

## Accelerated Bridge Construction – On the Fast Track to Success

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### **ABSTRACT**

Accelerated techniques for bridge construction should be used where the benefits have a positive effect on the construction costs and impacts of the project. At this time, the bridge specific costs on small accelerated construction projects are more than conventional construction, however it is anticipated that costs will come down as more accelerated projects are let. The savings in accelerated construction projects are found in other aspects of the total project such as time, equipment use and labour savings.

Decisions to use accelerated bridge construction techniques should be made after considering the following factors:

- Temporary Roadways and Bridges
- Reductions in Environmental Impacts
- User Costs
- Political Pressures
- Long Detours

This paper summarizes the manual *Guidelines for Accelerated Bridge Construction Using Precast/Prestressed Concrete Components* (1) which was developed in 2006, by the Precast/Prestressed Concrete Institute Northeast’s Bridge Technical Committee. The manual promotes a greater degree of uniformity among owners, engineers and industry with respect to planning, designing, fabricating and constructing prefabricated concrete highway bridges. The manual encompasses the Federal Highway Administration (FHWA) philosophy of accelerated bridge construction (2) and can easily be adopted by Canadian practitioners.

Key words: precast, prestressed, concrete, accelerated, bridge construction, fast track

## INTRODUCTION

Accelerated construction should always be considered in cases where temporary bridges and roadways are anticipated. This is especially true where a reasonable detour is available. It may be desirable to close a roadway completely, build the bridge quickly, and live with a detour. Recent accelerated construction projects have shown that commuters and businesses prefer a short-term impact over a significant long-term moderate impact. For bridges over water courses, impacts to the environment can be lessened by the elimination of a temporary bridge.

Often the need for accelerated construction can be driven by political pressures. The impacts of construction on commuters and businesses in urban areas can be devastating, and accelerated construction for bridge construction can be used to limit the time frames for construction projects in these areas. The cost of construction to highway users is significant. Savings to commuters are not typically reflected in construction budgets for highway projects; however there is a significant financial impact to the entire community due to travel delays caused by road closures or detours. In many cases, the cost of accelerated construction techniques can be offset by reductions in user costs.

On some projects, the use of staging and temporary bridges is not feasible due to limited right of way and environmental issues. In these cases detours are the only option. Accelerated construction techniques should be considered if there are concerns with traffic volumes on detours and access for emergency vehicles.

Although the intent of the manual *Guidelines for Accelerated Bridge Construction Using Precast/Prestressed Concrete Components* is to provide information that applies to precast/prestressed components used in bridge construction, using these components in non-prestressed concrete structures is also encouraged. For example, the designer may wish to use a precast substructure with steel girders and overlay with precast deck panels.

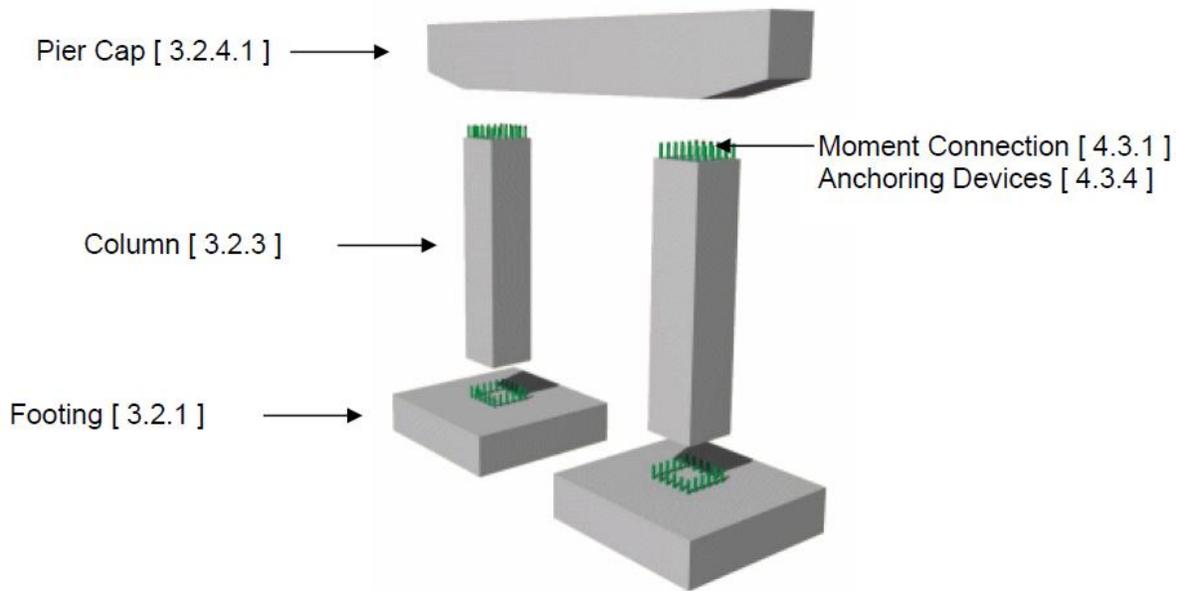
The manual comprises ten sections as follows, and the paper provides an overview of each:

