Precast Options for Bridge Superstructure Design

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Paper prepared for presentation at the
Bridges – Economical and Social Linkages Session
of the 2007 Annual Conference of the
Transportation Association of Canada
Saskatoon, Saskatchewan

ABSTRACT

Precast construction offers many options for bridge owners and designers: Traditional solutions are I-girders, slab girders and box girders with traditional I-girders being replaced by a new family of more efficient bulb T girders with depths ranging from 1200 to over 2400 mm. Box and trapezoidal girders provide lower span/depth ratios and are more aesthetically pleasing.

Each province has their own limitations on the size and weight of bridge members that can be transported by road. Multi-axle and steerable trailers are available to maximize girder component size. Spliced girder construction can be used when these limits are exceeded; here girder elements are erected on temporary scaffolding, connected together and post-tensioned to achieve spans of 60 to 80 m. Longitudinal post-tensioning through girders for live loading may reducing the number of girder lines.

Custom solutions can be explored for large projects where the tooling-up costs can be spread over a large number of similar precast concrete components. The same thing can apply with new solutions for types of bridges that can be repeated on a variety of sites over a number of years.

The fast erection of precast bridge components can speed up bridge construction. Installation in urban areas can occur in off-peak and at night to minimize traffic interruptions. Multiple cranes, barges, temporary bridges, launching trusses can be implemented on difficult sites to help protect the environment.

Safe efficient precast concrete construction with built-in durability will ensure the lowest total cost of ownership for the traveling public.

1.0 INTRODUCTION

Bridge designers have a variety of options available when considering the advantages of precast concrete construction.

Superstructure design is usually based on the following parameters:

- Roadway width and the provision for sidewalks and/or bicycle lanes
- Bridge length will be determined by what is being crossed, hydraulic opening requirements and topography
- The cost of the bridge relative to the approaches can sometimes establish the best abutment location.

Span lengths will be determined by:

- Available pier locations
- Vertical clearance requirements and flexibility in road profile
- Safety standards
- Offset requirements from substructure elements to adjacent lanes
- Relative cost of the superstructure and the supporting piers

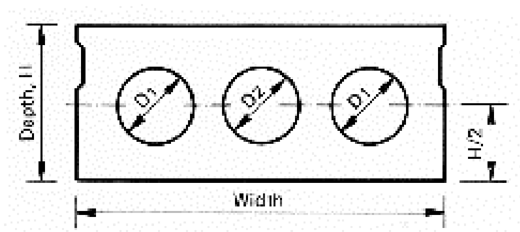
Structure depth will be determined by span length.

Bridge skew will be determined by bridge alignment relative to what is being crossed.

2.0 TRADITIONAL SECTIONS

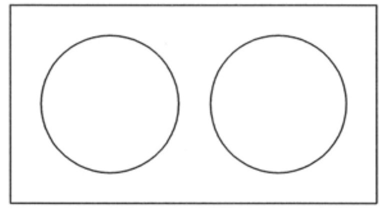
2.1 Slab Bridge Sections

Voided Slab Girders



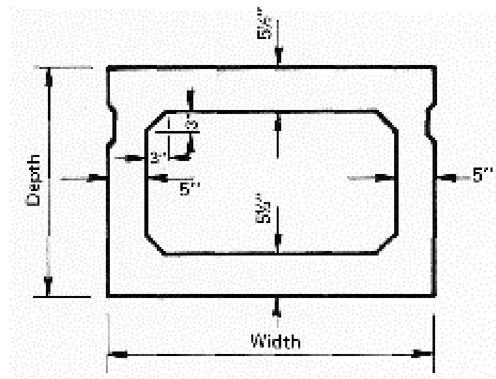
Width: 1220
Depths: 305, 381, 457, 510, 533, 635 mm
Span Range: 6 to 17 m
Span/Depth: 25 – 30

