Chapter 14 Accelerated and Innovative Bridge Construction

Contents

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14.1 Introduction

14.1.1 General

The purpose of this chapter is to provide guidance for the planning and implementation of projects that may benefit from the application of rapid bridge construction technologies and methods. This chapter was prepared to provide bridge engineers with a basic understanding of different Accelerated Bridge Construction (ABC) methods available, help guide project specific selection of ABC methods, and to encourage the use of the ABC methods described in this chapter, or other innovative approaches to rapid bridge construction. It was also prepared to provide guidance with the design and detailing of precast concrete superstructure and substructure elements for accelerated bridge construction. For the sake of this chapter, ABC and Innovative Bridge Construction are encompassed in the term "ABC."

This chapter is written in accordance with the AASHTO *Guide Specifications for LRFD Bridge Seismic Design*, 2nd Edition (SEISMIC). It is WSDOT's application of the Federal Highway Administration's Every Day Counts. It is intended to compliment the AASHTO *LRFD Guide Specifications for Accelerated Bridge Construction*, 1st Edition (LRFD-ABCGS).

Modern implementations of ABC have been demanded by tight traffic control requirements in urban areas. Bridges used to be constructed on new alignments, connecting communities together in modern ways for the first time where there was no traffic and lower demand to travel from one community to another. Prior to modern times, the advancements made during the Industrial Revolution in new materials and construction techniques sped up construction. We saw bridge construction transform from stone construction used in ancient times, to include steel, concrete, and members subject to much larger forces than in the past. It's the expressed desire here to apply the benefits of new advancements in materials and construction techniques to a wider array of projects and take the position of minimal time on site as the expectation of every project.

The goal of ABC is to deliver projects earlier to the traveling public, reducing the impacts of on-site construction to motorists, promoting traveler and worker safety, and reducing environmental impacts. ABC uses different methods of project delivery and construction to reduce the project schedule, on-site construction time, and public impact. With the ever increasing demand on transportation infrastructure, and the number of bridges that are approaching the end of their service lives, the need for ABC becomes more apparent. ABC should be viewed as a subset of a larger accelerated project delivery effort encompassing all aspects of project development including contract administration through construction contract acceptance.

ABC methods are generally safer than conventional construction methods because much of the construction can be done offsite, away from traffic. Quality can also be improved because the construction is often completed in a more controlled environment compared to on-site conditions. Ease of construction and design can be improved as standardized bridge pieces are developed. The use of ABC comes with challenges that need to be overcome on a project-specific basis, often accelerating the schedule increases the cost of the project. This increased project delivery cost can be offset by reductions in road user costs and economic loss to the affected communities.

14.1.2 ABC Methods

Many different methods to facilitate ABC are available. Some of those methods are discussed in greater detail later in this chapter. They include the following:

- precast bridge piers
- geosynthetic reinforced abutments with precast slab or deck girder superstructures
- precast decks
- precast footings
- entire precast abutments

Installation of these bridge elements can be aided with use of lateral sliding of large bridge members or self-propelled modular transporters, or heavy cranes. Contractually, ABC can be aided with the use of alternate project delivery methods, such as Design-Bid-Build, Design-Build or General Contractor/Construction Manager.

14.2 Application of ABC

14.2.1 Economics of ABC

Long construction time allotments may provide for a cheaper bottom line on a project, but they introduce a number of unassigned risks that provide an intangible cost to the contractor, and ultimately to the public.

Construction times have significant economic cost to the public through traffic delays and interruption to commerce. It may come as longer traffic jams in already busy urban areas, or as crowded interstates between urban centers, especially on holiday weekends, and subsequent traffic jams on local roads adjacent to the highway.

Another cost to consider is that which results from unfamiliar technologies. Until ABC methods are more fully understood by contractors, the estimated costs of the intangible and unfamiliar things will likely be higher than methods common today. This is due to the added risk associated with those unfamiliar construction techniques. With more exposure and familiarity come lower costs as the contractors develop their means and methods.

14.2.2 Practical Applications

Locations where time is critical, or access is difficult are where ABC Construction methods would be most fully utilized. Building piers in busy highway medians, installing columns in waters with narrow fish window times, or building bridges on mountain roads far from concrete production facilities are excellent places to consider ABC. ABC Methods may also be fitting for construction over a large body of water, where access is difficult and heavy moving equipment, perhaps on a barge, is easy to bring to the site. Pouring concrete underwater can be difficult, and perhaps installing a precast element in the water may be easier than constructing a coffer dam.

Other locations to consider are where the overall footprint of a job site may be a concern. Realize that accessing the connections of precast members can take up a lot of space and may not be necessary. Rebar would come with the precast member instead of being placed before the concrete, eliminating the need for access for workers and equipment near to the ends of the precast member. By moving more duties off site, less space is needed on site, and the offsite location could be at a less sensitive location. If there were concerns with disturbing the adjacent ground, smaller construction sites near a bridge could be beneficial.

Bridge designs with many similar pieces, such as long retaining walls, bridge decks, or bridges with many piers are also good candidates for ABC. The smaller pieces can be shipped in on semi-trucks and placed immediately. The repetition would bring more economic value to the ABC component of the project and bring the cost of the precast piece down.

Often precast pieces can be used to provide a structural shell that will serve multiple purposes. Precast pieces can be used to form a caisson or a coffer dam that will define a dry work zone which would be filled in with concrete later. The shell could simply provide a void that makes shipping a piece easier, which will get filled with concrete when another bridge portion is poured.