- Section 1: Application Overview
- Section 2: General Requirements
- Section 3: Precast Components
- Section 4: Joints
- Section 5: Grouting
- Section 6: Seismic Conditions
- Section 7: Fabrication/Construction
- Section 8: Case Study 1, Upton, Maine
- Section 9: Case Study 2, Brooksville, Maine
- Section 10: Case Study 3, Epping, New Hampshire

The accelerated bridge construction guide is not intended for structural design, rather it is a resource for structural design engineers and project engineers to use as a tool to accompany design. Precast concrete materials in Canada must conform to the requirements of CSA A 23.4-09 *Precast Concrete – Materials and Construction* (3) and bridge design is in accordance with CSA-S6-06-*Canadian Highway Bridge Design Code* (4).

## SECTION 1: APPLICATION OVERVIEW

The first section of the manual is divided into five subsections; 1.1 When to Use Accelerated Construction, 1.2 Rehabilitation Projects, 1.3 Examples of Prefabricated Components, 1.4 Architectural Treatments, and 1.5 Definitions. The first two sections provide a general overview on considerations to use precast/prestressed accelerated construction techniques either for new construction or rehabilitation projects. Section 1.3 provides three dimensional renditions that demonstrate the prefabricated components for typical conditions. Section 1.4 references the practitioner to sources for architectural guidance such as Chapter 5 of the *PCI Bridge Design Manual* (5) and the *Minnesota Department of Transportation's Aesthetic Guidelines for Bridge Design* (6). Precast concrete components lend themselves to adaptable, innovative, and consistent architectural finishes in a range of designs, colours and textures. These guidelines may be used to proportion components to fit together to meet the function of the structure as well as to enhance aesthetics. Section 1.5 provides definitions unique to precast/prestressed concrete that are beneficial to practitioners, especially those who are being introduced to precast/prestressed bridge construction methods.



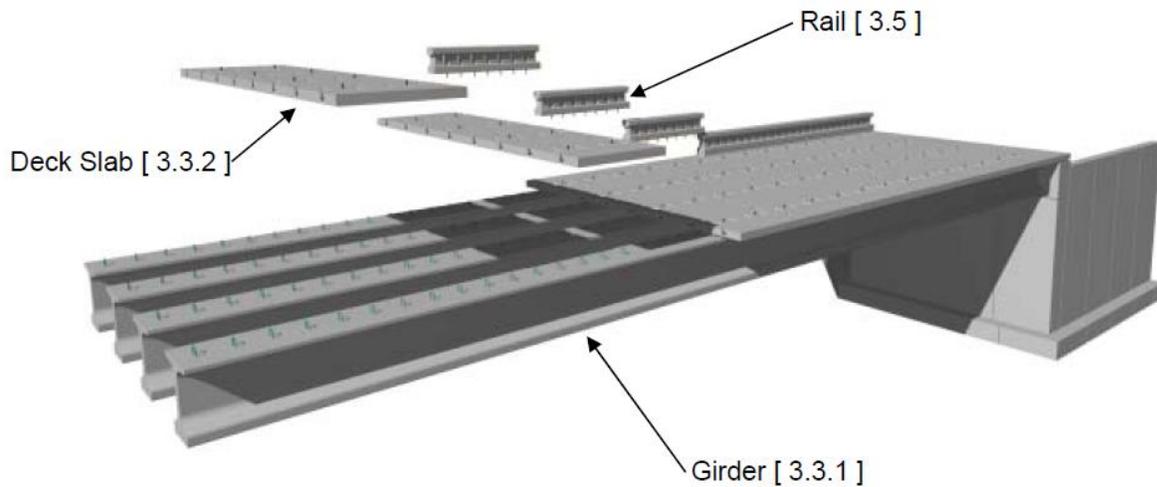


Figure 1: The manual provides descriptive diagrams of prefabricated components for several conditions. The diagrams above show the components for typical substructure and superstructure construction. Numbers in parentheses indicate the section in the manual where specific guidance is provided. (Source: PCI).