Alberta Hollow Slab Girder



Width 1206 mm, depth 650 mm
Void diameter 450 mm
Span Range 16 to 20 m

Box Girders



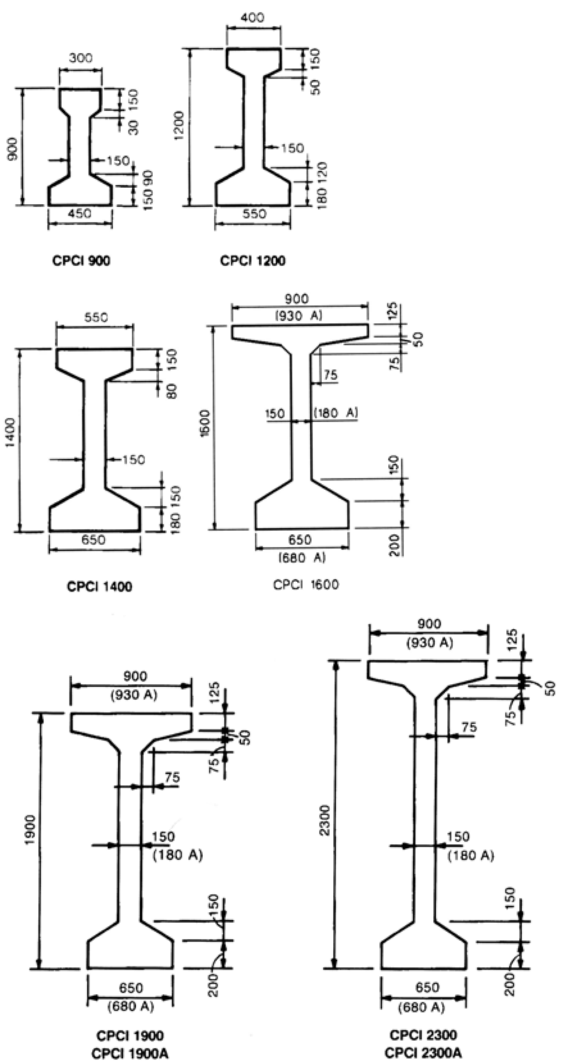
Width: 1220
Depths: 685, 750, 838, 991, 1067, 1300 mm
Span Range: 15 to 32 m
Span/Depth: 25 - 35

Slab Bridge Options

Adjacent girder bridges are slender and require no deck forming.

Spaced girder bridges require fewer girders and can be shallower than I-girder bridges.

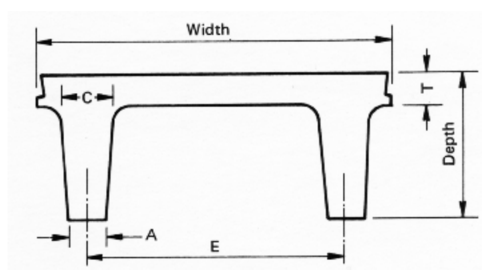
2.2 CPCI Bridge Girder Sections

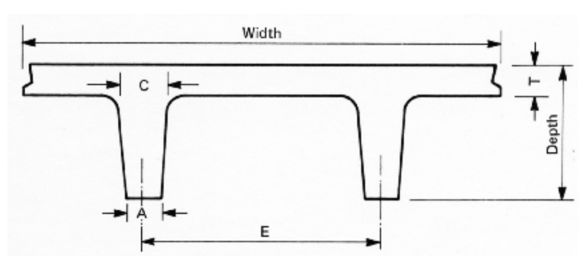


Depths: 900, 1200, 1400, 1600, 1900, 2300
Span Range: 20 to 45 m
Span/Depth: 15 – 20

Conventional rebar reinforcement

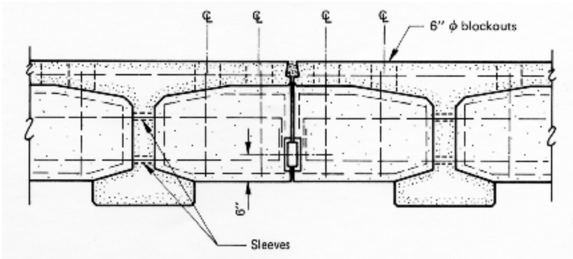
2.3 Channel and Double Stemmed Bridge Sections



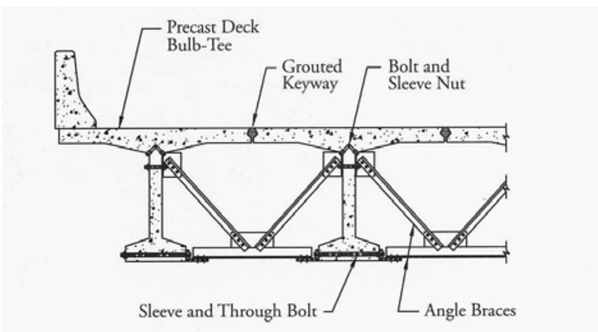


Limited Use: These sections can be designed using existing double tee forms and may be suitable for secondary road bridges.

2.4 Girder Diaphragms



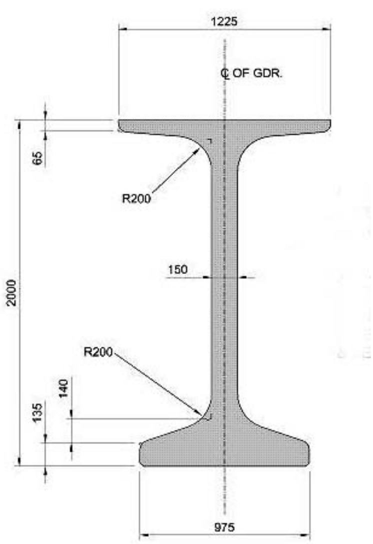
Bulb-Tee bridge half diaphragms can be integrally cast at the precast plant and joined together at the site by welding or post-tensioning.



