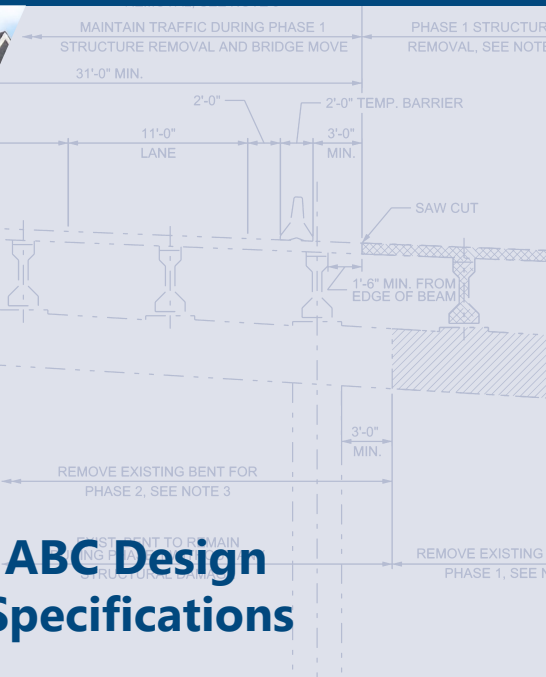
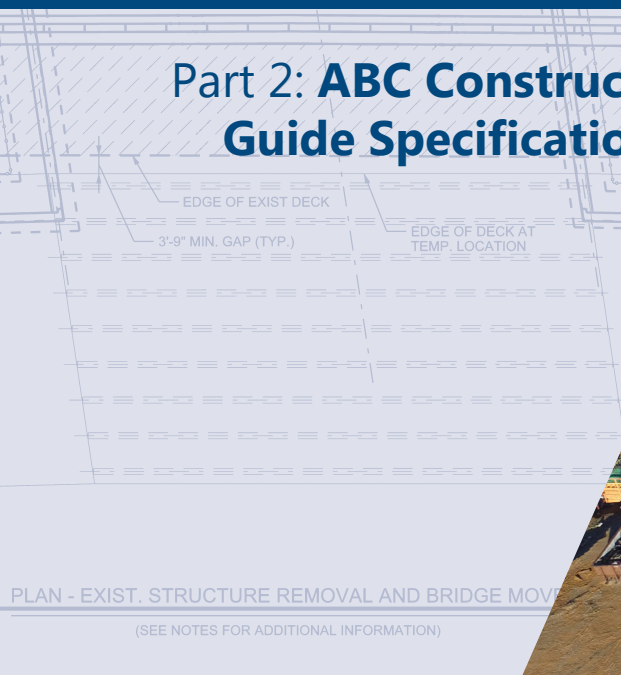




Part 1: ABC Design Guide Specifications

LRFD Guide Specifications for Accelerated Bridge Construction

Part 2: ABC Construction Guide Specifications



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**Part 1: ABC Design
Guide Specifications**

LRFD Guide Specifications for Accelerated Bridge Construction

**Part 2: ABC Construction
Guide Specifications**



1st Edition • 2018



American Association of State Highway and Transportation Officials
444 North Capitol Street, NW, Suite 249
Washington, DC 20001
202-624-5800 phone/202-624-5806 fax
www.transportation.org

Cover photos: **Top Left:** ABC deck modules sitting on falsework ready for installation three days prior to bridge opening, Warren Avenue Bridge Project, East Providence, RI, courtesy of Finn Hubbard, Fickett Structural Solutions. **Top Right and Lower Left:** Blueprints of C 1004 Summit, courtesy of Utah DOT. **Lower Right:** Hill Field Road, Lateral Slide, courtesy of Utah DOT.

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ABBREVIATED TABLE OF CONTENTS

The *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction*, First Edition contains the following sections:

Part 1: ABC Design Guide Specifications

1. Design Introduction
2. General Design Provisions
3. Design of Prefabricated Elements
4. Detailing Requirements
5. Durability of ABC Technologies

Part 2: ABC Construction Guide Specifications

6. Construction Introduction
7. Temporary Works
8. Fabrication and Assembly Planning
9. Layout and Tolerances
10. Concrete Structures
11. Steel Structures
12. Geosynthetic Reinforced Soil–Integrated Bridge System (GRS-IBS)

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FOREWORD

Accelerated Bridge Construction (ABC) technologies have evolved from the laboratory to trial installations into mainstream use. To date, the design and construction of ABC projects has been completed using engineering judgement and existing design and construction provisions that are contained in the *AASHTO LRFD Bridge Design Specifications* and the *AASHTO LRFD Bridge Construction Specifications*. These specifications fulfill the majority of the design and construction specification needs for an ABC project. This set of specifications is intended to fill the gaps for design and construction specification that are not specifically covered in the current AASHTO specifications.

The approach taken for the development of these guide specifications is to develop a document that supplements the current published design and construction specifications. The breakdown of sections within this document was based on a logical division of design and construction processes for ABC, as opposed to having provisions that would be integrated directly into the structure of provisions in the published documents.

This document was developed under NCHRP Project 12-102.

NCHRP Project 12-98 involved the development of several documents related to ABC. They are entitled *Guidelines for Prefabricated Bridge Elements and Systems Tolerances* and *Guidelines for Dynamic Effects for Bridge Systems*. These documents, which are not AASHTO publications, are referenced within this document and are available through NCHRP.

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PREFACE

Units

This Guide Specification uses U.S. Customary Units only. Per a decision by the AASHTO Subcommittee on Bridges and Structures in 2009, SI units will no longer be included in specification documents.

References

If a standard is available as a stand-alone publication—for example, the ACI standards—the title is *italicized* in the text and listed in the references. If a standard is available as part of a larger publication—for example, the AASHTO materials specifications—the standard’s title is not italicized and the larger publication—in this case, *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*—is listed in the references.

Unit Abbreviations

Unit abbreviations in this document are consistent with the units in the *AASHTO LRFD Bridge Design Specifications* and *AASHTO LRFD Bridge Construction Specifications*. Users of this specification should refer to these documents for frequently used abbreviations.

Also, please note the following:

- Abbreviations for singular and plural are the same
- Most units of time have one letter abbreviation. Unit abbreviations are always set in roman type, while variables and factors are set in *italic* type. Thus, “2 h” is the abbreviation for “two hours.”

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Part 1: ABC Design Guide Specifications

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SECTION 1: DESIGN INTRODUCTION

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SECTION 1

DESIGN INTRODUCTION

1.1—SCOPE

The provisions in this section serve as an introductory section of the overall guide specifications. Included herein are definitions of common prefabricated elements and systems, recommended roles and responsibilities for Accelerated Bridge Construction (ABC) projects and design considerations for different types of ABC projects.

1.2—USE OF THESE SPECIFICATIONS

These specifications are a guide document for the design of ABC projects.

The provisions contained herein shall be used in conjunction with the *AASHTO LRFD Bridge Design Specifications*.

These guide specifications are intended for use on typical girder/stringer type bridges.

Collaboration between the Designer and the Contractor is a key element of most ABC projects. Portions of these specifications outline the roles and responsibilities of each in the design and construction phases of the project.

C1.2

This document should not be considered a full specification. Users of this document should exercise engineering judgement in conjunction with the provisions contained herein. This document makes use of the terms “shall,” “should,” “may,” and “recommended.” The following describes how these terms should be interpreted:

- The term “shall” denotes a requirement for compliance with these specifications.
- The term “should” indicates a strong preference for a given criterion.
- The term “may” indicates a criterion that is usable, but other local and suitably documented, verified, and approved criterion may also be used in a manner consistent with the LRFD approach to bridge design.
- The term “recommended” is used to give guidance based on past experiences.

This is not a stand-alone design specification. In many cases, provisions will refer to other AASHTO documents. This document is intended to supplement the *AASHTO LRFD Bridge Design Specifications*.

Many of these provisions are also applicable to other bridge types such as segmental bridges, trusses, and arches.

An example of collaboration is the need for the Designer to develop a preliminary Self-Propelled Modular Transporter (SPMT) and Lateral Slide Design to help define the constructability of the design, and then allowing the Contractor to finalize the construction methods working with the Designer for final approval.

1.3—DEFINITIONS

The definitions contained herein refer to common terms in use in Accelerated Bridge Construction.

C1.3

Many of the terms contained herein are for information only. Not all of the terms included are specifically referenced in provisions in these guide specifications. For example, there are no specific provisions for grid decks since they are covered in the current *AASHTO LRFD Bridge Design Specifications*.