## **SECTION 2: GENERAL REQUIREMENTS**

Sections 2 through 7 are written in “clause format” with additional commentary provided in a right hand column on a per clause basis. Section 2 is divided in to five sections; 2.1 Partial Replacement Projects, 2.2 Design, 2.3 Geometric Configurations, 2.4 Tolerances and 2.5 Shipping and Handling. Section 2.2 describes the design of prefabricated bridges using the same approach as traditional cast in place concrete structures. Using discrete precast components, substructures are designed to emulate cast-in-place design and connections between components are designed to emulate traditional construction joints. The reader is referred to ACI 550.1R-01 *Emulating Cast-in-Place Detailing in Precast Concrete Structures* (7) for specifications on emulation design. Canadian practitioners are also directed to CONCISE Beam (8) which is an easy to use Microsoft Windows based software program for the design of precast concrete beams to CSA A23.3 or CSA S6, and the *CPCI Design Manual Fourth Edition* (9).

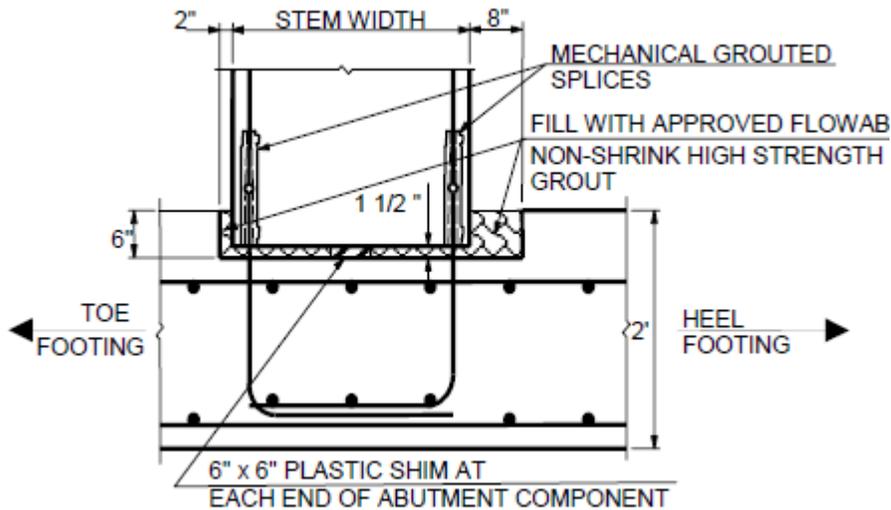


Figure 2: The most common connector is a grouted sleeve. (Source: PCI)

### SECTION 3: PRECAST COMPONENTS

This section discusses precast piling, precast substructure components (footings, wall segments, columns and girder supports), precast superstructure components, proprietary bridge systems, and precast bridge railings. The designer is referred to *PCI Bridge Design Manual BM-02-04* chapter 20 for precast concrete alternatives to steel H piles. Sub-footings of low strength concrete are required to facilitate load distribution as well as a working platform for the installation of the precast footings. Levelling screw details and grouting procedures between the footing and sub-footing via ports that are cast in the footing, are also described. This section includes many descriptive images as seen in Figures 3 through 12.



Figure 3: Placing the precast footing on the sub-footing. The sub-footing does not need to be formed. (Source: PCI)



Figure 4: Completed segmental precast footing. (Source: PCI)