Bulb-Tee diaphragms can also be structural steel X-bracing left exposed or cast into the finished diaphragm.

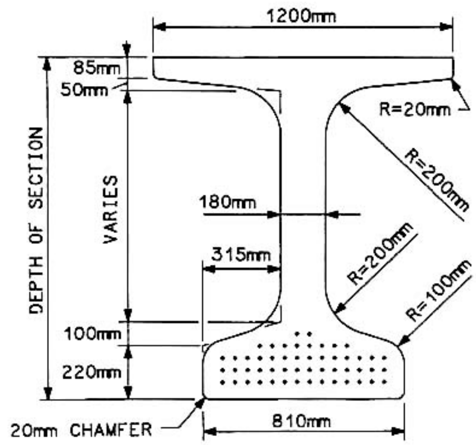
3.0 NEW BULB-TEE BRIDGE GIRDER SECTIONS

I-girders are being replaced by a new family of more efficient bulb T girders with depths ranging from 1200 to over 2400 mm.



3.1 NU Girders [9]

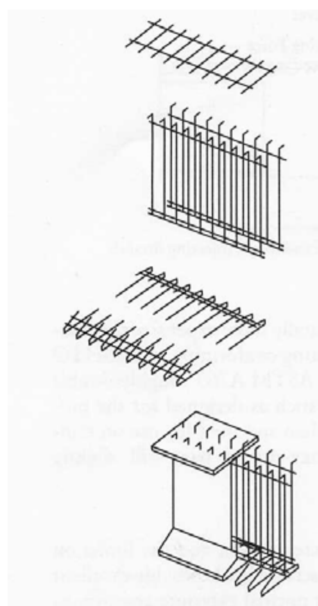
NU Girders are used in Western Canada. Web width is 180 mm when post-tensioning ducts are cast in the web for continuity and splicing sections together.



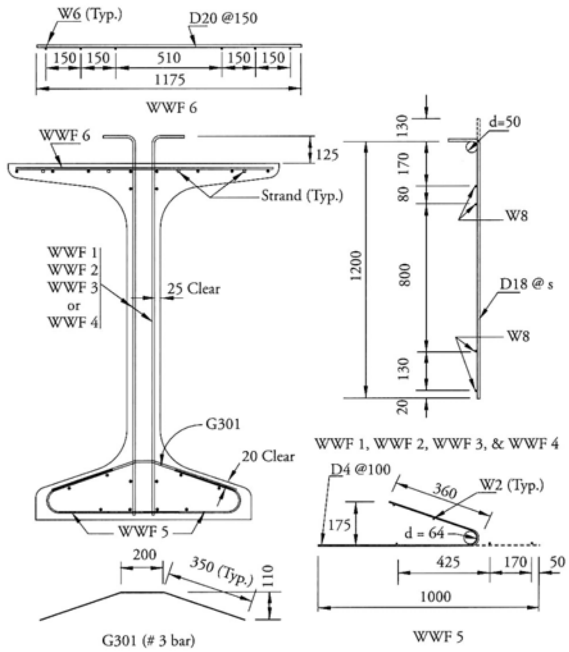
3.2 NEBT Girders [10]

NEBT Girders are used in the Maritimes and Quebec. These are heavier sections with more cover to protect the reinforcement against salt exposure.

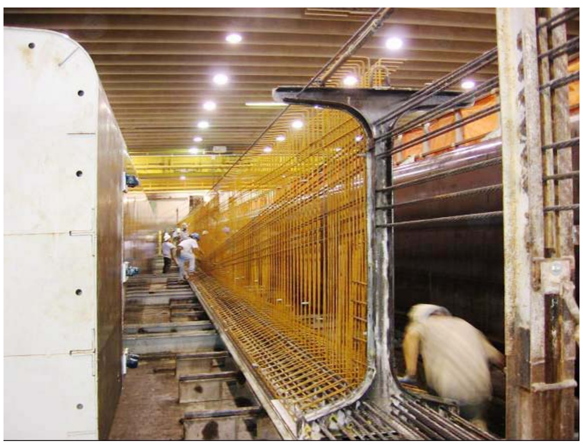
3.3 Bulb-Tee Manufacturing



Welded wire reinforcement is made to order and bent to size for individual projects.



Fabric Designation	WWF1	WWF2	WWF3	WWF4
Spacing, s (mm)	50	100	200	300



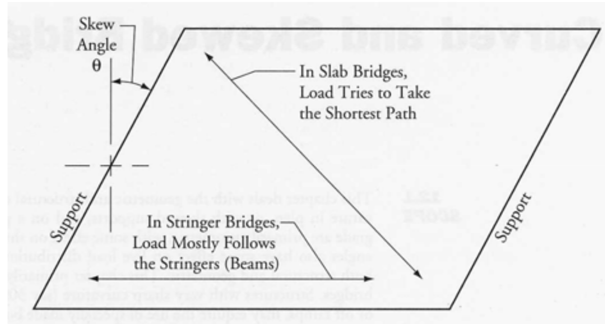
Welded Wire Reinforcement [12]

Welded wire reinforcement is a cost effective way to place mild reinforcing steel in precast girders. Cold drawn wires are welded together in a square or rectangular grid. While material costs may be higher, installation costs can be substantially lower.