Construction schedules can make ABC worth considering. Lateral sliding of bridge superstructures have been used such that an existing bridge can remain until the critical moment where one bridge is rolled out, and a new one rolled in. Months of construction can take place next to the location the bridge would be used, and in a matter of hours the new structure could be slid into place.

In general, where time on a job site ought to be minimized, ABC would make a good choice to consider.

14.2.3 Prefabricated Bridge Elements and Systems

For the sake of bridge design, use of Prefabricated Bridge Elements and Systems (PBES) is one strategy that can meet the objectives of accelerated bridge construction. PBES are structural components of a bridge that are built offsite, or near-site of a bridge, and include features that reduce the onsite construction time and mobility impact time that occur from conventional construction methods. PBES includes innovations in design and high-performance materials and can be combined with the use of project delivery and material procurement methods that invoke faster on-site construction. Because PBES are built off the critical path and under controlled environmental conditions, improvements in safety, quality, and long-term durability can be better achieved.

14.2.3.1 Prefabricated Bridge Elements

Prefabricated bridge elements (PBE) are a single structural component of a bridge built using PBES methods. PBE can be used in combination with other accelerated bridge construction methods. Commonly used WSDOT prefabricated bridge elements are Wide Flange-girders, Deck girders, Tub girders, Slab girders, stay-in-place concrete deck panels, prefabricated pier crossbeams, pier columns, and footings, as well as precast three-sided and four-sided box culverts. For a list and definition of additional specific prefabricated elements refer to section 1.3.2 to 1.3.7 of LRFD-ABCGS.

Prefabricated bridge elements are used to reduce the on-site time required for concrete forming, rebar tying and concrete curing, saving weeks to months of construction time. Deck girder elements eliminate conventional onsite deck forming activities. To reduce onsite deck forming operations, deck girder elements are typically placed in an abutting manner.

Prefabricated elements are often of higher quality than conventional field-constructed elements, because the concrete is cast and cured in a controlled environment. The elements are often connected using high strength grout, and post-tensioning or pre-tensioning. Connection strength is an important consideration and close attention shall be given to their design. There are many tools available to provide durable, high strength connections. Their design and details shall follow the guidance given in LRFD-ABCGS section 3.6 Connection Design and Detailing.

14.2.3.2 Prefabricated Systems

Prefabricated Systems are a category of PBES that consists of an entire superstructure, an entire substructure, or a total bridge that is procured in a modular manner such that traffic operations can be allowed to resume after placement. Prefabricated systems are rolled, launched, slid, lifted, or otherwise transported into place, having the deck and preferably the barriers in place such that no separate construction phase is required after placement. Due to the manner in which they are installed, prefabricated systems often require innovations in planning, engineering design, high-performance materials, and structural placement methods.

Benefits of using prefabricated systems include:

- Minimal utility relocation and right-of-way take, if any at all
- No-to-minimal traffic detouring over an extended period of time
- Preservation of existing roadway alignment
- No use of temporary alignments
- No temporary bridge structures
- No-to-minimal traffic phasing or staging

For a list and definition of prefabricated systems refer to section 1.3.8 of LRFD-ABCGS.

14.2.5 Project Delivery Methods

At WSDOT, region engineers determine which project delivery method to be employed. *Design Manual* M 22-01 describes the policy and process for determination of the most appropriate project delivery method.

14.2.6 Decision Making Tools

Figures 14.2.6-1 and 14.2.6-2 are tools that may be used for each bridge project, and considered at the Preliminary Plans stage of each project, or sooner. These tools are intended to be used together. It is expected each project will consider ABC to some degree. The questionnaire and flowchart provide some rational measure for how well suited a project may be for ABC.

The questionnaire is intended to review the entire project, including items beyond the immediate interests of the bridge, and assign a measure of relevance and priority to each item of concern. This assures that not only is a specific item being considered, but so is its significance to the project. The relevance value should be multiplied by the priority value for each question. The product of each of those numbers shall be added up at the bottom of the questionnaire, and that number will be the ABC Rating.

The flow chart is intended to be a situational evaluation regardless of magnitude or relevance of other items. To use the flowchart, the ABC Rating needs to be determined from the questionnaire, and the path one takes through the flowchart is based upon that rating. The outcome of the flow chart will provide the designer with a recommendation to either pursue the ABC approach or to use conventional methods.