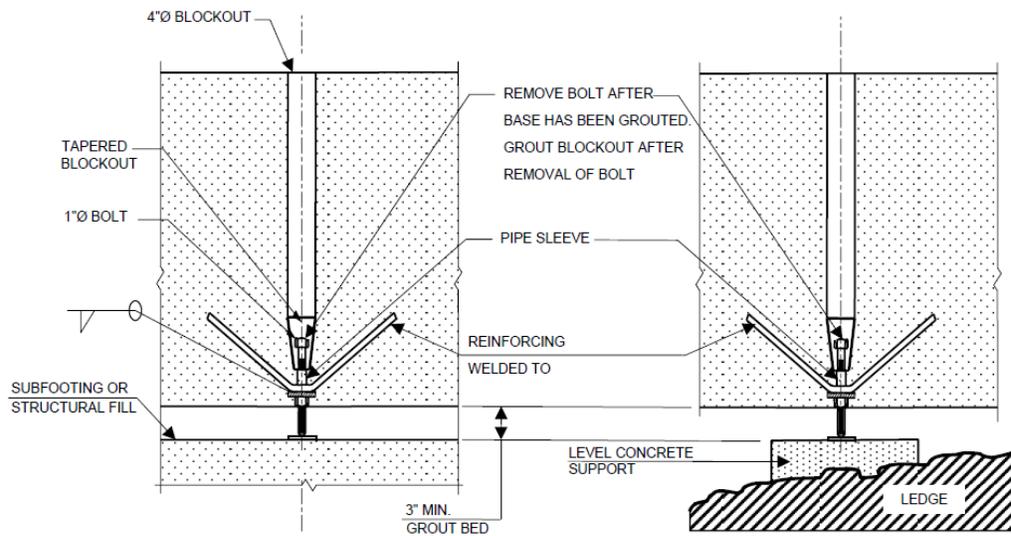


Figure 5: Typical details for levelling devices and grouting over a prepared sub-footing or over cast-in-place supports for uneven conditions. (Source: PCI)



Figure 6: Placement of precast abutment section. (Source: PCI)



Figure 7: Precast abutment with pin connection. (Source: PCI)



Figure 8: Assembly of a precast pier cap. (Source: PCI)

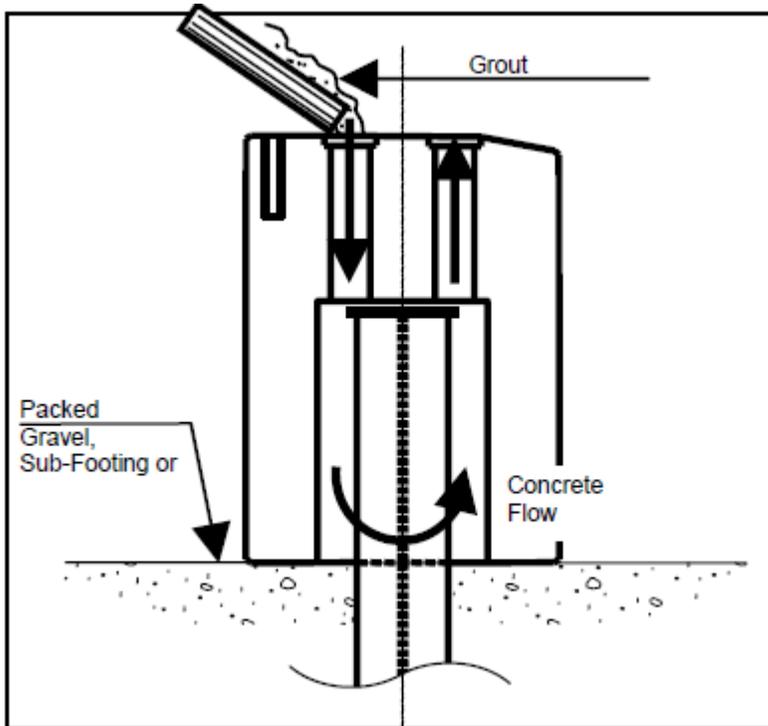


Figure 9: Concrete flow in an abutment section placed over piles. Construction on piles will in general follow the guidelines for construction on soil. A concrete sub-footing may be used, or the footing can be temporarily supported on load distribution plates on soil. (Source: PCI)



Figure 10: Completed integral precast abutment section. (Source: PCI)