4.0 GIRDER DESIGN AND MODELING

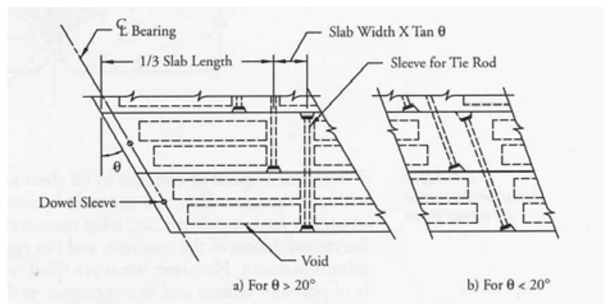
Precast bridge girders are designed for shipping and handling stresses as well as for in-service loads.

4.1 Stringer Bridge vs. Slab Bridge Behaviour [1]



Structural behavior of slab and stringer bridges

4.2 Slab/Slab Bridge Connections [1]



Horizontal ties joining slab bridge elements

4.3 Continuity

A “semi-continuous” design approach is typically adopted to avoid expansion joints at piers. Girders are erected as “simple” spans and are made continuous by casting the reinforced concrete deck slab and diaphragms.

The girders act as simple spans under self weight and the wet slab load. Under superimposed dead loads and live load, girders are continuous, hence the term semi-continuous. In addition to eliminating expensive and failure prone joints, this approach also is more structurally efficient and economic than one that uses simple spans.

Full continuity can be achieved through post-tensioning (see Section 7 below).

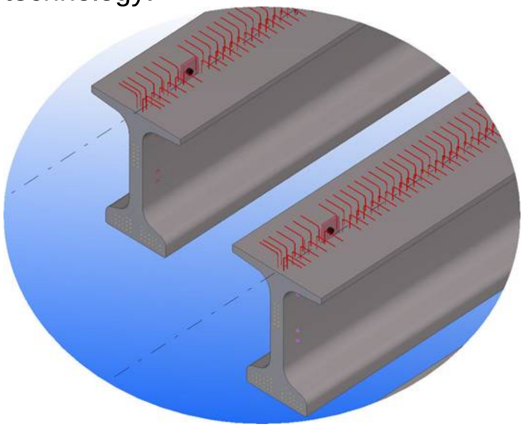
4.4 Integral Abutments

Integral abutment designs have become very common in the last 10 years for short to medium span structures (total length of 150m to 200m). In this design, the bridge superstructure is rigidly connected to the abutments, thereby eliminating the abutment expansion joints. Longitudinal movements of the superstructure (thermal creep, shrinkage) are accommodated by a single row of flexible piles that support the abutment stem. Movements occur at the ends of the approach slabs where control joints are installed.

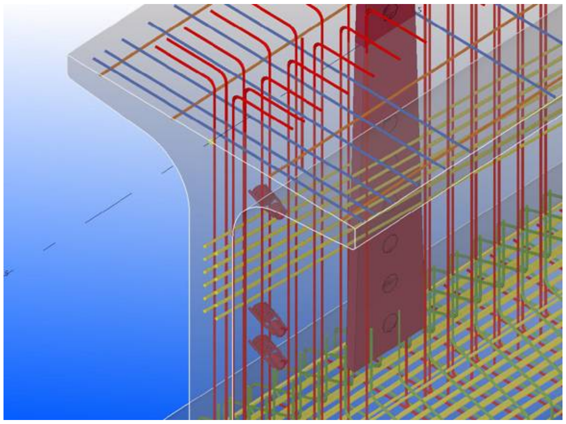
This approach is well suited to precast girder bridges. Like the continuous bridges described in the preceding section, girders are erected as simple spans and rigid connections to the abutments are achieved by casting a reinforced concrete diaphragm. Hooked dowels protruding from the ends of the girders connect with straight dowels installed through the girder webs to ensure a rigid connection.

4.5 PC-3D Modeling [13]

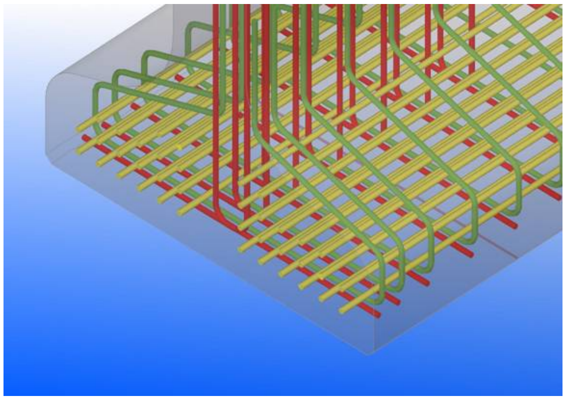
Precast bridge components can now be modeled using precast concrete 3D technology.