Figure 14.2.6-1 ABC Questionnaire

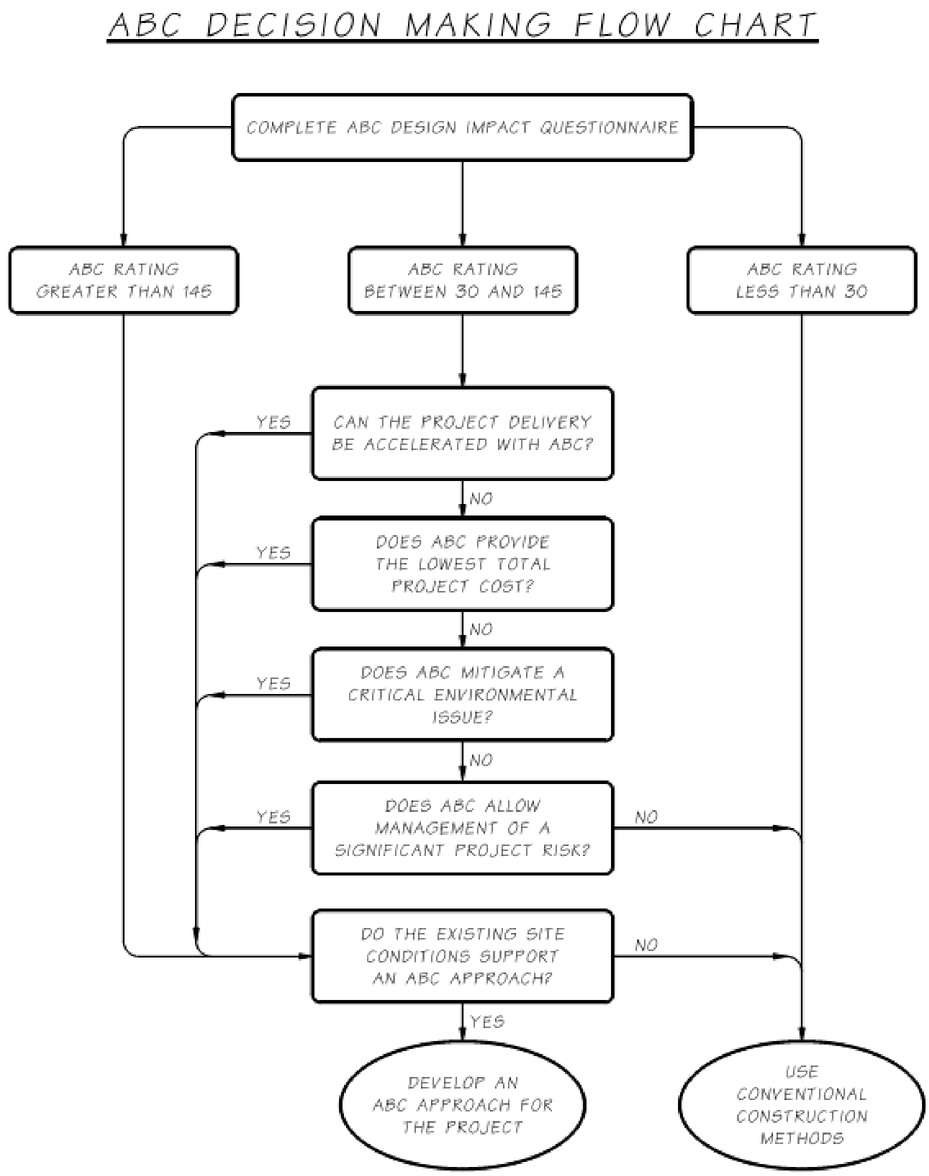
ABC DESIGN IMPACT QUESTIONNAIRE

PROJECT:

DATE:
COMPLETED BY:

CATEGORY	DECISION MAKING QUESTION	(R) RELEVANCE RANGE 0 = N.A. 1 = LOW TO 5 = HIGH	(P) PRIORITY RATING 1 = LOW 2 = MEDIUM 3 = HIGH	(R x P) SCORE
CONSTRUCTION TIME	ARE THERE WEATHER LIMITATIONS FOR CONVENTIONAL CONSTRUCTION?			
	IS THERE RESTRICTED CONSTRUCTION TIME DUE TO ENVIRONMENTAL SCHEDULES?			
	IS THERE RESTRICTED CONSTRUCTION TIME DUE TO ECONOMIC IMPACT?			
	HAS THE REGION EXPRESSED DESIRE TO COMPLETE THE BRIDGE CONSTRCUTION IN ONE SEASON?			
	IS THE BRIDGE CONSTRUCTION ON A CRITICAL PATH OF THE TOTAL PROJECT?			
ENVIRONMENTAL	DOES ABC MITIGATE A CRITICAL ENVIRONMENTAL IMPACT, ARCHAEOLOGICAL CONCERN, OR OTHER SENSITIVE ISSUE?			
USER COSTS AND DELAYS	DOES THE BRIDGE CARRY, OR IS IT OVER A ROUTE WITH A HIGH ADT AND/OR ADTT?			
	WOULD ABC SIGNIFICANTLY IMPROVE THE TRAFFIC CONTROL PLAN?			
	ARE ONLY SHORT TERM CLOSURES ALLOWED?			
	WILL CONVENTIONAL CONSTRUCTION CAUSE A SIGNIFICANT DELAY OR DETOUR TIME?			
	WILL BRIDGE CONSTRUCTION HAVE AN ADVERSE IMPACT ON THE LOCAL ECONOMY?			
SITE CONDITIONS	ARE THERE EXISTING RAILROADS THAT IMPACT THE CONSTRUCTION WINDOW OR ACTIVITIES?			
	ARE THERE EXISTING UTILITIES THAT IMPACT THE CONSTRUCTION WINDOW OR ACTIVITIES?			
	DOES THE SITE CAUSE PROBLEMS FOR CONVENTIONAL CONSTRUCTION METHODS?			
	IS THE BRIDGE OVER A WATERWAY?			
RISK MANAGEMENT	DOES ABC IMROVE WORKER SAFETY?			
	DOES ABC IMPROVE TRAVELER SAFETY?			
	DOES ABC ALLOW MANAGEMENT OF ANOTHER SPECIFIC RISK?			
OTHER	WILL REPETITION OF ELEMENTS ALLOW FOR ECONOMY OF SCALE?			
		TOTAL SCORE = ABC RATING =		

Figure 14.2.6-2 ABC Flow Chart



14.3 Structural Systems

This section describes a few structural systems that an engineer may wish to consider. These systems are ones WSDOT has reviewed and developed to a level that is ready for production work. This section discusses the precast bent system. WSDOT has worked closely with researchers and industry in the development of the precast bent system for high seismic regions and supports it use in appropriate applications.