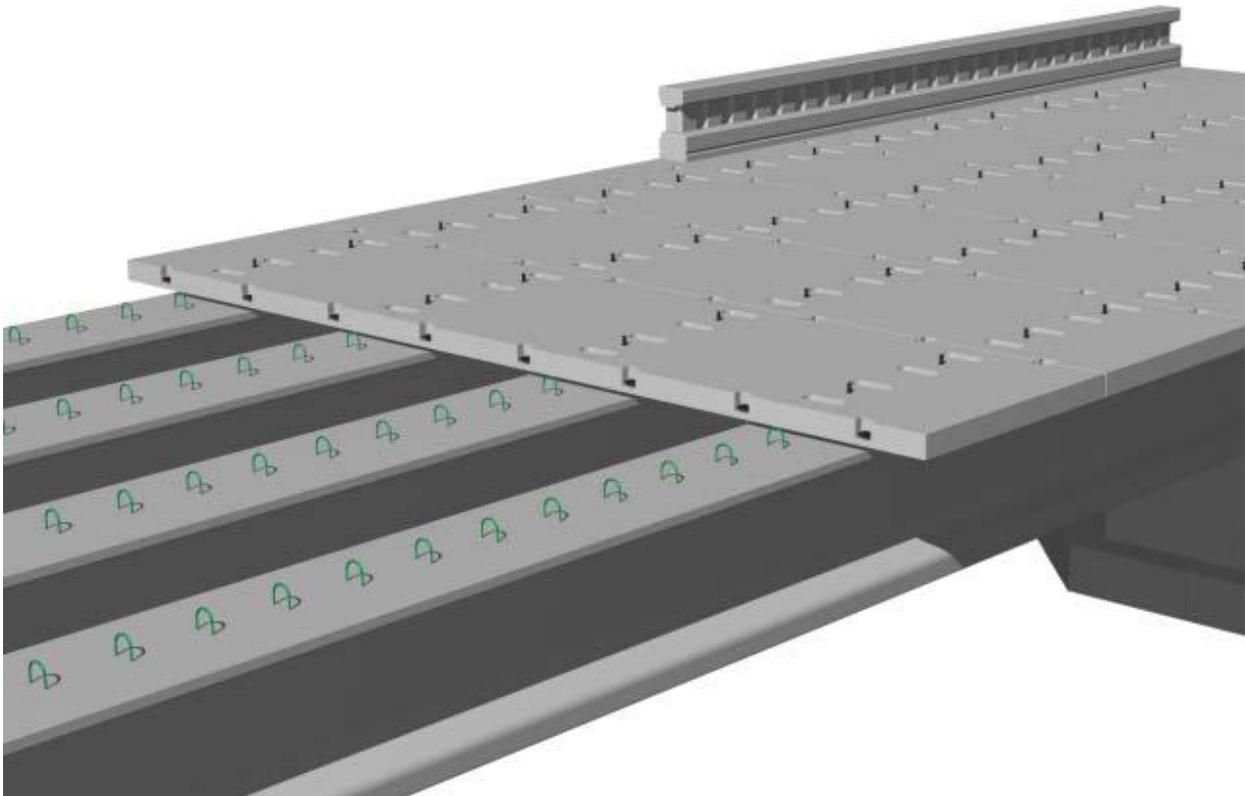


Figure 11: Schematic of precast deck assembly. (Source: PCI)



Figure 12: Placing precast deck slabs. (Source: PCI)

## SECTION 4: JOINTS

This section is divided in to 4 subsections; 4.1 General, 4.2 Layout of Joints, 4.3 Structural Joints, and 4.4 Non structural Joints. In general, the designer should show the proposed layout plans for all joints that form connections in the structure. This layout plan will be used as a guide to determine sizes of components and general construction sequencing. Structural joint details include moment connections for stem joint, cast in place closure pours for horizontal moment joints, and post tensioning details for complex structures (tall piers), or to eliminate closure pours for horizontal moment connections (integral abutment stems, pier caps, etc.). Shear connection details include vertical grouted keys for footing and wall sections. Integral abutment pile connections are demonstrated by providing a block-out in the precast component, and are detailed for designs that develop the full moment capacity of the pile.

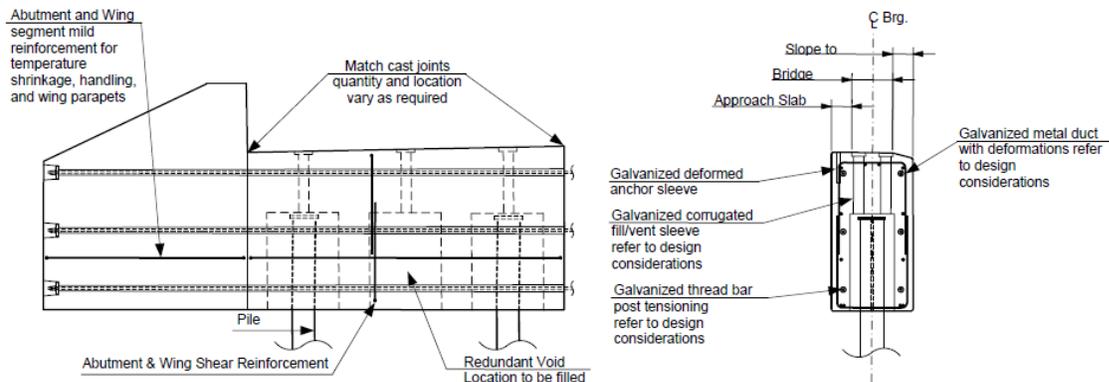


Figure 13: Typical integral pile details. (Source: PCI)