This software allows manufacturers and consultants to readily develop and visualize the many facets of precast construction.



Construction methods, layouts, details, reinforcing and erection procedures can all be readily visualized within the model. Drawings required to produce individual precast pieces and erection layout drawings are all generated directly from the software.



The benefits of using PC-3D modeling software are numerous. Projects can be “pre-built” within the virtual world of the BIM software. All the geometry, details, and connections can be developed.
Design issues can be easily identified and resolved prior to manufacture and erection. Potential project complications can be examined within the model, and resolved prior to issuing drawings for construction.

The use of PC-3D modeling inherently removes the possibility of misaligned connections or geometry conflicts, and provides a database of information useful for estimating, production, and construction.

5.0 GIRDER SHIPPING

Bow River Bridges, Calgary, AB

Sixteen 2800 NU girders with main span sections, weighing over 130 t each, were shipped over 10 km from the precast plant and installed at the jobsite.

Transportation Restrictions

Transportation from the precast plant to the bridge site can determine the maximum length of girders.

- Multi-axle trailers are used to distribute the loads
- Steerable back dolly trailers help long girders to turn corners
- Local travel restrictions will apply - 50+ m girders have been shipped (see above)
- Travel/time-of-day/escort restrictions will apply

6.0 GIRDER INSTALLATION

- The use of a mobile crane or cranes is the preferred method of installation.

- Night erection of girders can minimize inconvenience to motorists.

- A launching truss can be used to erect girders over water crossings.
- Barge mounted cranes are also used to install girders on long river crossings.

7.0 SPLICED GIRDER CONSTRUCTION [8]

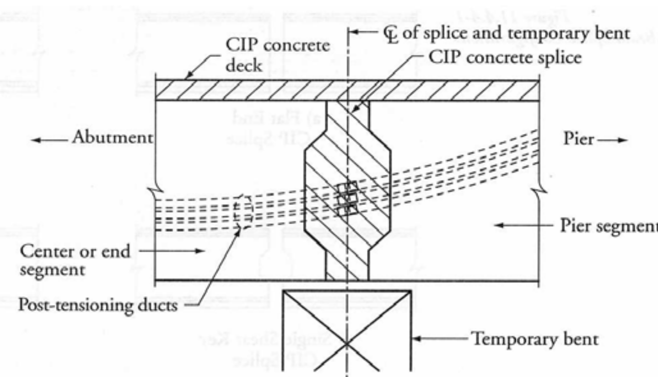
7.1 Spliced Girder Benefits

Function - When longer spans are dictated by site conditions

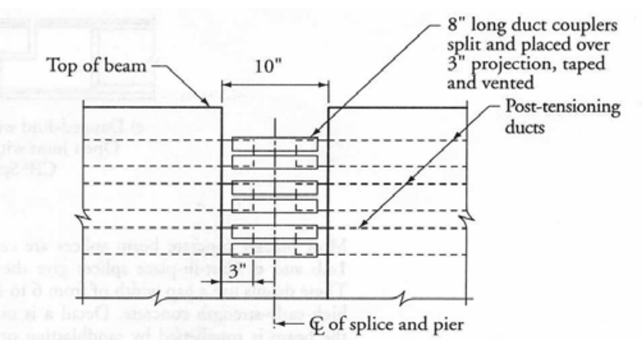
Safety - Underpasses - better clearances, sight lines

Improved Navigation - Better flow of ice and debris

7.2 Spliced Girder Connections



a) Post-Tensioned In-Span Splice with Shear Key



b) Duct Splice Detail at Pier

7.3 Examples of Spliced Girder Design and Installation

7.3.1 Crane Erection

Humber River Bridges, Toronto, ON
Twin Bridges - parallel designs - steel/concrete
3 spans - 40 m - 50 m - 40 m
CPCI 2300 girders - 8/span @ 3.0 m c/c
Girder weights - end spans 88 t, centre span 74 t.

Girders were pretensioned for handling. The centre span girders were manufactured in two segments. After the girders were erected and the diaphragms poured, the girders were continuously post-tensioned from abutment to abutment for structural efficiency.
Owner: Ontario Transportation Capital Corp.
Engineers: M.M. Dillon Limited / Giffels Associates Limited / Totten Simms Hubicki Associates Limited

Oldman River Bridge, Taber, AB [17]
5 spans - 3 main spans of 62 m and 2 end spans of 57.5 m
Composite deck roadway is supported by 4 lines of 2800 NU girders spaced at 2500 mm c/c.
The centre span girders were manufactured in two segments and post-tensioned together at the bridge site.
Designer: Campbell Woodhall & Associates

7.3.2 Launching Truss Installation

Perley Bridge, Hawksbury, ON [14]
Width 21.8 m – (4 - 3.65 m traffic lanes),(2 - 2m shoulders) + (2 m sidewalk on the West side)
10 Spans - total length 650 m - 8 main spans of 68.5 m, 2 end spans of 51 m
Girders, 68.5 m long, consisting of a haunched segment and 3 straight segments were assembled and post-tensioned together behind one abutment. Girders were winched to the launching truss one span at a time and installed. Stage post-tensioning connected the girders together before the deck was cast-in-place.