14.3.1 Precast Bent System Design for High Seismic Regions

This system is often referred to as the Highways for Life (HfL) system, Precast Pier System, or Precast Bent System. It's configured to be used with precast girder superstructures that are supported on crossbeams that are constructed in two phases. The first or lower-stage crossbeam is constructed, the girders are then set on this beam, and finally the second or upper-stage crossbeam is constructed using cast-in-place concrete to integrate the superstructure and substructure. This precast bent system is an adaptation of a common type of reinforced concrete bent or pier construction used throughout the United States. It utilizes the grouted duct technology developed through university research.

Unique features of the precast bent system are a socket connection at the column-to-foundation connection and a grouted-duct arrangement at the column-to-crossbeam connection. This system utilizes precast columns and precast lower-stage crossbeams. The system also can include splices in the column to facilitate weight control for the columns, whereby splitting the column into multiple segments. This can control the weight of precast elements that must be transported. Similarly the precast crossbeam can be split into segments for the same reason. Both of these splice connections are configured to be capacity protected for seismic forces. The lower column socket connection has also been configured to be used with spread footings, pile caps and drilled shafts.

Design criteria for these connections shall follow the LRFD-ABCGS specific guidelines in Section 3.6.

A demonstration project was constructed using this technology on a bridge in Washington State over Interstate 5, Bridge Number 12/118. The details of the design for this project are included in the paper "*Accelerated Bridge Construction in Washington State: From Research to Practice*" in the Fall 2012 PCI Journal, and so are construction photos and a lessons-learned section relating the contractor's feedback following construction. The development and deployment of this technology has been a success, and the owner, the Washington State Department of Transportation, continues to look for opportunities to apply the technology, along with other methods, to accelerate bridge construction in the state.

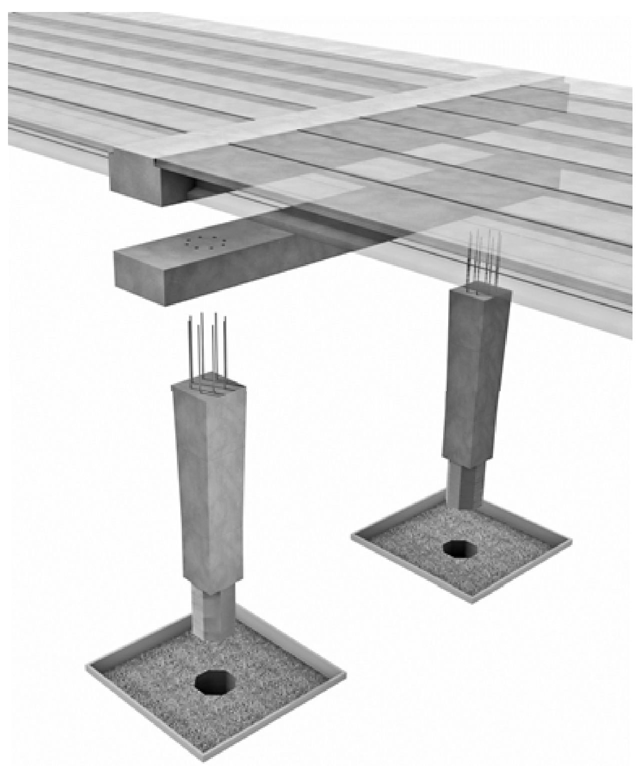
14.3.1.1 Description of System

The bent system is comprised of precast columns supported by either spread footings or drilled shafts and a precast crossbeam that supports pre-stressed concrete girders. The bent is integrated with the superstructure using a cast-in-place concrete diaphragm. The crossbeam thus created is a two-stage dropped crossbeam with the lower precast portion known as the first stage crossbeam and the upper diaphragm known as the second stage of the crossbeam. The bridge deck slab is cast on top of the girders and diaphragm. This concept is illustrated in Figure 14.3.1.1-1.

The system consists of a socket connection at the foundation level and a grouted bar connection to the crossbeam. The foundation must be cast around the precast column to form the socket connection, and the interface between the column and foundation must be intentionally roughened to ensure vertical load carrying capacity. In the HfL Bent System, the connection to the crossbeam is intended to consist of large diameter bars such that fewer bars are required. These bars are grouted into steel ducts with generous diameters relative to the bars, 2 to 3 inches larger in diameter, to facilitate fit up as shown in Figure 14.3.1.1-1.

For many typical bridges a single precast column element is sufficient. However, the segmental column concept was included in the validation and HfL demonstration project.

Figure 14.3.1.1-1 Precast Bent System, Exploded View



14.3.1.2 Design Philosophy

This process emulates cast-in-place connections with precast elements. CIP construction joints are typically detailed with dowels and lap splices. Emulation design replaces the traditional lap splice with a grouted duct sleeve. The design of column connections is especially difficult for high seismic zones. Confinement of column reinforcing is possible with precast concrete elements. The AASHTO design specifications do not mandate the confinement reinforcing bars be continuous from the column into the adjacent members footing or crossbeam. The confinement reinforcing can be terminated in the column and separate confinement reinforcement can be added to the adjacent element.

14.3.1.3 Design Provisions

Design of precast bent systems shall meet the criteria specified in Section 3.4 of AASHTO LRFD-ABCGS. The seismic analysis and design method shall be displacement-based design per Section 3.4.1.3 of AASHTO LRFD-ABCGS.

Interior joints of multi-column bents shall be considered “T” joints for joint shear analysis. Exterior joints shall be considered knee joints and require special analysis and detailing that are not addressed herein, unless special analysis determines that “T” joint analysis is appropriate for an exterior joint based on the actual bent configuration. Criteria to establish appropriate design and detailing provisions for exterior joints shall be approved by the Bridge Design Engineer.

