc.
Engineer: Stantec Consulting
General Contractor: Miller Paving

3.0 Conclusion

The Mosquito Creek Bridge, built in North Vancouver in 1952, has the distinction of being the first prestressed concrete bridge built in Canada. The bridge used precast pretensioned slab girders. This bridge proved to be both economical and satisfactory from a structural viewpoint. The bridge is still in service, having been widened on both sides over the years.

The structural precast concrete industry has extensive knowledge and experience in the manufacturing, delivery and installation of precast bridge components. The industry is ready and willing to work with ministries of transport, bridge consultants and contractors under certain conditions:

- Standard tender methods are not conducive to innovative solutions. In many cases, precast manufacturers are reluctant to share their expertise and ideas with others prior to bidding.
- As voluntary alternates are not considered unless the contractor is the low bidder, new ideas and value engineering may not be worth the risk or effort. *The precaster generally has no access to the designer during the tender period to answer technical questions.*
- Require that precast concrete elements manufactured in precast plants be certified in accordance with CSA Standard A23.4 or provincial standards prior to tenders being issued. This will prevent the possibility of poor or unacceptable results due to unqualified fabricators. CPCI members have access to the latest bridge design and technology throughout North America. *In some cases the Contractors are encouraged to bid the precast work and the precast industry is in a situation where they are supplying their tendered number and ideas directly to their competition.*
- Standard bridge details should be revised or relaxed if they become a barrier to innovation and new ways of construction.
- Use large precast components to speed up the construction. Consult with precast manufacturers regarding constructability, shippable sizes and weights and erection equipment required to install the large pieces at the jobsite.
- Industry standard tolerances are given in CSA Standard A23.4. Do not require unnecessary tolerances. Design details that can accommodate the length and out-of-square tolerances in large precast members. *New sections, if developed, need standard tolerances as their camber behavior is only theoretical.*
- Construction Management contracts should be used, initially on a trial basis, to team all trades including the precast contractors with forward looking engineers to find new ways to accelerate the construction without sacrificing the design life of structures. *The quality control in certified precast plants can be used to everyone's advantage.*
- If the idea is to speed up construction, put a value on the reduced time and require guaranteed schedules.

- Scope and contracts should be performance related and clearly outline all functional requirements of a structure.
- Don’t be afraid to try new ideas. Keep an open mind. Not everything will work as expected. Some ideas will exceed expectation. *There has to be a reward to promote innovation and incur risk.*

Use prototypes to try out new techniques on a smaller scale. Be prepared to pay a premium for these trials. If the prototypes are successful and/or require modifications, proper tooling up and formwork can be purchased when these prototypes become standard construction methods for future projects.

4.0 References

1. Prefabricated Bridge Elements and Systems, Federal Highway Administration: www.fhwa.dot.gov/bridge/prefab

2. Precast/Prestressed Concrete Institute (PCI), Chicago, IL: www.pci.org

3. Canadian Precast/Prestressed Concrete Institute (CPCI), Ottawa, ON: www.cpci.ca

SPEAKER'S BIOGRAPHICAL NOTES

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Paper Title: **Accelerated Bridge Construction**

Session: Bridges for the 21st Century

Biographical Notes:

John R. Fowler, P. Eng., is the president of the Canadian Precast/Prestressed Concrete Institute. CPCI is a non-profit organization based in Ottawa whose purpose is to advance the use of structural precast prestressed concrete, architectural precast concrete and post-tensioned concrete in Canada. Mr. Fowler, a civil engineering graduate of Queen's University, has served the Institute since his appointment in June 1985.

Fowler is a past chair (1980) of the Canadian Prestressed Concrete Institute. He is a member of several technical committees, CSA Standard A23.3 "Design of Concrete Structures", CSA Standard S413 "Parking Structures", CSA Standard A23.4 "Precast Concrete - Materials and Construction", CSA Standard S806 "Design and Construction of Building Components with Fibre Reinforced Polymers" and the Standing Committee on Structural Design for the National Building Code of Canada. Fowler served on the Research Board and the Industry Liaison Board of the Concrete Canada, Network of Centres of Excellence on High Performance Concrete. He is a member of the Professional Engineers of Ontario (PEO) and is a professional member of the American Concrete Institute (ACI), the Precast/Prestressed Concrete Institute (PCI), the Post-Tensioning Institute (PTI) and is a fellow of the Canadian Society for Civil Engineering (CSCE).

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