1.3.1—GENERAL ABC DEFINITIONS

Accelerated Bridge Construction	Bridge construction that uses innovative planning, design, materials, and construction methods in a safe and cost-effective manner to reduce the onsite construction time that occurs when building new bridges or replacing and rehabilitating existing bridges.
Conventional Bridge Construction	Construction method where prefabrication is typically limited to beams and girders; contrast Accelerated Bridge Construction
Lateral Slide	A method of moving a bridge system built adjacent to the final bridge location using hydraulic jacks or cable winches while supported on sliding materials or rollers. The bridge is typically built parallel to its final alignment, facilitating the installation.
Prefabricated Bridge Elements and Systems (PBES)	Structural components of a bridge that are built offsite or near the site that include features to reduce the on-site construction time compared to conventional bridge construction.
Prefabricated Bridge Element (PBE)	A single structural component of a bridge built using PBES methods. Prefabricated Bridge Elements can be made of any approved structural material.
Self-Propelled Modular Transporter (SPMT)	A high-capacity transport device that can lift and move prefabricated elements and systems with a high degree of precision and maneuverability in all three directional axes without the aid of a tractor for propulsion.
SPMT Line	The transverse grouping of two wheel sets on an SPMT that are akin to an axle in a conventional transport trailer.
SPMT Power Pack SPMT	A module that is attached to an SPMT that provides hydraulic power for adjustments and movement.
Unit	An SPMT machine that contains a grouping of axles that are interconnected with a hydraulic system. Multiple units can be joined together longitudinally and transversely in a modular fashion to create larger SPMT configurations.
SPMT Wheel Set	A grouping of wheels that are controlled by hydraulic systems. Each wheel set has the ability to raise and lower to adjust the height of the SPMT, and pivot to provide steering of the SPMT.

1.3.2—DECK ELEMENTS

Aluminum Deck	A full thickness deck made with extruded aluminum elements that are connected to form an orthotropic deck system.
Exodermic Deck	A steel grid deck system made with a partially filled concrete composite topping that is placed above the top of the grid.

Full-Depth Precast Deck Panel w/ PT	A full-thickness deck panel that makes up the entire structural deck. Connected in the distribution direction with post-tensioning (PT).
Full-Depth Precast Deck Panel w/o PT	A full-thickness deck panel that makes up the entire structural deck. Connected in the distribution direction without post-tensioning (typically with a reinforced concrete closure joint).
Orthotropic Deck	A steel deck system made with a steel plate deck combined with welded transverse and longitudinal ribs.
Partial-Depth Precast Deck Panel	A reinforced or prestressed concrete deck panel that makes up the lower portion of the bridge deck that is combined with a reinforced cast-in-place concrete topping to form the completed structural deck.
Steel Grid (open)	A steel grid deck system made without concrete fill.
Steel Grid (concrete filled)	A steel grid deck system made with partially filled concrete placed within the grid.

1.3.3—BEAM ELEMENTS

Adjacent Deck Beam Element	Beams fabricated with an integral deck that is separated by a small grouted joint, or a small closure joint. Also referred to as butted beams. Adjacent beams come in several shapes including Deck Bulb T, Inverted T, Double T, Box, Slabs, Voided Slabs, etc.
Full Width Beam Element	An element that eliminates conventional on-site beam placement activities. It is typically rolled, slid, or lifted into place to allow deck placement operations to begin immediately after placement. Given the size and weight of the element, the entire deck is not included.
Modular Decked Beam (MDB)	An element that is fabricated with beams combined with an integral composite reinforced concrete deck to form a modular unit. MDBs can be made with steel or prestressed concrete beams. A MDB is typically made with two or three beam elements.

1.3.4—PIER ELEMENTS

Precast Caisson Cap	A reinforced concrete element that is placed on top of piles or drilled shafts that is designed to support reinforcing and cast-in-place concrete that is placed after the cap is erected.
Precast Cap Shell	A reinforced concrete element that is fabricated without the core concrete. The core concrete is placed after the shell has been erected.
Precast Cap and Column	A reinforced concrete pier element comprised of a precast column cap combined with precast column(s).
Precast Column	A vertical reinforced concrete element that supports a beam or cap.
Precast Column Cap	A reinforced concrete element placed on top of column elements.
Precast Integral Cap	A reinforced concrete element that is integrally connected to the superstructure and the lower pier elements to form a rigid connection.
Precast Footing	A reinforced concrete element that makes up the structural footing of a substructure or wall.
Precast Footing Shell	A reinforced concrete shell that is used as a stay-in-place form for a cast-in-place reinforced concrete footing.
Precast Pile Cap	A reinforced concrete element that is placed directly on top of piles.

Precast Semi-Integral Cap	A reinforced concrete element that is integrally connected to the superstructure and pinned to the lower pier elements to form a pinned connection.
Steel Cap and Column	A structural steel element comprised of a steel column cap combined with integral steel column(s).
Steel Column	A vertical structural steel element that supports a beam or cap.
Steel Column Cap	A structural steel element placed on top of column elements.
Steel Pile Cap	A structural steel element that is placed directly on top of piles.

1.3.5—ABUTMENT AND WALL ELEMENTS

Precast Abutment Cap	A beam type element that is placed directly on top of and connected to the abutment wall elements to form the bridge seat.
Precast Abutment Stem	A wall element that is located above the abutment footing that retains embankment fill.
Precast Backwall	A wall panel element that is behind the end of the superstructure that retains the upper portion of the embankment fill.
Precast Cheek Wall	A wall element that is placed at the corner of the abutment seat to hide or retain the beam ends.
Precast Footing	A footing element that is placed on soil that supports a substructure element.
Precast Lagging Panel	Panel element placed between vertical structural elements to form the face of an earth retaining wall system.
Precast Semi-Integral Abutment	A wall panel element that is attached to the end of longitudinal beams to form a semi-integral abutment backwall.
Precast Sheet Pile	A vertical precast element that is driven or jetted into the soil to create a cantilever wall (abutment or retaining wall).
Precast Wingwall	A wall element that retains embankment fill behind or alongside the abutment.
Precast 3-sided Culvert	A precast culvert element that has a top and sides, but no bottom, placed on footings or pile caps to form a bottomless culvert structure.
Modular Block Wall	A precast wall system made up of stacked precast block elements that form a gravity retaining wall. The elements can be solid or voided. Soil or crushed stone are typically placed within the voids to enhance the resistance of the system.
Mechanically Stabilized Earth (MSE) Wall	A mechanically stabilized earth retaining wall system made up of wall face elements connected to horizontal soil reinforcing elements.
Semi-Integral Abutment	A detailing method where the end of the superstructure is used to retain the upper portion of the embankment soil mass (as opposed to an abutment backwall). A key feature is that the superstructure is pinned to the lower abutment section at the beam seat, not requiring a complex connection. Semi-integral abutments can be used to facilitate the construction of bridge systems.
Steel Sheet Piling	Interlocking vertical steel elements that are vibrated or driven into soil to create a cantilever wall (abutment or retaining wall).

1.3.6—GEOSYNTHETIC REINFORCED SOIL INTEGRATED BRIDGE SYSTEM (GRS-IBS)

GRS-IBS	A bridge that is directly supported on a GRS-IBS abutment that blends the roadway into the superstructure to create a jointless interface between the superstructure and the approach embankment.
GRS-IBS Abutment	Alternating layers of compacted fill and closely spaced geosynthetic reinforcement combined with a facing to provide support for the bridge and retain the embankment soils.
Integrated Approach	Alternating layers of compacted fill and closely spaced geosynthetic reinforcement placed behind the superstructure ends and between the top of the GRS-IBS abutment and the pavement structure. The integrated approach blends the superstructure with substructure and existing roadway. The integrated approach is an alternative to the traditional approach slabs.
Reinforced Soil Foundation (RSF)	Granular fill material below the GRS-IBS abutment that is compacted and encapsulated with a geotextile. The RSF is a ground improvement method that improves bearing capacity and reduces settlement. It also provides a firm, stable, and level surface to start construction of the GRS-IBS abutment.

1.3.7—MISCELLANEOUS ELEMENTS AND DEFINITIONS

Assembly Plan	A package of plans, specifications, and calculations developed by the contractor that describes the process for the assembly of prefabricated elements. The assembly plan may include handling and erection plans, materials specifications, details and calculations for bridge temporary works, and construction scheduling.
Bars in Splice Coupler	A connection that provides tension, shear, and/or moment force transfer between two precast concrete elements via a mechanical connection that uses a projecting bar from one element grouted into a reinforcing bar splice device cast into the adjacent element.
Closure Joint	A gap between two elements or systems that is filled with materials to form a connection. The joint may or may not include reinforcing. The width of the closure joint can vary based on the type of material used to fill the joint and the reinforcing within the joint. This feature is also referred to as a “closure pour” by some agencies.
Closure Joint: CIP Reinforced	A connection that provides tension, shear, and/or moment force transfer between two precast concrete elements via lapped reinforcing bars combined with cast-in-place (CIP) concrete, Ultra-High Performance Concrete (UHPC), or grout.
Closure Joint: Grouted Key	A connection that provides compression or shear force transfer between two precast concrete elements via a keyed joint filled with a cast-in-place concrete or grout. Grouted key closure joints can be combined with post-tensioning to form a moment connection.
Closure Joint: Match Cast	A connection between two adjacent elements with a very small width epoxy grouted joint that is fabricated by casting one element against the adjacent element in the fabrication shop to form identical matching surfaces. Match cast joints may be used to provide a shear connection or combined with post-tensioning to form a moment connection.
Connection	A means of transferring force between two or more elements.