14.3.1.3.1 Socket-Type Footing Connections

Where socket-type connections are used to connect precast columns to CIP spread footings or pile caps, the following requirements shall be followed.

The interface of the precast column with the footing shall be intentionally roughened to a minimum amplitude of 0.70 in. The column-to-footing shear interface shall be designed for interface shear using Section 5.7.4 of AASHTO LRFD-BDS. To account for potential shrinkage cracking around the column, the cohesion factor, c, shall be taken as zero. The friction factor, μ, and the factors, K_1 and K_2 may be taken as those for normal weight concrete placed against a clean concrete surface.

14.3.1.3.2 Drilled Shaft

Where socket-type connections are used to connect precast columns to drilled shafts the column-to-shaft side interface shall be intentionally roughened to a minimum amplitude of 0.70 in.

14.3.1.3.3 Precast Column

Precast columns and crossbeams that are used with the HfL bent system are covered by Section 8 of AASHTO LRFD-SGS. The columns of such systems are not considered precast concrete piles.

A. Interface Shear Transfer Capacity of Precast Bent Systems

The interface shear capacity between precast column and crossbeam or between segments of precast columns shall be determined using Section 5.7.4 of AASHTO LRFD-BDS. To account for cyclic loading effects and the potential for significant cracking, the cohesion factor, c, shall be taken as zero and the friction factor, μ, shall be 0.60. The factors, K_1 and K_2 shall be 0.2 and 0.8 ksi, respectively.

14.3.1.4 Geometry and General Requirements

The following geometric requirements shall apply to precast bent systems without requiring approval of the WSDOT Bridge Design Engineer:

- Columns shall be located under crossbeams.
- Grouted ducts shall have their centerlines oriented plumb.
- Footings abutting precast columns shall be poured around the end of the column.
- Grouted duct connections are not allowed in footings.
- Precast columns shall not be connected to precast footings.
- Crossbeam splices shall be located at points of contraflexure in the crossbeam and not within B_{eff} of the column, as defined in Section 3.6.12 of AASHTO LRFD-ABCGS..
- Column splices shall incorporate grouted ducts on at least one abutting end of a column within a joint. Rebar that is expected to protrude into a duct shall be cast with the rest of the column segment.
- Concrete segments may be constructed on site or at a precast manufacturing facility.
- WSDOT's *Standard Specifications* M 41-10 shall apply.

14.3.2 Geosynthetic Reinforced Soil Integrated Bridge System

The Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS) described in AASHTO LRFD-ABCGS may be used but shall follow the design criteria given in BDM Section 7.5.2.

Proprietary SE walls supporting abutments shall not be considered preapproved, and shall not be used beyond the limits described herein unless approved by the WSDOT State Geotechnical Engineer and the WSDOT Bridge Design Engineer.

14.3.3 Precast Decks

Full-depth precast deck panels and connections shall follow the requirements In LRFD-ABCGS Section 3.6.8

14.3.4 Link Slabs

Link slabs as defined in LRFD-ABCGS 1.3.7 shall not be used.

14.4 Innovative Bridge Construction

Innovative Bridge Construction is simply an idea that encourages outside the box thinking encouraging engineers to consider principles that will enhance bridge performance, speed up construction, or add any other benefit to the industry. There is no single or handful of ideas that can contain or describe Innovative Bridge Construction. It's simply a mentality that new ideas ought to be explored. Innovation might be defined as any contribution to the bridge industry that takes bridge construction past the current standard practice of bridge construction. Some items produced recently are described in the following sections.

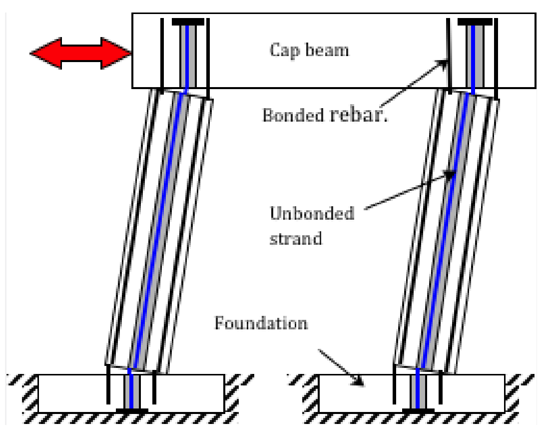
14.4.1 Self-Centering Columns

Self-centering columns are columns designed to restore much of their original shape after a seismic event. They're intended to improve the serviceability of a bridge after an earthquake.

Self-centering columns are constructed with a precast concrete column segment with a duct running through it longitudinally. They rest on footings with post-tensioning (PT) strand developed into them. Once the precast column piece is set on the footing, the PT strand threads through the duct and gets anchored into the crossbeam above the column. The PT strand is unbonded to the column segment. As a column experiences a lateral load, the PT strand elastically stretches to absorb the seismic energy and returns to its original tension load after the seismic event. The expectation is the column would rotate as a rigid body and the PT strand would almost spring the column back to its original orientation.

A depiction of the self-centering concept is shown in Figure 14.4.1-1.