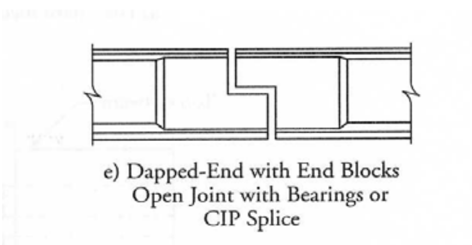
Owners: Financed/built by Governments of Canada, Ontario and Quebec
Structural Engineer: DS-Lea Associates Limited
General Contractor: Dufferin Construction Company
Parallel designs - steel/concrete

Bronte Creek Bridge, Mississauga, ON [15]
Two four lane bridges
3 spans of 55 m/ 60 m/ 35 m
7 CPCI 2300 girders / span @ 3.18 m c/c
The bridge consists of two separate structures supported on common abutments. To simplify construction, the same span arrangement was used for both structures, and simply reversed for the eastbound and westbound lanes. The optimal solution was precast girders launched from the top of the 23 m deep valley. The 55 and 60 m girders were assembled from 2 girder segments were stage 1 post-tensioned together behind one abutment. A launching truss was installed between the two bridges. Girders were winched longitudinally across the structure and laterally into position using side-shifter carriages. Continuous stage 2

post-tensioning abutment/abutment was applied to each girder line.
Engineer: McCormick Rankin Corporation

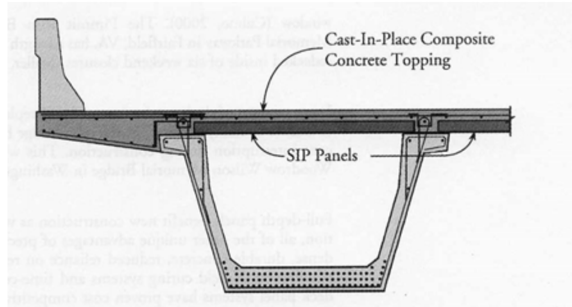
7.3.3 Crane on Barge Installation

Annacis Channel East Bridge, Richmond, BC [18]



Parallel designs - steel/concrete
Total - 9 spans – 6 lanes - curved alignment
3 main spans - 60 m - 71 m - 60 m
Drop-in girders - 2750 bulb tees - wt. = 112 t – length = 50 m
Cantilever stub girders - 20 m long
Girders were erected using floating cranes.
The main span superstructure consists of two continuous spans on either side of a mid-channel simple span. Each 71.4 m continuous span is formed by erecting 10-51.4 m girders from one pier and post-tensioning them to 10-20 m stub girders cantilevering 10 m on either side of the next pier. Girders were angled slightly at each joint to follow the horizontal curve and set at different elevations to achieve the superelevated bridge alignment. The deck overhang was varied to achieve the final deck curve.
Engineers: Willis Cunliffe Tait / Delcan
Contractor: Dillingham Construction

7.4.4 Trapezoidal Girder Bridges [5]



Trapezoidal girder sections are a popular design option because of their strength and pleasing shape.

<u>Top flange in</u> Can make different depths in the same form	<u>Top flange out</u> Require a separate form for each girder depth

Provencer Bridge, Winnipeg, MB [16]
Bridge is a curved five span, precast, post-tensioned, trapezoidal concrete girder structure.
The bridge used 5 lines of trapezoidal girders ranging from 25 to 29 m for a total length of approximately 245 m. Haunched girders are 3000 mm deep at the pier locations. These girders were supported on temporary supports during the construction. Drop in girders are 2250 mm deep. Girders were post-tensioned in stages as the construction progressed.
Client/Owner: City of Winnipeg
Prime Consultant: Wardrop Engineering

8.0 PRECAST CONCRETE DECK SLABS

Common bridge deck construction consists of prestressed concrete girders or steel girders supporting a concrete deck slab.

Precast deck slabs can be used when:

- The installation and stripping of formwork is difficult.
- The placement of large quantities of cast-in-place concrete is difficult.
- Disruption of traffic is an overriding concern due to access, safety or user costs.