Connection: Grouted Duct	A connection that provides tension, shear, and/or or moment force transfer between two precast concrete elements via a mechanical connection that uses a projecting reinforcing bar from one element grouted into a metal duct cast into the adjacent element.
Connection: Pocket	A connection between two prefabricated elements thru the projection of multiple bars or connectors of one element into a single void that is cast internal to the receiving element. The void is then filled with either concrete, grout, or other suitable material.
Connection: Socket	A connection between two prefabricated elements thru the projection of a single portion of one element into a single void of the receiving element. The gap between the two elements is then filled with either concrete, grout, or other suitable material.
Contractor	The company responsible for the construction of the bridge or structure.
Designer	The engineer responsible for the design of the bridge. Also known as the engineer of record.
Fabricator	The company responsible for the fabrication of the prefabricated element.
Falsework	Temporary construction used to support portions of the entire permanent structure until it becomes self-supporting. Falsework could include steel or timber beams, girder column piles and foundations, and any proprietary equipment including modular shoring frames, posts shores, self-propelled modular transporters, and horizontal shoring.
Grouted Blockout w/ Shear Connectors	A means of creating a composite connection between a full-depth precast deck and a supporting beam or girder via shear connectors in a grouted pocket.
Link Slab	A transverse deck level connection at piers between the decks of two adjacent spans, providing a jointless bridge without continuity.
Load Path	A continuous path along which a load travels through structural elements and connections.
Precast Approach Slab	A reinforced concrete slab element that spans between the end of a bridge deck or abutment and the approach pavement.
Prefabricated Railing	An element used at the edge of a bridge deck to contain vehicles, bicycles, and pedestrians.
Post-Tensioning (PT) Ducts, Bonded	A prestressing system used in concrete comprised of a duct and a prestressing tendon that is grouted after stressing to form a bonded reinforcing system.
PT Ducts, Un-bonded	A prestressing system used in concrete comprised of a duct and a prestressing tendon that is stressed to form an unbonded reinforcing system.
Seismic System	A series of connected elements that transfer seismic loads through the structure to the foundations.
Seismic Subsystem	A localized group of elements and connections within a seismic system that serves a specific design function, such as a knee-joint, plastic hinge region, etc.
Shear Key	A faceted surface along the edge of a concrete element that provides resistance to shear across a joint between the element and an adjacent element. Shear keys may be dry-fit-interlocked or grouted. The shear

	resistance of the connection is provided by the resistance of the sum of the potential concrete shear failure planes in the elements and/or the grout material
Shop Drawing	A drawing that depicts the fabrication of elements based on the requirements of the project plans and specifications.
Special Material	A material used in construction that is proprietary or non-conventional. A special material often requires the use of a performance specification.
Temporary Works	Structures and other construction that are used to facilitate the construction in progress, but removed in the final structure. In some cases, temporary works can be left in place; however they are not part of the completed structure.
Ultra-High Performance Concrete	Ultra-High Performance Concrete (UHPC) is a very high strength cementitious concrete mix that is reinforced with steel fibers to enhance the tensile and bond properties of the material.
Working Drawings	Details and calculations developed for bridge temporary works that involve the design of elements and processes. Specifications for working drawings often require a seal by a professional engineer.

1.3.8—SYSTEMS

Prefabricated System	A category of PBES that consists of an entire superstructure, an entire superstructure and substructure, or a total bridge that is procured in a modular manner such that traffic operations can be allowed to resume after placement. A prefabricated system is rolled, launched, slid, lifted, or otherwise transported into place, having the deck and preferably the railing in place such that no separate construction phase is required after placement.
Lateral Slide System	A system installation that uses Lateral Sliding equipment to move the structure.
Superstructure System	A system that includes both the deck and primary supporting members integrated in a modular unit.
Superstructure/Substructure System	A system that includes either the interior piers or abutments which are integrated in a modular manner with the superstructure as described for the superstructure system.
Total Bridge System	A system that includes the entire superstructure and substructures (both abutments and piers) that are integral with the superstructure that are built off-line and installed as a unit.
SPMT System	A system installation that uses Self-Propelled Modular Transporters (SPMTs) to move the structure.

1.4—DESIGN RESPONSIBILITIES FOR PREFABRICATED ELEMENTS

C1.4

The most common form of prefabrication involves the use of emulative behavior wherein the bridge and its elements are designed to resist forces in the same manner as a bridge built with conventional construction. In this case, the design methods for the prefabricated bridge may be the same as a bridge built with conventional construction.

This approach is the basis for the majority of the provisions in these Guide Specifications.

It is also possible to design prefabricated elements with details that do not emulate conventional construction. This may affect the overall design process. This document contains these types of elements including recommended design procedures.

1.4.1—DESIGNER

The Designer is responsible for the design of all elements and connections according to the *AASHTO LRFD Bridge Design Specifications* as supplemented in these Guide Specifications.

The Designer may detail a schematic specialty structure or component and require that the contractor complete the final design. This shall be clearly indicated on the plans and in the project specifications along with the specific performance and design parameters.

For complex structures where the means of construction are not self-evident, the Designer shall detail at least one feasible construction method on the plans.

1.4.1.1—Designer’s Role in Shipping and Handling of Elements

Project specifications shall require that the contractor be responsible for all lifting and handling of elements. The Designer shall be responsible for reviewing the Contractor’s methods and calculations for shipping and handling for general conformance with the contract documents.

The Designer should investigate the shipping and handling requirements for very large or unusually shaped elements. Schematic erection plans and procedures shall be included in the project plans in these situations.

The investigation shall be limited to general equipment needs and stability. In some cases, the Designer should contact erection contractors to verify that an element can be erected. The Designer shall also verify that the construction area is adequate to accommodate the required crane(s) and the delivery trucks.

1.4.1.2—Establishment of Tolerances and Joints

The Designer is responsible for the specification of element tolerances, erection tolerances, and joint width tolerances. Element tolerance details shall be shown on the plans or included in the project specifications. Erection tolerances shall be shown on a structure layout drawing, or included in the specifications. Joint width tolerances shall be included in the joint details.

C1.4.1

Recommendations for the design of elements and connections are included in these Guide Specifications.

Examples of this approach include but are not limited to precast culvert structures and proprietary retaining walls.

C1.4.1.1

See Section 8.4 for more information on shipping and handling of elements. There are different configurations of shipping and lifting equipment for elements. The selection and design of these devices falls under the realm of “contractor means and methods.”

C1.4.1.2

Recommended tolerances and detailing of tolerances is included in the document *Guidelines for Prefabricated Bridge Elements And Systems Tolerances* (Culmo, et al., 2017). This guideline is to be developed under NCHRP Project 12-98.

Some agencies allow contractors to fabricate elements onsite or near site. The tolerances specified in the above cited document may be followed, however, the Owner may choose to specify different criteria. The

1.4.1.3—Specification of Special Materials

The Designer is responsible for the specification of specialized materials for use in prefabricated bridge construction. Performance or prescriptive specifications may be used.

1.4.2—CONTRACTOR

In general, the Contractor's role in the design of prefabricated elements is limited to means and methods of construction.

The Contractor may be required to complete the final design of the structure or components if specified on the contract plans.

1.4.2.1—Temporary Works

All temporary works shall be designed by the contractor. The *AASHTO Guide Design Specifications for Bridge Temporary Works* shall be followed unless otherwise specified herein or by the Owner.

1.4.2.2—Element Shipping and Handling Calculations including Lifting Hardware

The Contractor shall be responsible for the lifting and handling of prefabricated elements. This includes but is not limited to lifting equipment and hardware, crane sizes, and delivery vehicles. The Contractor shall also be required to verify that the lifting methods will not overstress the elements.

1.5—DESIGN RESPONSIBILITIES FOR SPMT SYSTEMS

The design of bridges that are intended to be installed using SPMTs is the same as the design of bridges using conventional construction. The design of the bridge shall meet all the applicable requirements as specified in the *AASHTO LRFD Bridge Design Specifications* and provisions contained herein.

Additional checks on lifting and moving stresses are also required.

cited document is recommended as a basis for establishment of Owner-specified tolerances.

C1.4.1.3

Performance specifications allow for more flexibility in the use of specialized materials. Examples include, but are not limited to:

- high early strength concrete
- non-shrink grout
- mechanical connectors

See Part 2 for recommendations on performance specifications.