Figure 14.4.1-1 Self-Centering Column Concept

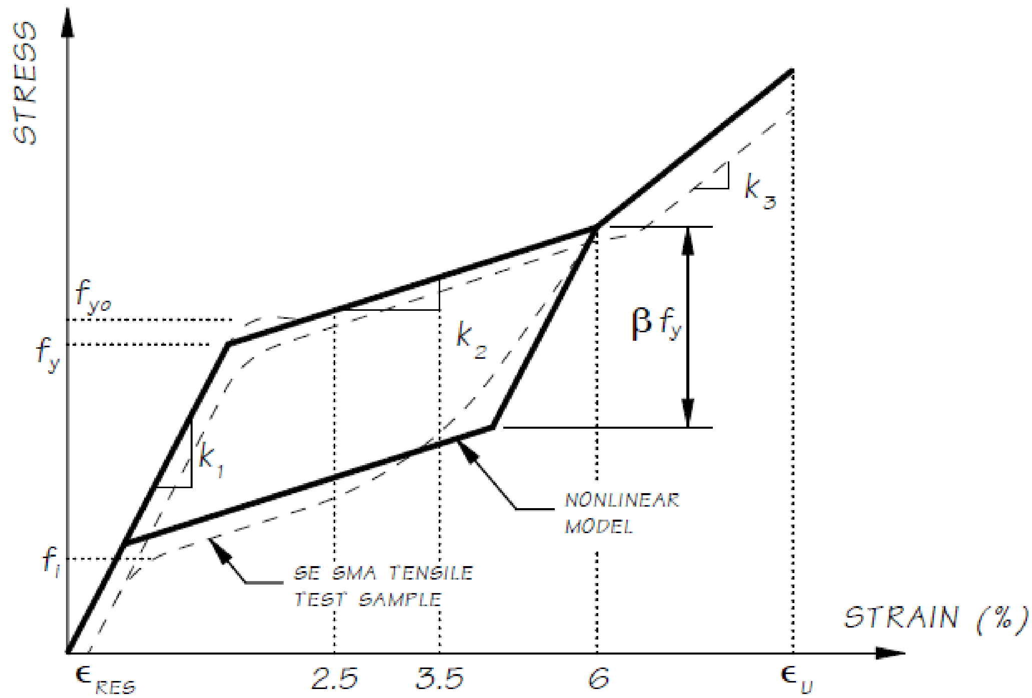


14.4.2 Shape Memory Alloy

Like self-centering columns, Shape Memory Alloy (SMA) and Engineered Cementitious Composite (ECC) products are introduced into bridge design as a means to improve ductility, seismic resilience, and serviceability of a bridge after an earthquake.

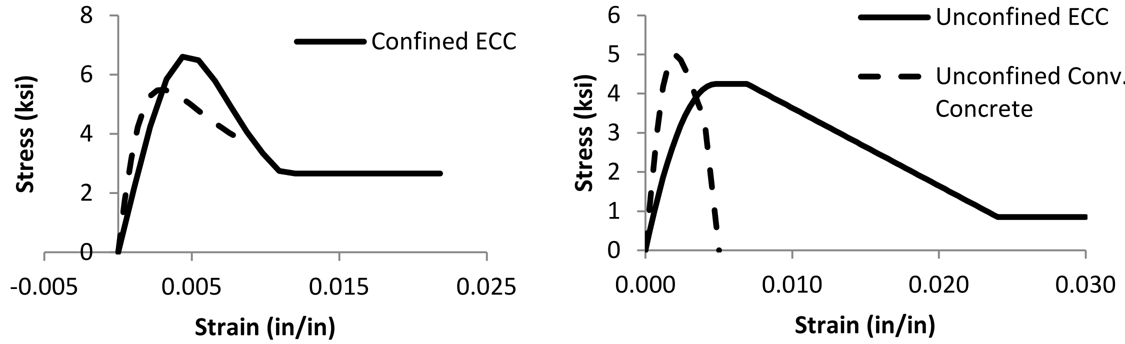
SMA is a class of alloys that are manufactured from either a combination of nickel and titanium or copper, magnesium and aluminum. The alloy is shaped into round bars in sizes similar to conventional steel reinforcement. When stressed, the SMA can undergo large deformations and return to original shape. This deformation can be recovered by either the application of heat (Shape Memory Effect) or removal of stress (Superelastic or Pseudoelastic effect) (Lagoudas 2008 and Hodgson 1990). Figure 14.4.2-1 shows the stress-strain profile for loading and unloading of SMA. The SR 99 Alaskan Way Viaduct Replacement – South Access project demonstrated that yield strengths of 55 ksi can be achieved with an initial modulus of elasticity of approximately 5400 ksi. Under service and strength limit states the SMA in the column is designed similarly to traditional mild reinforcement, the stress in the bar is limited to the yield strength. During a seismic event, when the yield stress is exceeded, the bars deform trilinearly and restore to the undeformed state as the stress dissipates.

Figure 14.4.2-1 Shape Memory Alloy Stress-Strain Model



ECC is in the family of High Performance Fiber Reinforced Cementitious Composites and is similar to traditional concrete mixes, except that the mix includes a polyvinyl alcohol fiber and omits the course aggregate. ECC replaces conventional concrete in columns to provide a moderate tensile strength and increase ductility to accommodate the large deformations of the SMA. The use of ECC eliminates the spalling expected of conventional concretes in the hinge region. Figure 14.4.2-2 shows the stress-strain profile comparison of confined and unconfined ECC ($f`_c$ = 5 ksi) and conventional concrete ($f`_c$ = 4 ksi)(Li 2007 and Xu 2010).