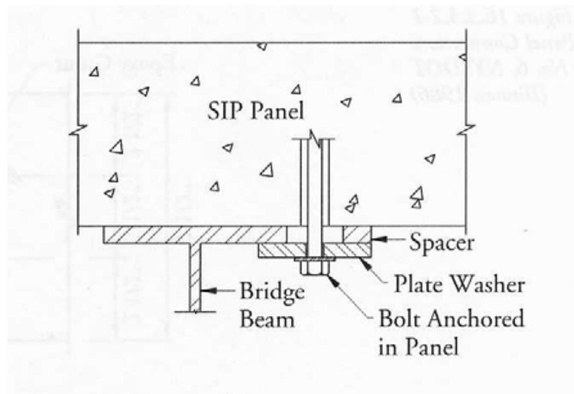
8.1 Precast Concrete Partial Depth Deck Slabs [7]

Precast prestressed concrete composite bridge deck slabs can eliminate the need for most field forming. The deck slabs and cast-in-place top slab act compositely. Mild steel reinforcement or prestressing strands in the deck slabs provide the necessary lateral bottom reinforcement.

8.2 Full Depth Bridge Deck Slabs [6]

Full depth precast concrete deck slabs can be used for both rehabilitation of existing bridge or for new structures.

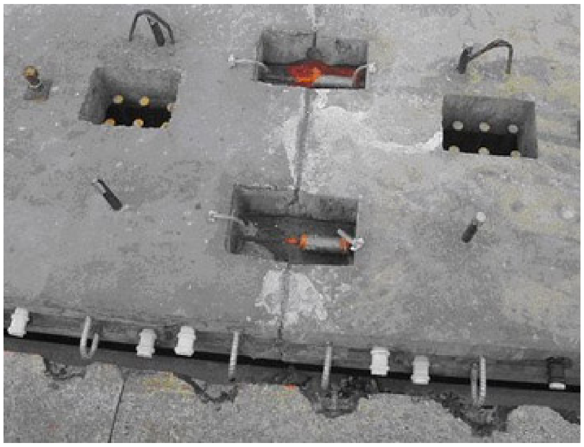
Precast bridge deck slabs can either be reinforced with mild steel reinforcing bars or with pretensioning strand. In addition, longitudinal post-tensioning can be used to stress multiple slab units together after erection.



Connections to the supporting girders to achieve composite action can be achieved by use of grouted, welded or bolted connections.

Seal Island Precast Concrete Bridge Deck Replacement [19]
Cape Breton, NS

The project involved the replacement of the existing cast-in-place concrete deck with full-depth, precast, prestressed, half-deck width concrete panels post-tensioned longitudinally to close the transverse joints and finally transversely once the centre closure strip had been cast.



The deck design was facilitated by a grillage model that incorporated all deck components and accounted for the stiffness in both the transverse and longitudinal directions. This ensured that the deck was fully prestressed in the transverse direction and that sufficient distribution reinforcing was present to satisfy the load requirements at ultimate limit states. The concrete mix selected is a 45 MPa HPC mix, with air entrainment, and strict permeability limits (max. 1,000 coulombs at 90 days). The resulting deck is a crack-free design under service conditions.

Owner: Nova Scotia Department of Transportation
Design Engineer: CBCL Limited, Halifax

9.0 PRECAST CONCRETE PIER CONSTRUCTION

<u>Benefits:</u>

- Reduced construction time
- Reduced inconvenience to the public during construction
- Lower cost
- Plant-cast quality precast concrete
    - Match casting
    - Better tolerances
    - Architectural treatments

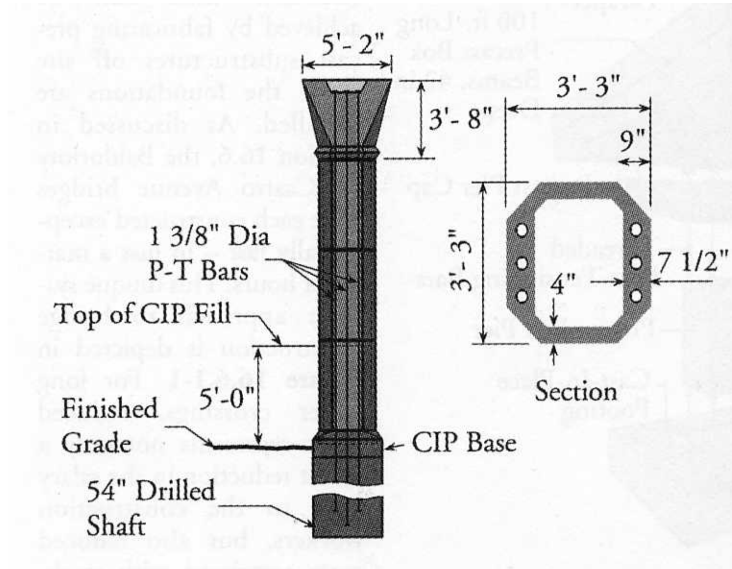
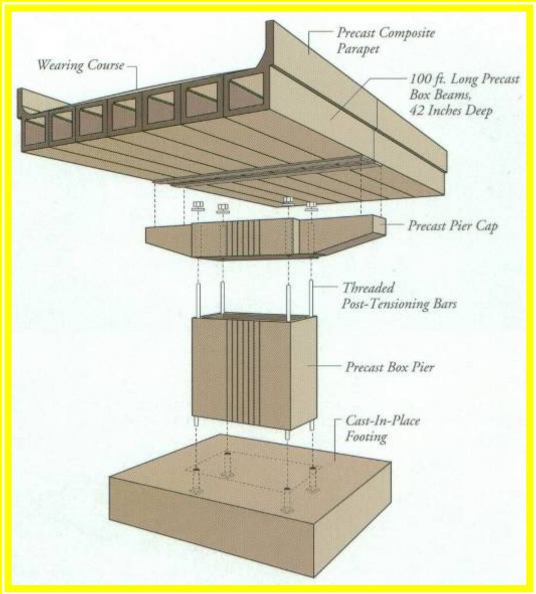