Examples of non-structural joints include retaining wall expansion and contraction joints, joints between different substructure units (abutment to wing-wall interface), and joints in long pier bents (where effects of thermal movement can cause large internal frame forces). They are intended to allow for thermal or differential settlement movement of the adjacent sections of the structure, and to provide fabrication and construction tolerance. These non structural joints do not transfer moment, axial or shear forces between adjacent components.

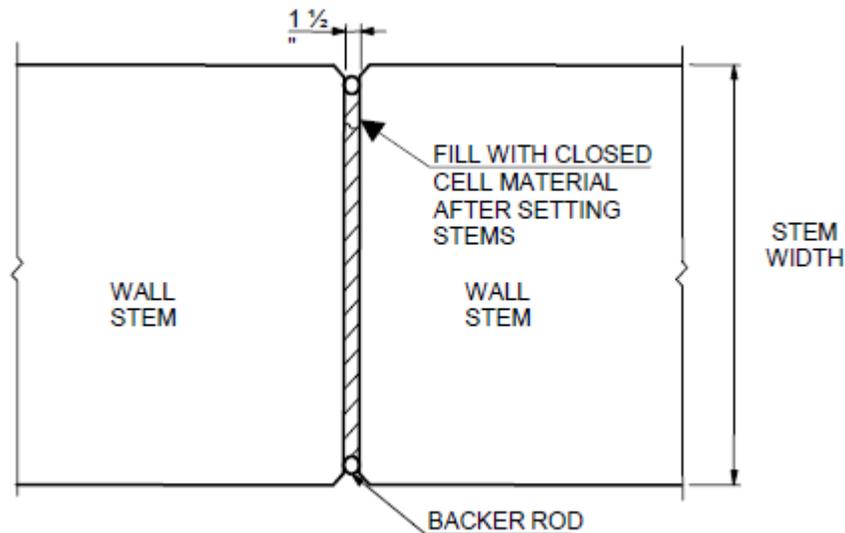


Figure 14: Non structural vertical joint. (Source: PCI)

## SECTION 5: GROUTING

This section includes sub sections on sub footings, component to component grouting, pile caps, post tensioning ducts, and block-outs for anchoring devices. Detailed grouting procedures are also discussed. An example from the manual for grouting of the stem footing joint shown previously in figure 2, follows below:

**Step 1:** Fill the key to just below the lower part of the grouted mechanical splice. The grout should be installed by pouring the grout into the key from the front face of the vertical component and moved through the joint to the back-side of the key to promote complete filling of the joint. This procedure should be started at one end of the joint and proceed continuously along the joint.

The grout placed in step 1 shall be kept out of the mechanical splice by the use of a washer or stopper.

**Step 2:** Grout the mechanical splice.

**Step 3:** Fill the remainder of the key.

## **SECTION 6: SEISMIC CONSIDERATIONS**

The process of designing seismic reinforcement is much the same as for a cast in place concrete structure, however variations in detailing may be required because of the use of precast components. These issues are covered in this section. The section includes subsections; 6.1 General Criteria, 6.2 Connections of Superstructure to Substructure (keeper blocks, pilasters, abutment back wall, anchor rods, integral connections), 6.3 Column Connections (column base and cap, splices along column length, confinement reinforcement, and 6.4 Footings (internal reinforcement, pile uplift). The details in this guideline are based on non-staggered mechanical grouted splices, since the majority of the bridges in the US are in low to moderate seismic zones. Designers can modify the details in this document to satisfy these requirements for higher seismic zones and/or Canadian conditions.

## **SECTION 7: FABRICATION/CONSTRUCTION**

This section includes guidance on lifting devices, handling and shipping, assembly plans, coordination, tolerances during fabrication, inspection, and backfill operations.

The location and design of lifting devices is the responsibility of the precast manufacturer. Locations that are visually sensitive should be identified on the contract drawings. Lifting devices should not be used in these areas if possible. Lifting devices in these areas need to be recessed, easily removed, and patched to match the surrounding concrete. The size of precast components should be finalized by the precaster and contractor with consideration for shipping restrictions, equipment availability and site constraints. The final component sizes will be shown on the assembly plan.