Figure 14.4.2-2 Engineered Cementitious Concrete Stress-Strain Model

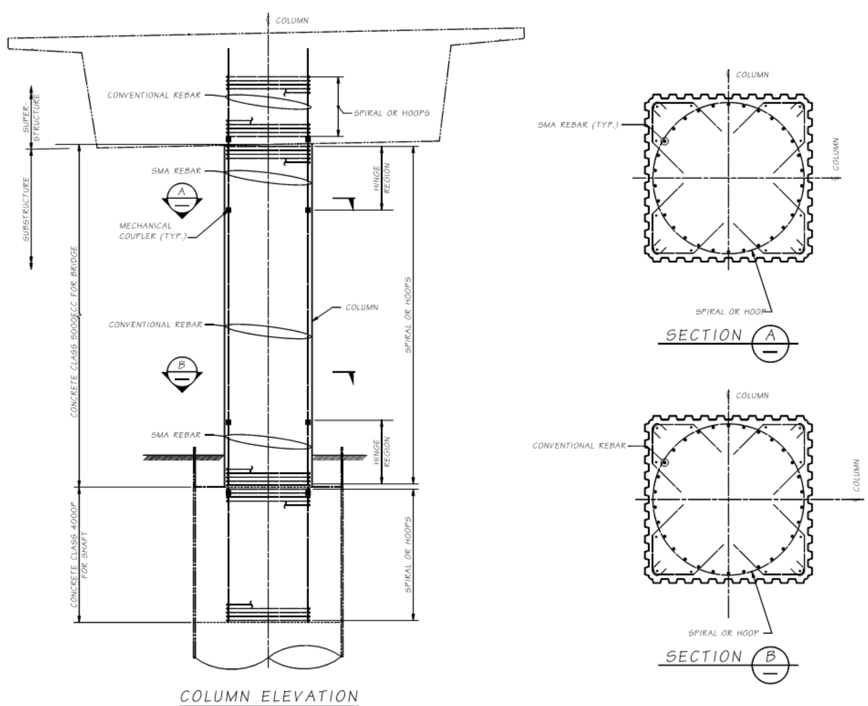


When combined in the plastic hinge zones of bridge columns, the SMA and ECC materials are designed to provide high levels of strain with a super-elastic performance to allow for large deflections with negligible permanent deformation and minimal damage. This combination of materials provides the ductility a bridge column needs to perform well in a seismic event while providing enough elasticity to restore the bridge closer to its original shape than conventional concrete and rebar, even with proper detailing (Cruz 2012).

Bars fabricated with SMA are coupled with conventional steel reinforcing located outside the plastic hinge region to reduce the amount of SMA used in the bridge column. The engineered cementitious material can be poured within the plastic hinge region separately from the rest of the column concrete.

An example of a column with ECC and SMA reinforcing in the plastic hinge regions is shown in Figure 14.4.2-3.

Figure 14.4.2-3 Shape Memory Alloy and Engineered Cementitious Column (Elevation and Sections)



14.5 Shipping, Handling and Erection

14.5.1 Lifting Devices

Lifting locations for precast elements shall be shown in the design plans. The engineer is responsible for checking the handling stresses in the element for the lifting locations shown on the plans. Elements shall be designed using the following general criteria:

For stripping from the form, use two point picks for columns and pier crossbeams, similar to prestressed beams. Columns will require additional pick points for tipping into the vertical orientation during erection. Wall panels generally require four or more pick points when lifting horizontal and additional pick points for tipping into the vertical orientation during erection.

- Use an allowable stress of $0.16\sqrt{f'_c}$ on the static tensile stress in the concrete during handling. This is typical in the industry and provides a 50 percent buffer against exceeding the modulus of rupture during handling.
- Do not show specific lifting hardware on the drawings. Verify that at least one lifting hardware manufacturer can provide a device that can resist the anticipated loads. Consider reducing the size of the element or switch to a more sophisticated lifting system if no manufacturer can meet the required resistance. Consult with fabricators for these situations.

The contractor may choose alternate lifting locations with approval from the engineer. The contractor will provide the spacing and location of the lifting devices and submit plan and handling stress calculations for approval prior to construction of the element.

Unless buried in a subsequent cast-in-place concrete pour, lifting devices shall be recessed a minimum of 1” below the exposed surface of the precast element. Recesses at the lifting devices shall have a roughened finish. Some recesses are formed and cannot be broomed during finishing. In those cases a surface retarder can be used to provide a roughened surface. After the element is placed in its final position, the lifting device shall be removed to the base of the recess and the recess shall be filled with structural non-shrink grout or other approved patching material. In some cases the recess may be on a vertical surface and non-shrink grout may not be feasible.

14.5.2 Handling, Storage and Shipping

The contractor is responsible for the handling, storage and shipping of precast elements in such a manner that does not cause undue stress on the element. The contract specifications shall require the contractor to submit a handling, storage and shipping plan to the engineer for review prior to the construction of any element.

14.5.3 Tolerances

The tolerance of casting elements is critical to a successful installation. One of the most important tolerances is the location of the grouted duct splices. Make the dimension measurements from a common working point or line in order to specify tolerances of critical elements. Templates shall be used where practical. Center to center measurements can lead to a build-up of tolerance errors.

The typical detail drawings shall include details of maximum allowable tolerances. Include these details in all precast substructure projects.

Include a requirement in the project specifications that templates shall be used. Details of the templates shall be shown in the shop drawings. Note that erection tolerances are also extremely important, especially with placement of the crossbeam on multiple columns prior to installation of the elements at the bridge site. This is especially true for grouted splice couplers. Verify the spacing of the couplers as well as their orientation within the element. The splice reinforcement is often left longer than required in the fabrication yard so that the bars can be cut the exact length in the field as the construction progresses. The dry fit can still be done in this case with the longer bars.

14.5.4 Assembly Plans

Most bridge construction projects require contractors to submit erection plans for bridge girders. Prefabricated substructures require an even higher level of pre-construction planning. The contract specifications shall include requirements that the contractor submit an assembly plan for the construction of the entire structure including the precast substructure.