C1.4.2

See Article C1.4.1 for examples of this approach.

C1.4.2.1

This approach is intended to allow for flexibility in construction and to allow the Contractor to make use of equipment and materials that are on hand, thereby reducing project costs.

C1.4.2.2

See Part 2 for more information on element shipping and handling specifications.

C1.5

The Designer needs to verify the constructability of the bridge with respect to the installation methods. The following articles outline the recommended tasks that the Designer should follow.

These provisions are with regard to design and construction of the bridge and falsework. Other planning and project development work would normally be necessary. The FHWA document “Manual on the Use of Self-Propelled Modular Transporters to Remove and Replace Bridges” (2007) is recommended for further guidance on this subject.

1.5.1—DESIGNER

The Designer shall be responsible for the design of the entire bridge, verification that the bridge can be reasonably moved within the proposed work zone, and specifying the requirements of the Contractor to complete the construction.

1.5.1.1—Bridge Design

The Designer shall make assumptions on the methods of lifting and moving the bridge using SPMTs. The Designer shall take into account the assumed methods in all aspects of the design.

The Designer shall design the bridge to resist the lifting and moving process based on the assumed layout of the SPMTs.

The Designer shall clearly state all assumptions on the lifting and moving of the bridge on the design plans. The plans shall also state the variations in the lifting and moving methods which will require an evaluation of the bridge by the contractor.

1.5.1.1.1—Superstructure Types

It is possible to move many different structure types using SPMTs. The Designer shall consider the potential SPMT lift points in the structure type study phase to ensure that the bridge can be lifted as planned.

1.5.1.1.2—Analysis for Jacking Locations

The Designer shall design the bridge system for the move. The design shall be based on the preliminary layout of the SPMTs. The system shall be evaluated for the following conditions:

C1.5.1

The temporary support of the bridge in the staging area and the equipment/falsework used to move a bridge with SPMTs falls under the realm of “contractor means and methods.” There are several brands of transporters in the market and falsework varies from project to project, therefore the Designer should not be involved in a detailed design of these components.

C1.5.1.1.1

In general, SPMT bridge moves involve lifting the bridge at a location that is not coincident with the bearing locations, which will induce stresses in the structure that are different than the stresses in the completed structure. Truss and arch bridges may require special considerations and temporary falsework within the structure to provide adequate resistance to lifting stresses.

It is feasible to move multiple span bridges. In most cases, this will require two lifting points per span, thereby complicating the move equipment, travel path, and falsework. Designers may consider using span-by-span construction combined with either live load continuity or link slabs. See Section 3 for more information on these options.

C1.5.1.1.2

The design of the bridge will most likely require changes to the beam designs and/or supplemental reinforcement in the structure. Cross frames and intermediate bearing stiffeners may be required at the

- on the proposed temporary supports,
- on the SPMT supports during the move, and
- on the SPMT supports during the move with the system displaced to the maximum specified twist

The Designer shall identify the acceptable methods of connecting the falsework to the bridge system. If bracing connections are allowed, the plans shall clearly indicate the types of acceptable connections.

The design of the bridge shall meet or exceed all of the requirements specified in the *AASHTO LRFD Bridge Design Specifications* under all conditions during construction.

The Designer shall account for dynamic effects during the move.

1.5.1.1.3—Determine Allowable Deformations

The Designer shall analyze the bridge to determine the allowable twist in the structure during the bridge move. The analysis shall investigate at a minimum, the stresses in the beams, girder, deck, and barriers.

The Designer shall analyze the bridge to determine the allowable differential support elevations during the bridge move for systems with three or more SPMT units. The analysis shall investigate at a minimum, the stresses in the beams, girder, deck, and barriers.

The combination of twist and differential support variations need not be studied unless specified by the Owner.

1.5.1.2—Preliminary SPMT Investigation

The Designer shall prepare a preliminary SPMT layout and investigate the potential staging area and travel path for the bridge move.

1.5.1.2.1—Preliminary SPMT Layout

SPMTs can be assembled in a number of different configurations. Figure 1.5.1.2.1-1 shows several

temporary lift points. The Designer may detail a schematic of a basic pinned connection. The Designer may also elect to allow bracing connections between the bridge system and the falsework to aid in stability of the SPMTs.

In most cases, the Designer need only check the structure for vertical dynamic effects brought on by the movement of the bridge on the SPMTs. The document “Guidelines for Dynamic Effects during Bridge System Installations” is recommended for use in this analysis.

C1.5.1.1.3

Twist is the variation in planar supports between adjacent SPMT support points. The contractor will need this value for use in monitoring the bridge during the move. The analysis for twist should be based on a refined analysis. Grid analysis is not recommended for calculating deck stresses.

Differential support variations are related to SPMT bridge moves that have indeterminate support conditions. For example, a bridge portion that is proposed to be moved with three independent SPMTs has the potential for one SPMT to be higher or lower than the others. This analysis is essentially the same as analysis of a bridge for differential settlement.

This recommendation is based on the assumption that the maximum twist and maximum differential support variation would not occur at the same time. The Owner may elect to require a combined analysis for special structures that may be sensitive to these combined deflections.

When checking the bridge for the allowable deformations, the load combinations specified in Article 2.4.2 should be followed.

C1.5.1.2

The Designer needs to determine the feasibility of the bridge move by investigating these features of the move.

The Contractor should be responsible for the final SPMT layout, falsework design, and investigation of the travel path. See Article 1.5.2 for more information on contractor responsibilities.

C1.5.1.2.1

The layout of the SPMTs will establish the lifting points of the bridge move. This information is necessary

configurations. The modular nature of SPMT units is that they can be joined together longitudinally and transversely to form a larger platform. The preliminary layout of the SPMT platform should be based on the following assumed criteria:

- Width of transporter: 8 ft
- Length of transporter: Sum of axles $\times$ axle spacing
- Length of power pack: 12 ft
- Number of axles line per unit: 4 and 6
- Number of tires per line: 4
- Axle line spacing within unit: 4.625 ft
- Axle line spacing between adjacent units: 4.625 ft
- Axle line load capacity: 30 tons
- Unit height: 48 in. min., 72 in. max.

to complete the design requirements specified in Article 1.5.1.1.

The dimensions and capacities of SPMT units vary depending on the manufacturer. The assumed criteria are based on typical units that are used and have proven to provide an adequate estimate of the final configuration. SPMT units can be linked longitudinally or laterally to achieve the number and configuration of axle lines required by the load.

Example: 650 ton load on the SPMT unit

Number of required axle lines = $650/30 = 21.7$

Use 24 axle lines (rounded up)

12 axle lines double wide

Width: $8 \text{ ft} \times 2 = 16 \text{ ft}$

Length: $4.625 \times 12 = 55.5 \text{ ft}$

Approx. capacity = $30 \text{ tons} \times 12 \times 2 = 720 \text{ tons}$

Designers should consider rounding up the number of axle lines by approximately 10 percent as shown above to account for the potential of a local failure during a move (flat tires or hydraulic problem). In this case, the Designer should specify that the Contractor use a similar approach for the final layout of the SPMTs.

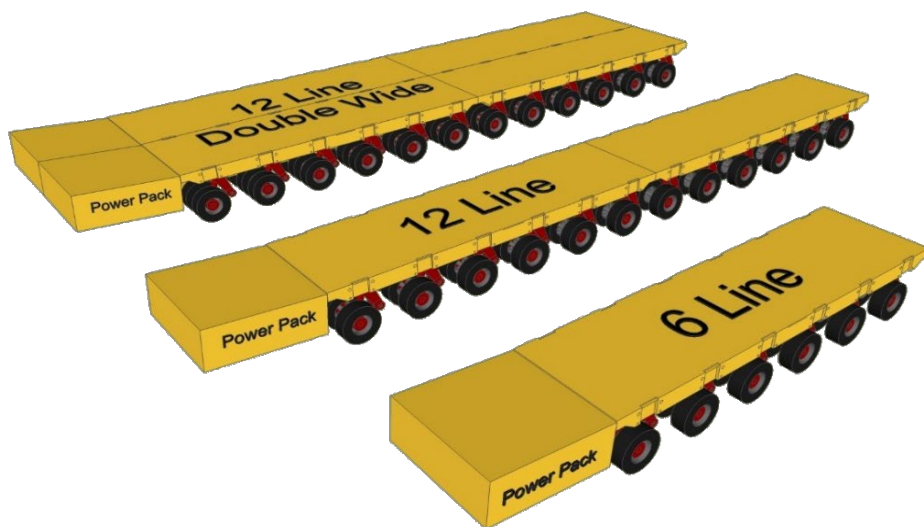


Figure 1.5.1.2.1-1—Sample SPMT Configurations

The weight applied to the SPMT shall account for the total weight of the bridge, and the estimated weight of falsework and any vertical dynamic effects.