Figure 16.6-1
Louetta Road Overpass Precast Segmental Pier Column

Edison Bridges, Fort Myers, Florida
The project consisted of two bridges each one mile long. Each bridge took one year to build.

The general contractor saved two months on each bridge by precasting the piers and caps, minimizing the labour required on site and over the water. Higher quality precast components installed near sea water will increase durability.



Baldoriety de Castro Avenue Bridges
San Juan, Puerto Rico
Create an expressway with:

- Separate at-grade intersections
- Two intersections, four bridges

100,000 average daily traffic volume

- 2 overpass bridges – 700 ft long
- 2 overpass bridges – 900 ft long

In addition to the precast concrete abutments and deck girders, all piers and caps are precast concrete.

Manitoba Floodway Expansion Project [20]
Temporary Precast Concrete Rail Bridge Piers:
The temporary piers for the 3 detour rail bridges use match-cast precast segments, varying from 3 to 8 segments high. New segments were cast against previously cast segments, separated by a bond breaker, to ensure a perfect fit.

Typical segments are 7750 mm long, 2500 mm wide and 1120 mm high, each containing 3 voids to reduce the weight. Cap pieces are solid precast, 500 mm high, to receive the bridge bearings and superstructure. Typical segments weigh 27.2 t.

Base units were accurately located using leveling cleats 40 mm above the pile cap, before the base joint was grouted. A bond breaker was applied to the underside of the base unit to accommodate future removal.

Vertical sleeves were cast through all the segments for temporary post-tensioning bars that stressed the segments together.

Dillon Consulting Limited is the lead consultant in association with EarthTech, ND LEA, UMA, and Wardrop

10.0 DESIGN ASSISTANCE

■ The PCI Bridge Design Manuals [1] contains information on all aspects of precast prestressed concrete bridge construction. The manuals are written in accordance with AASHTO LRFD design criteria.

■ The structural precast concrete industry has extensive knowledge and over 50 years of 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 fair conditions. *Consult local CPCI members for available girder sizes in your area.*

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15 Bronte Creek Bridge, Mississauga, ON: http://www.cpci.ca/?sc=potm&pn=monthly112002

16 Provencer Bridge, Winnipeg, MB: http://www.cpci.ca/?sc=potm&pn=monthly42006

17 Oldman River Bridge, Taber, AB: http://www.cpci.ca/?sc=potm&pn=monthly32001

18 Annacis Channel East Bridge, Canadian Portland Cement Association, E 002.01 WC

19 Seal Island Precast Concrete Bridge Deck Replacement, Cape Breton, NS: http://www.cpci.ca/?sc=potm&pn=monthly92002

20 Manitoba Floodway Expansion Project, Norman Ulyatt, IMAGINEERING, Winter/Spring 2007, Vol 1, Issue 2

SPEAKER'S BIOGRAPHICAL NOTES

2007 TAC Annual Conference
October 14-17, 2007
Saskatoon, Saskatchewan

The information you provide on this form will be used by your session chair to introduce you before your presentation. Please outline your education, current position and responsibilities, and any special awards or recognition received.

Return this form to TAC with your full paper **by April 27, 2007**.

Name: John R. Fowler

Paper Title: **Precast Options for Bridge Superstructure Design**

Session: Bridges – Economical and Social Linkages

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". 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).

AUDIOVISUAL REQUEST FORM

2007 TAC Annual Conference
October 14-17
Saskatoon, Saskatchewan

Arrangements for equipment rentals must be made well before the conference. Please complete this form and return it to TAC with your full paper **by April 27**.

❑ Please check here if you will NOT be using AV equipment.

Please indicate the equipment you will need for your presentation:

✓ LCD data projector, pointer and screen **(Note: Speakers must bring their own computers.)**

- ❑ VGA (640 x 480)
- ✓ SVGA (800 x 600)
- ❑ XGA (1024 x 768)
- ❑ SXGA (1280 x 1024)

❑ 35mm carousel slide projector, remote control, pointer and screen

❑ Overhead projector, pointer and screen

❑ Other

(Please specify.) ____

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