Include as a minimum the following in the assembly plan:

- size and weights of all elements
- minimum curing time of elements before shipping to the site
- picking points of all elements
- sequence of erection
- temporary shoring and bracing
- grouting procedures
- location and types of cranes
- a detailed timeline for the construction including time for curing grouts and closure pours

14.5.5 Element Sizes

The size of precast concrete substructure elements can become an issue for elements that need to be shipped long distances. For precast elements requiring shipping, use the following general guidelines for sizing precast concrete substructure elements:

- **Width**

  Keep the width, short dimension, of the element and any projecting reinforcing below 14 feet. This is to keep the widths reasonable for shipping.

- **Height**

  Keep the maximum height of any element including any projecting reinforcing less than 10 feet so the element can be transported below existing bridges.

- **Length**

  Length ought to be considered to ensure the load can be distributed well with conventional shipping equipment.

- **Weight**

  Keep the maximum weight of each element to less than 100,000 pounds in order to keep the size of site cranes reasonable.

The above limits can be increased for some projects, particularly where precast elements are not required to be shipped to the site. The designer can work with both the fabricator and contractor to size the elements based on the available equipment and the proposed shipping routes.

For large pieces, weight can be managed to make the precast pieces more workable. Weight can be minimized with lightweight concrete, voids, or smaller pieces with more joints.

14.6 Installation Method Options

Installation methods should be determined by the contractor. Designers shall include a suggested construction sequence as part of the contract plans. Considering means of installation is important for any engineering task one pursues. But it is especially important for ABC since so much of the cost will be driven by the constructability of the project.

There are a multitude of installation methods available for the construction of ABC projects. Besides the standard method of lifting and placing precast elements with mobile cranes, construction could be achieved by pivoting, launching, lateral sliding, lifting from overhead with gantry cranes, or even lifting from underneath with self-propelled modular transporters.

General information for placement by cranes is similar to that given for prestressed girders in Sections 2.3.4, and 2.6.2 of the BDM, with the exception of limiting sizes and weight which should follow Section 14.5.

Lateral sliding and self-propelled modular transporters have both been used on significant WSDOT projects.

14.6.1 Lateral Slide Systems

Bridge placement using lateral sliding is a type of ABC where the entire superstructure is constructed in a temporary location and is moved into place over a night or weekend. This method is typically used for bridge replacement of a primary roadway where the new superstructure is constructed on temporary supports adjacent and parallel to the bridge being replaced. Once the superstructure is fully constructed, the existing bridge structure is demolished, and the new bridge is moved transversely into place.

Lateral sliding can be used for switching out a new and old superstructure. It may also be used for moving an existing bridge to a new alignment, in effort to make room to build a new bridge at the original alignment.

Refer to AASHTO LRFD-ABCGS section 1.6 for design requirements and general information concerning the use of Lateral Slide Systems.

14.6.2 Self-Propelled Modular Transporter Systems

Self-Propelled Modular Transporters (SPMT) are remote-controlled, self-leveling, multi-axle platform vehicles capable of transporting several thousand tons of weight. SPMTs have the ability to move laterally, rotate 360° with carousel steering, and typically have a jack stroke of 18 to 24 inches. They have traditionally been used to move heavy equipment that is too large for standard trucks to carry.

Refer to AASHTO LRFD-ABCGS for design requirements and general information concerning the use of SPMTs.

14.7 Examples of Accelerated and Innovative Bridge Construction

A document with examples of WSDOT projects where ABC has been utilized is on the Bridge and Structures' ABC website. This document includes a brief description of the benefits and reasons for using ABC in the project and the lessons learned. Below is a list of the types of construction and the projects that used each type.

Lateral Sliding

I-5, Skagit River Bridge – Bridge No. 5/712
Mount Vernon and Burlington, Washington

SR 104, Hood Canal Bridge–Bridge Number 104/4 and 104/5 East and West Approaches–Port Gamble, Washington

SR 167, Puyallup River Bridge–Bridge Number 167/20E
Puyallup, Washington

Precast Deck

I-5, 38th Street–Bridge Number 5/430 Tacoma, Washington

SR 104, Hood Canal Bridge–Bridge Number 104/5
East Half Partial Deck Panel–Port Gamble, Washington

Precast Crossbeam

SR 16, Eastbound Nalley Valley–Bridge Number 16/6W-N
Tacoma, Washington

SR 520/SR 202 Interchange–Bridge Number 520/46
Redmond, Washington

I-5, Highways for Life Demonstration Project–Bridge Number 12/118
Grand Mound, Washington

SR 520, Floating Bridge & Landings – Bridge Number 520/7.5
Seattle, Washington

Precast Column

SR 520, 36th Street Bridge–Bridge Number 520/36.5
Redmond, Washington

I-405, NE 8th Street Ramp–Bridge Number 405/43
Bellevue, Washington

SR 16, Cedar Street and Union Avenue Bridges
Bridge Numbers 16/12E, 16/12W, 16/14E, and 16/14W
Tacoma, Washington

Adjacent Deck Bulb Tee Beams

I-5, Skagit River Bridge–Bridge Number 5/712
Mount Vernon and Burlington, Washington

I-90, Easton Avenue Bridge – Bridge Number 90/121
Easton, Washington

Self-Propelled Modular Transporter

SR 104, Hood Canal Bridge–Bridge Number 104/4 and 104/5
East and West Approaches–Port Gamble, Washington

SR 433, Lewis & Clark Bridge – Bridge 433/1
Longview, Washington–Rainier, Oregon

Other Precast Elements

SR 303, Manette Bridge–Bridge Number 303/4A
Bremerton, Washington

14.99 References

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