The center of gravity of the bridge system (in the horizontal plane) should be coincident with the plan centroid of the SPMT units.

The document *Guidelines for Dynamic Effects during Bridge System Installations* is recommended for use in these calculations.

This approach is generally acceptable for preliminary design. The final layout for the SPMT units by the Contractor may result in minor shifts of the centroid based on the hydraulic zone set up.

In general, the SPMTs should be laid out to match the skew of the bridge system being moved.

The grades along the travel path shall be considered in the layout of the SPMT units. The top of the SPMT configuration should be level during the move. The combination of travel path cross slope and longitudinal grade should be considered in the layout of the SPMTs. The variation in surface grades may be accommodated with the available hydraulic stroke on each wheel set of the SPMT units. Temporary compacted fill combined with steel plates and/or pavement may be required along the travel path to reduce the grade differential across the SPMT system footprint.

The Designer shall investigate the geometric interaction of the SPMT layout, available roadway width, and the desired lifting points on the bridge system. The layout shall account for minor maneuverability during setting of the bridge. A minimum buffer value of 1 foot shall be planned between the SPMTs or falsework and any horizontal obstructions.

It is recommended that the length of the preliminary SPMT configuration be approximately equal to the width of the bridge being moved. Coordinating the length of the SPMT configuration to the width of the bridge will result in falsework that will more evenly distribute the bridge weight along the length of the SPMT units. Large extensions or SPMT axle lines beyond the falsework footprint can lead to overstresses in the internal SPMT machine frames. This can be overcome through the use of supplemental framing placed on top of the SPMT units.

The skew layout of the SPMT units should account for the roadway geometry along the travel path and at the bridge site. Lifting a skewed bridge with squared SPMTs is possible. Special analysis of the bridge system may be required to account for the torsion that may develop in the system. Special SPMT layouts may also be necessary, since the load on the SPMTs may vary. Designers should contact heavy lift contractors for guidance on this approach.

The SPMTs account for travel path grade variations via the hydraulic stroke of the units, which can be assumed to be 24 inches. The variation on roadway grades across the footprint of the entire SPMT layout should be considered and kept within the stroke limit. Different configurations of SPMTs can be explored in order to reduce the effects of grade. For example, on a road with significant longitudinal profile grade, a single wide 16 line SPMT can be changed to a double wide 8 line SPMT, thereby reducing the longitudinal footprint of the SPMT along with the required stroke to accommodate the grade.

In special cases when the stroke limit of the SPMT is exceeded, the top of the SPMT can be tilted slightly. This can have an impact on the stability of the system. Designers should consult with heavy lift contractors in these cases to explore the feasibility of the move.

The spacing of the SPMTs will be affected by roadway width along the travel path and at the bridge site. Double wide or triple wide SPMT configurations may lead to support points that are a significant distance from the permanent bearing locations, leading to large cantilevers. It is possible to accommodate minor offsets of the temporary support points from the SPMT plan centroid through the use of spreader beams placed within the falsework. If significant offsets are desired, the Designer should consult with heavy lift contractors regarding the feasibility of offset supports.

It is recommended to limit the maximum length of bridge cantilevers to approximately 20 percent of the span length being supported. This value is based on experience of several agencies. This value may not be acceptable for certain bridge structures such as

1.5.1.2.2—Vertical Geometry Management at Bridge Site

The Designer shall consider the geometry and details of the bridge seat and their effect on the SPMT systems. The preliminary SPMT layout should account for the need to adjust the vertical elevation of the bridge system on top of the SPMTs during final setting.

1.5.1.2.3—Staging Area and Travel Path Investigation

The Designer shall investigate an appropriate location(s) for the staging area(s). The staging area shall be kept as close as practical to the final bridge site. The staging area shall have adequate space to accommodate the construction of the bridge system, temporary falsework supports, assembly area for the SPMT units and falsework, and adequate areas for cranes and equipment.

The Designer shall investigate the anticipated travel path, which can be straight or curved. Pivoting about a common point is also possible. The investigation shall include, but not be limited to, the following:

- Accurately survey the travel path to determine the roadway grades, cross slopes, and minor obstructions (curbs and islands) that need to be traversed. This information shall be used to verify the stroke capacity of the SPMTs as described in Articles 1.5.1.2.1 and 1.5.1.2.2.
- Determine the presence of any horizontal and vertical obstructions and aerial utilities that may

prestressed concrete beam superstructures. In most cases, the minimum distance from the permanent bearing lines to the temporary support points should be 12 feet unless special falsework is used to shift the temporary support points as described above.

Cl.5.1.2.2

Several features of bridge superstructures and substructures can lead to a need to elevate the bridge during final placement of the bridge system. Roadway cross slope, roadway crowns, and bridge seat features can produce conflicts between the substructures and the bridge system being moved. These geometric issues are further complicated with skewed bridges. In many cases the bridge system needs to be elevated to avoid these conflicts. SPMTs have significant vertical adjustment capabilities; however portions of the vertical adjustability can be needed to account for roadway grades and cross slopes (see Article 1.5.1.2.1). The Designer should investigate the roadway grades below the bridge at the bridge site to determine the amount of available hydraulic stroke in the SPMT for adjusting the height of the bridge during final setting.

If there is not sufficient vertical stroke available to set the bridge, the Designer should consider specifying that a secondary auxiliary jacking system be added to the falsework on top of the SPMT. The Designer can also modify details of the bridge seat to reduce the potential for conflicts during final setting.

Cl.5.1.2.3

The staging area is the location where the bridge system will be prefabricated. It may be possible to assemble the SPMT units and falsework in a secondary staging area provided there is a clear travel path between the two areas.

Linked units act as a single unit and are run off a single controller. The controller has four basic commands—steer, lift, drive, and brake. SPMT units use electronic steering that allows the vehicles to drive forward and backward, transversely, diagonally, at any angle, and in a carousel motion.

Profile and cross slope grades exceeding 4 percent can be difficult to traverse. Designers should consult with heavy lift contractors for these situations.

impede the movement of the SPMTs and the bridge system. If obstructions are present, determine if they can be temporarily or permanently moved.

- Determine the presence of any underground utilities, structures, or facilities that may be sensitive to the anticipated bearing pressures.
- Geotechnical investigations of the soils along the travel path shall be considered.

1.5.1.2.4—Support of the Bridge in the Staging Area

The Designer shall verify that adequate support can be provided for the bridge system in the staging area. Geotechnical investigations shall be undertaken for locations of temporary falsework supports. The Designer shall include a recommended foundation type for the temporary falsework supports.

The Designer shall indicate the locations of the supports in the staging area. The following methods of support are considered acceptable for single span bridge systems. Similar methods may be used for multi-span continuous bridges. The Designer shall evaluate the effects of the change in support and loading conditions on the resistance of the bridge.

Method A: Temporary supports coincident with the permanent bearing points, but not coincident with the SPMT lifting points.

The Designer shall evaluate the effect of these methods on the stresses in the deck and the parapets based on the composite section properties and the change in moment on the system during the bridge move.

Additional longitudinal reinforcement may be required in the bridge deck and barriers. The design approach for this reinforcement shall follow the same requirements for deck designs in negative moment regions of continuous span structures.

Geotechnical investigations of roadways along the travel path may be not be required since the wheel loads on the SPMTs can be limited to standard permit vehicles. Geotechnical investigations should be included for travel paths along un-developed land. Soil improvements or steel plating may be required in these areas.

C1.5.1.2.4

The Designer should show a schematic temporary falsework support system (also referred to as temporary abutments) on the plans including recommended foundations. If deep foundations are required, the plans should indicate approximate pile sizes and allowable pile loads. If shallow foundations are appropriate, the allowable bearing pressures should be stated.

The method of support can have a significant impact on the stresses in the girder and deck and the camber of the beams. The methods shown herein are applicable to single span bridges. The same approach could be applied to multi-span continuous bridges. When checking the bridge for these conditions, the load combinations specified in Article 2.4.2 should be followed.

Advantages of this method include:

- Simplified transfer from the temporary support to the SPMT support.
- Better control of elevations and grades.

Disadvantages of this method include:

- Change in moment on the system due to the change in support location, which causes tension in the deck and barriers.

The stresses in the deck and barriers are caused by the change in moment from the temporary support condition to the SPMT support condition. Figure C1.5.1.2.4-1 is a schematic representation of the changes in the system moments during construction when using this method. The moments for each stage of construction are shown as additive. The Designer should apply these moments to the appropriate girder section properties when calculating girder and deck stresses for each condition.