The assembly plan is described as being created by the precaster and contractor and submitted to the owner for approval. It provides detailed information on the contractor's means and methods for assembling the components. The assembly plan should at the very least, include all information required to complete the work such as:

- Engineer of Record for the assembly plan.
- Shop drawings of all components.
- Specific product names and other material requirements for all grout products proposed for use.
- Proposed method of erection and the amount and character of equipment required.
- Temporary support requirements for substructures including levelling screws and/or shims and lateral load and moment resistance requirements for vertical components during assembly.
- Component assembly sequence.
- Tolerance requirements for the assembly of the components.
- Grouting plan.

Fabrication tolerances are according to standard precast practice. Practitioners should specify fabrication of precast/prestressed concrete components from certified plants according to *CPCI*

*Certification Program for Architectural and Structural Precast Products and Systems* (10). The CPCI certification program is designed to qualify manufacturers who fabricate architectural and structural precast concrete. The purpose of this audit based program is to provide owners and designers with the confidence that certified precast concrete manufacturers are qualified to manufacture the products they supply to the marketplace, are competent to provide quality precast and have adequate personnel and facilities. The program is governed by an independent multidisciplinary body and each plant, in addition to having a mandated number of audits annually, also requires a comprehensive Quality System Manual (QSM). The certification ensures conformance to the requirements of CSA Standard A23.4, including Appendices A and B, and the *PCI Manuals for Quality Control, MNL-116 and 117* (11).

## **SECTION 8, 9, AND 10: CASE STUDIES**

Case studies are included in the guide for three U.S. projects. Case Study 1 is of the East B Hill Road in Upton, Maine constructed in 2004. An excerpt from the manual follows:

“This report is a case study on a project under taken by the Maine Department of Transportation in 2004. In September of 2004 the Maine Department of Transportation completed construction of the Andover Dam Bridge in Upton, Maine. The design of the bridge consists of a 65-ft single span, precast, butted box beam superstructure, founded on pile-supported, integral abutments. The bridge is located on a local road in rural Maine, and the use of a long detour and rapid bridge construction techniques were determined more cost effective than the use of a temporary bridge. For this project the use of self consolidating concrete combined with a precast concrete substructure and superstructure enabled the bridge to be constructed while the road was closed for a total duration of 96 hours. This case study discusses the background information, specifics of the new construction, traffic considerations, construction sequence, precast components, and lessons learned by the Department during the construction of this project.”

Case Study 2 is of the Davis Narrows Bridge in Brooksville, Maine constructed in 2004-2005. An excerpt from the manual follows:

“The unique features of the existing Bridge, the sensitive environmental habitat, and the tourist attraction at the Davis Narrows Bridge over the Bagaduce River in Brooksville, Maine created a set of issues that demanded a fast track approach to bridge design and construction. The Maine Department of Transportation after considering several options decided to custom design a single span bridge using all precast elements. The Precast abutments and wingwalls were designed as post-tensioned units over driven piles to reduce excavation, forming and curing time, and to eliminate the use of cofferdams. Extensive geotextiles were used to stabilize the causeways and reduce impacts to Eelgrass patches. The new abutments were installed behind the existing granite block abutments to avoid changes to hydraulics favored by locals and tourists. Precast Box-beams were erected efficiently using a launching girder. The entire project from demolition of the existing bridge to pavement and guardrail installation on the new 89 foot, \$1 million Bridge was completed in only 30 days. The ease with which the bridge was constructed not only impressed the locals but also the Contractor and the Owner.”

Case Study 3 is of the Mill Street Bridge Epping, New Hampshire (12). The Mill Street Bridge project won two awards in the 2005 PCI Design Awards Program – one for Best Bridge design for spans between 20 and 41 m and the other for “Best All-Precast Solution”.

## CONCLUSION

Many Canadian examples of precast/prestressed bridge construction exist (13) which demonstrate its capabilities for fast, efficient erection of substructures and superstructures. To take full advantage of these capabilities requires a consistent approach. The manual *Guidelines for Accelerated Bridge Construction Using Precast/Prestressed Concrete Components* developed in 2006, promotes a greater degree of uniformity among owners, engineers and industry with respect to planning, designing, fabricating and constructing prefabricated concrete highway bridges.

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