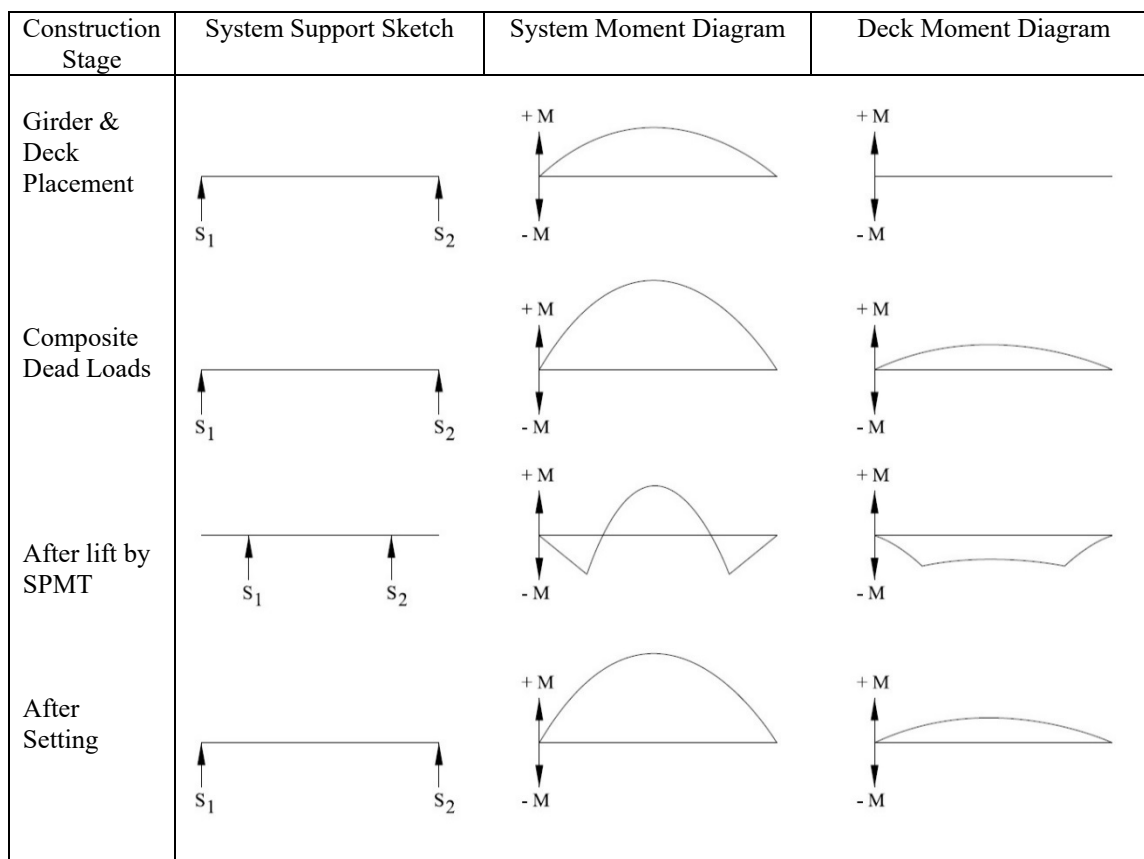


Figure C1.5.1.2.4-1—Method A Support Moments—Single Span Bridges

Method B: Temporary supports not coincident with the permanent bearing points, but coincident with the SPMT lifting points.

The Designer shall evaluate the effect of this method on the design of the beams, the blocking of the deck forms, and the final deck grades.

Advantages of this method include:

- Reduced positive dead load bending stresses at mid-span.
- No additional dead load stresses in the system during lifting.
- A permanent compressive load is induced in the deck and barriers after installation of the bridge.

Disadvantages of this method include:

- Deck casting will create negative dead load stresses in the beams (assuming that the beams are cantilevered beyond the temporary support points).
- Difficulty in estimating deflections to provide a smooth riding surface.
- Providing adequate camber to accommodate any future re-decking.
- Additional complexity in the temporary supports to permit the SPMTs to drive under the temporary supports before lifting the bridge.

The final compressive stresses in the deck and barrier are caused by the change in moment from the

SPMT support condition to the final support condition. Figure C1.5.1.2.4-2 is a schematic representation of the changes in the system moments during construction when using this method. The moments for each stage of construction are shown as additive. The Designer should apply these moments to the appropriate girder section properties when calculating girder and deck stresses for each condition.

The girders are a non-composite system during the deck pour. All future loading and change in support locations are on a composite section, which alters the final stresses in the bridge. In the majority of applications, the change increases the load capacity of the bridge. It is recommended that this increase in capacity not be accounted for when sizing elements if future redecking using conventional methods is anticipated.

Figure C1.5.1.2.4-3 includes photographs showing the type of support required to accommodate this method of construction. The support structure is detailed to allow the SPMT to drive under the support and lift it off the temporary foundations.

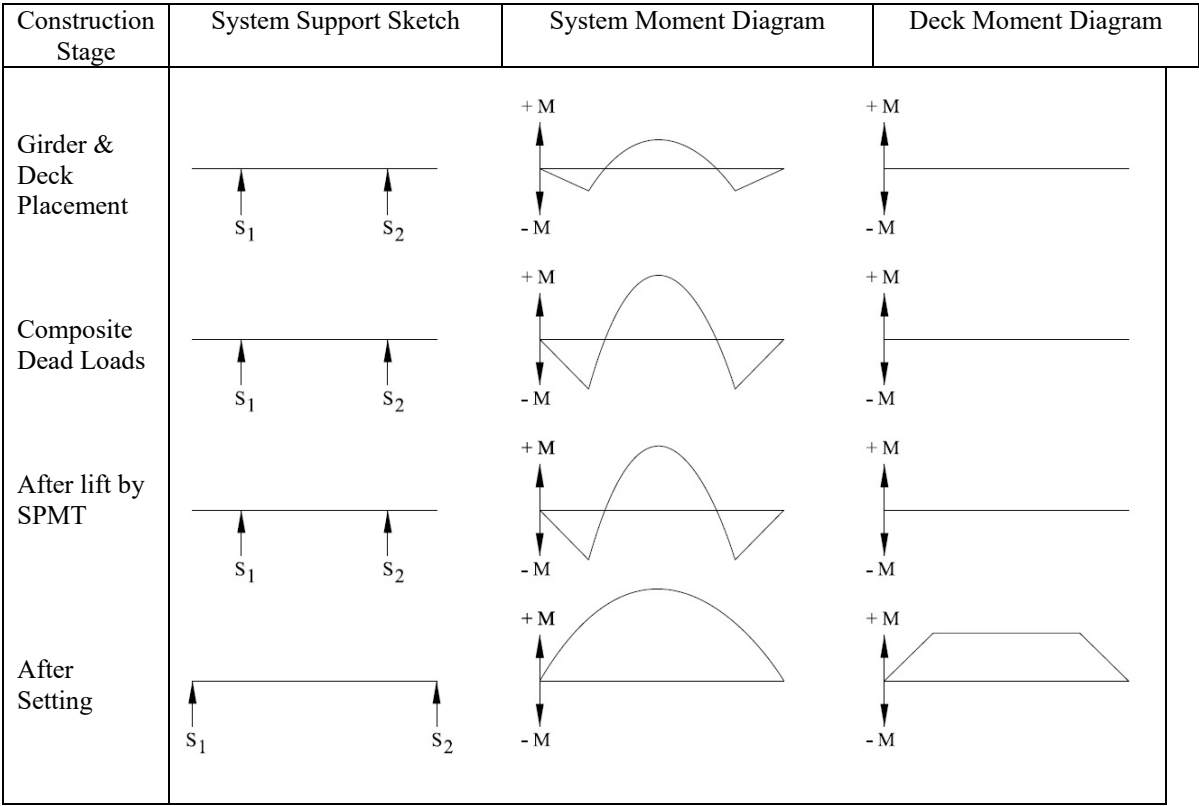


Figure C1.5.1.2.4-2—Method B Support Moments—Single Span Bridges



Figure C1.5.1.2.4-3—Method B Support Construction

1.5.1.3—Information to be Included on the Plans

The Designer shall indicate all design assumptions used for the development of the preliminary SPMT layout, staging area, and travel path.

1.5.2—CONTRACTOR

The Contractor is responsible for the final design and detailing of the temporary support structure for the bridge in the staging area, the equipment/falsework used to move a bridge, the final layout of the SPMTs, and verification of the adequacy of the proposed travel path.

The Contractor is also responsible for maintaining the integrity of the bridge during all aspects of the bridge fabrication and move.

1.5.2.1—Design of Temporary Supports in Staging Area

The Contractor shall design all temporary support structures based on the final configuration of the staging area and the SPMT equipment. The *AASHTO Guide Design Specifications for Bridge Temporary Works* shall be followed.

1.5.2.2—Final SPMT Design and Travel Path

The Contractor is responsible for the design of the final SPMT configuration and the falsework between the SPMT and the bridge structure. The *AASHTO Guide Design Specifications for Bridge Temporary Works* shall be followed.

The design of the SPMT layout and the falsework shall provide resistance for forces caused by horizontal and vertical dynamic effects.

The SPMT layout and design shall include local stability calculations of each individual SPMT unit and overall stability of the SPMT system during the move. The configuration of the hydraulics of the SPMT units

C1.5.1.3

See Article 4.5 for additional recommended information to be included on the plans.

C1.5.2

All of the items listed fall under the realm of “Contractor means and methods.” There are several brands of transporters in the market and falsework varies from project to project based on available materials.

In many cases, the Contractor will contract with a specialty engineer or heavy lift engineer for falsework and SPMT designs. Therefore, any reference to the “Contractor” in these Specifications would include the specialty engineer or heavy lift engineer.

In the case where the Designer specifies the lift points and allowable twist, the Contractor needs to ensure that these specifications are followed during all phases of the move. If these parameters are not specified, the Contractor will be responsible for all aspects of the bridge move including the calculation of lifting stresses and the allowable twist determination.

C1.5.2.1

Other design specifications may be used with permission from the Owner.

C1.5.2.2

Horizontal dynamic effects are generally caused by starting and stopping. Vertical dynamic effects are generally caused by traversing uneven ground. The document “Guidelines for Dynamic Effects during Bridge System Installations” is recommended for use in the calculation of dynamic effects. The lateral dynamic loads are calculated based on the stiffness and weight of the bridge and falsework.

SPMTs have hydraulic zone control valves that allow hydraulic suspension fluid to move between groups of wheel sets. The hydraulic stability of SPMT systems is achieved. It is possible to have more than

should be based on a three zone system, creating a three point determinate support system.

The flexibility of the falsework shall be considered in the design and detailing. Flexible support framing under girders shall include details that will ensure equal support to each beam.

The falsework shall be designed to provide the required stability of the SPMT units as well as resistance to horizontal loads (wind, dynamic loads, etc.). Lateral bracing such as framework, cables, or chains shall be used to provide stability and resist lateral forces. If cables and chains are used, a factor of safety of 1.5 shall be applied to the working load limit (WLL) of the cables or chains (capacity = WLL/1.5).

1.5.2.3—Monitoring System

The Contractor shall design and detail a system to monitor deflections and twist of the bridge system during the bridge move. The measurement system shall be capable of being monitored continuously during the move.

1.5.2.4—Bridge Analysis

A detailed analysis of the bridge structure by the Contractor may not be required, provided that the final SPMT layout and falsework meets all the design assumptions that are indicated on the plans.

A full analysis of the bridge structure would be warranted under the following conditions:

- If the plans do not specify preliminary SPMT layout or pick points
- Lifting the bridge at pick points that are not consistent with the assumed locations listed on the plans
- Use of falsework that does not provide support that is consistent with the assumed support conditions

three zones, however the indeterminacy of the system makes control of the system more difficult, and may require more axles than a three zone system due to inevitable support variations under the SPMTs caused by travel path variations. These variations can cause large increases in hydraulic zone pressures (this is analogous to a stiff four-legged chair on an uneven surface, teetering on two corner legs).

The flexing of the support beam under a superstructure will inevitably lead to unequal loading at each support point. Several approaches can be used to ensure more equal loading. A secondary hydraulic system can be placed between the support beam and the girders that will ensure that each hydraulic support has equal load. Variable height shims can also be placed at the support points. The height of the shims can be set equal to the anticipated deflection of the support framing.

This requirement accounts for anticipated wear of the chains or cables. This requirement may be waived by the Owner if the Contractor can certify the full working load limit through a special inspection.

C1.5.2.3

The system should be sufficient to measure and identify when the allowable deflections and twist specified by the Designer are reached. The SPMT system should have the capability to make adjustments to remedy this situation should it occur.

C1.5.2.4

The basis of this provision is to reduce the level of effort for the Contractor for typical bridge moves, and to avoid duplication of effort. In many cases, the Contractor can meet the assumed preliminary SPMT layout assumptions.

The Contractor needs to demonstrate to the Designer that the falsework can provide the required support conditions.

- If the project documents specify that an independent analysis is required.

If analysis of the bridge is required, the analysis shall at a minimum meet the requirements of Articles 1.5.1.1.2 and 1.5.1.1.3, or as specified by the Owner.

1.6—DESIGN RESPONSIBILITIES FOR LATERAL SLIDE SYSTEMS

In general, the Designer is responsible for the design of the bridge and the Contractor is responsible for the design of the falsework and slide system.

The design of the bridge and falsework shall account for the sliding forces. The Designer shall detail the assumed location of the application of the jacking/pulling force and design the bridge to resist this force. The jacking and friction forces shall be considered a construction load.

1.6.1—DESIGNER

1.6.1.1—Bridge Design

The design of a bridge superstructure for a lateral bridge slide is generally the same as a bridge built with conventional construction methods. The differences in the design are limited to the horizontal jacking locations and locations for vertical support during the lateral slide.

1.6.1.2—Preliminary Jacking Forces and Jacking Locations

The Designer shall identify the acceptable jacking/support locations on the bridge. This is applicable to the horizontal jacking points, vertical jacking points, and the support locations for the sliding devices.

The assumed jacking/support locations and associated forces shall be shown on the plans.

This approach may be warranted for complex bridges that are sensitive to minor variations in the layout of the SPMTs and falsework.

C1.6

There are several different sliding systems that can be used to move a bridge. Common sliding devices include sliding bearings, commercial rollers, jacks, and cable winches. The Designer can make a judgment as to the most appropriate system; however, the final system will most likely be based on the expertise and equipment available to the particular Contractor on the project. Therefore the Designer should not fully design the slide system. Schematic representations of a reasonable slide system should be adequate for most bridges.

This provision is consistent with the provisions for “Load Factors for Construction Loads,” as specified in the *AASHTO LRFD Bridge Design Specifications*.

C1.6.1.1

The Designer needs to verify that the bridge can resist the horizontal jacking loads and the vertical jacking loads based on an assumed slide system. The jacking and support locations are typically detailed along the bearing lines. Common details include the use of a continuous concrete end diaphragm at the bearing lines, which is suitable for horizontal jacking points and multiple vertical jacking/support points. It is possible to use conventional end diaphragms and support the bridge at each bearing; however, this is typically cost prohibitive.

1.6.1.3—Friction Forces

The Designer shall estimate the anticipated friction forces during the lateral slide operation based on an assumed sliding system.

1.6.1.4—Resolution of Sliding Forces

The approach to the preliminary layout of the slide system shall account for the resolution of friction forces. Two approaches can be used for friction force management and the interaction of the temporary falsework and the bridge substructure/foundation.

- Falsework attached to the bridge substructure: Figure 1.6.1.4-1 is a schematic representation of this approach. The connection between the falsework and the substructure shall be designed to resist the total sliding friction force in the system. If this assumption is used for the design of the substructure, the Designer shall indicate the need for this connection in the contract documents.
- Falsework not attached to the bridge substructure: Figure 1.6.1.4-2 is a schematic representation of this approach. The falsework and the substructure shall be designed to resist the total sliding friction force in the system.

C1.6.1.3

Friction in sliding systems can lead to large horizontal forces in the bridge during the lateral slide. Recommended friction design parameters are included in the document *Guidelines for Dynamic Effects during Bridge System Installations*. This guideline is to be developed under NCHRP Project 12-98.

C1.6.1.4

In this scenario, the forces in the lateral slide system form a continuous force loop resulting near zero force in the bridge substructure and the falsework structure. This will result in no significant changes to the design of the bridge substructures. The design implications are limited to the connection of the falsework and a load path for the friction forces to flow through the bridge seat area.

This approach will affect the design of the substructures foundation and the design of the temporary falsework. The friction forces will generate sliding and overturning forces that will need to be addressed in the design of both the substructures and falsework.

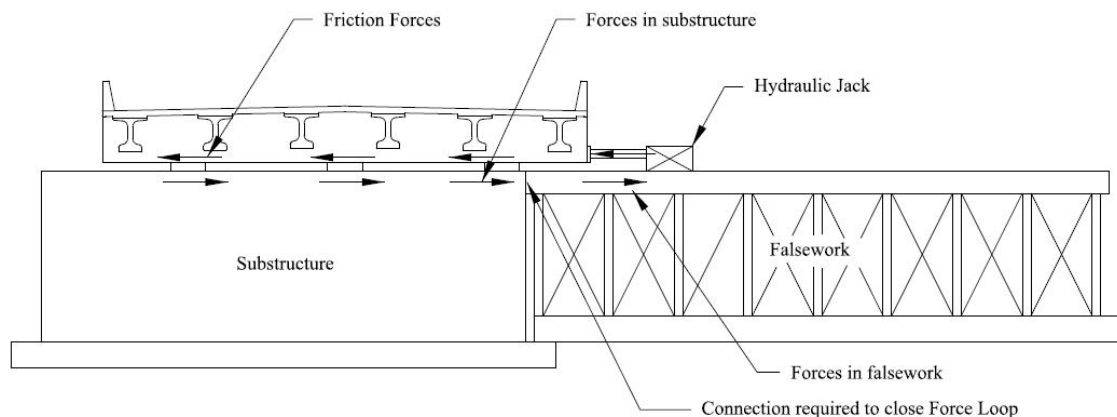


Figure 1.6.1.4-1—Falsework Connected to Substructure (Resolution of Friction Forces)

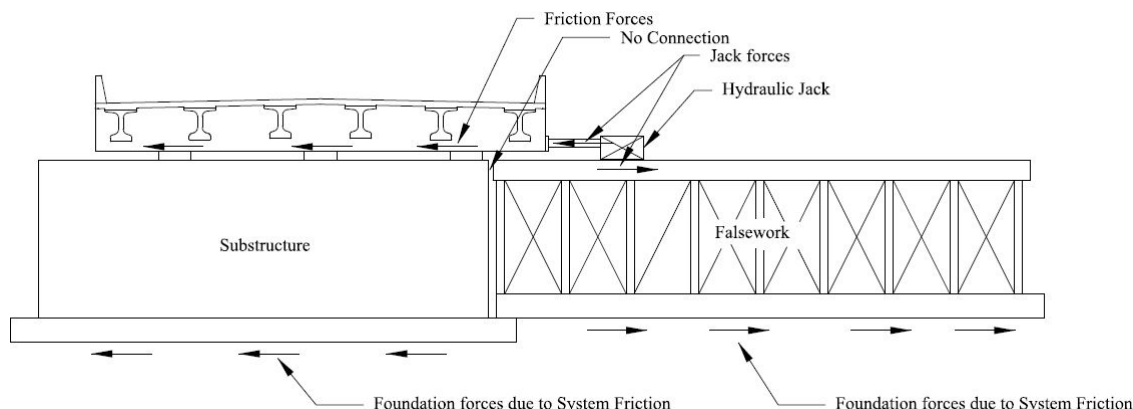


Figure 1.6.1.4-2—Falsework not Connected to Substructure (Resulting in Additional Foundation Forces)

1.6.1.5—Geotechnical Design for Sliding Systems

The Designer shall complete geotechnical investigations for the area under the anticipated falsework. The plans shall include subsurface exploration information and indicate acceptable foundation types for the falsework and the allowable loads on the foundations.

1.6.1.6—Substructure Design

The substructure shall be designed for all anticipated forces during the lateral slide based on the assumed jacking/support locations during the slide. The substructure shall be designed to resist the vertical dead load of the superstructure, treated as a moving load. Vertical dynamic effects may be neglected.

If the falsework and jacking system are assumed to be detached from the substructure during the lateral slide, the substructure shall be designed for the lateral friction forces. If the falsework and jacking system are assumed to be connected to the substructure during the lateral slide, then the design for friction forces is limited to the design of the bridge seat portion of the substructure.

1.6.1.7—Preliminary Falsework and Slide System Layout

The Designer shall indicate a schematic falsework system on the plans and verify that there is adequate space to construct the falsework.

C1.6.1.6

See Article 1.6.1.4 for information on resolution of sliding forces.

C1.6.1.7

The actual design of the falsework and slide system falls under the realm of “Contractor means and methods,” and is therefore not the responsibility of the Designer.

The Designer is responsible for verifying that the system can be built within the available right-of-way. The area required should be sufficient to accommodate the bridge and falsework. Additional space should be available for equipment such as jacking frames and other devices.

1.6.1.8—Specification Requirements

Specifications shall require the submission of a complete slide plan for review by the Designer.

Specifications shall allow alternate approaches to the falsework layout, slide system type, jacking points, support locations during the slide, etc. The Contractor shall be required to submit supporting calculations for alternate approaches.

Specifications shall include allowances for alternate temporary foundation types, provided the design is verified by the Contractor using the subsurface information provided and/or additional subsurface investigations.

1.6.2—CONTRACTOR

1.6.2.1—Design of Falsework and Sliding Systems

The Contractor is responsible for the final design of the falsework and the sliding system. The *AASHTO Guide Design Specifications for Bridge Temporary Works* shall be followed.

The deflection of the slide beam shall be kept to a minimum.

If a Contractor chooses to complete a lateral move of a bridge using SPMTs, the provisions of Article 1.5 shall be followed.

1.6.2.2—Final Design of Jacking Forces and Jacking Locations

The Contractor shall calculate the friction forces for the actual slide system to be used. If the friction forces exceed the friction forces shown on the plans or in the specification, the Contractor shall verify that the permanent bridge can resist the increased forces.

The jacking or pulling system used to move the bridge shall be designed to accommodate the calculated friction forces multiplied by a factor of 1.5.

1.6.2.3—Detailing of Slide System

The Contractor shall develop a complete design of the slide system including all framing, connections,

C1.6.1.8

More information on specification requirements can be found in Part 2.

C1.6.2.1

Deflections in the slide beam can lead to build-up of friction forces and binding of the system. The use of a very stiff beam or a beam supported by closely spaced posts should be considered.

It is reasonable to assume that a Contractor could elect to move a bridge in a lateral slide project using SPMTs as the slide mechanism in place of a slide track system or a rolling system.

C1.6.2.2

In most cases, the friction force will be the static or breakaway friction of the sliding system. Most sliding materials exhibit lower dynamic friction forces once the system is in motion.

Experience has shown that the initial force required to move the bridge can be higher than the estimated static friction. This is especially true if the bridge is resting on the sliding bearings for a period of time before the move. The specified factor is used to account for this anticipated additional breakaway force as well as any unintended surface conditions that might increase the friction forces. This requirement can be waived by the Owner if the Contractor can demonstrate consistent friction values in the proposed system.

C1.6.2.3

hardware, and equipment used to move the bridge. Methods of measuring bridge movement from each support location shall be included in the detailing.

The stroke capacity hydraulic pulling systems shall account for stretch in the pulling tension elements.

One method of moving a bridge involves the use of hydraulic pull jacks combined with rods or cables. If the rods or cables are long, a significant portion of the hydraulic stroke may be used to attain the required pull force, thereby limiting the effectiveness of the system and the time to complete the move. This potential difficulty should be investigated prior to the move.

1.7—REFERENCES

AASHTO. *AASHTO LRFD Bridge Design Specifications*, Eighth Edition with 2018 Errata. LRFD-8. American Association of State Highway and Transportation Officials, Washington, DC, 2017.

AASHTO. *AASHTO Guide Design Specifications for Bridge Temporary Works*, Second Edition. GSBTW-2. American Association of State Highway and Transportation Officials, Washington, DC, 2017.

Culmo, M.P., et al. *Guidelines for Prefabricated Bridge Elements and Systems Tolerances*. NCHRP Project 12-98, National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 2017.

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SECTION 2

GENERAL DESIGN PROVISIONS

2.1—SCOPE

C2.1

The provisions in this section contain information on recommended loads and load factors for ABC including prefabricated bridge elements and systems.

2.2—DEFINITIONS

See Section 1 for definitions of common prefabricated bridge elements.

2.3—NOTATION

- DL = dead loads applied to the bridge, falsework, and SPMTs (2.4.2.1) (2.4.2.2) (2.4.2.3)
 HDL = horizontal dynamic loads applied to the bridge, falsework, and SPMTs (2.4.2.3)
 VDL = vertical dynamic loads applied to the bridge, falsework, and SPMTs (2.4.2.1) (2.4.2.2) (2.4.2.3)
 γ_p = dead load factor as specified in the *AASHTO LRFD Bridge Design Specifications* (2.4.1.1) (2.4.2.2)
 γ_h = dynamic dead load factor for handling of prefabricated elements (2.4.1.1)

2.4—LOADS AND LOAD COMBINATIONS

C2.4

Prefabricated bridge elements and systems shall be designed to meet all of the load and load combination requirements of the *AASHTO LRFD Bridge Design Specifications* based on the completed structure.

The requirements of this article are based on the emulative design process, where the elements are designed and connected to behave as a structure built using conventional construction methods.

2.4.1—PREFABRICATED ELEMENTS

C2.4.1

This article contains recommendations for load combinations for prefabricated elements during construction.

Additional loads are imparted on prefabricated elements during fabrication, handling, and erection. This article includes recommendations for accounting for these loads in the design and construction process.

2.4.1.1—Shipping and Handling

All prefabricated elements shall be analyzed for shipping and handling forces during fabrication, shipping, and erection.

The following load combinations shall be used for shipping and handling calculations:

$$\text{Service I} = \gamma_h DL \quad (2.4.1.1-1)$$

$$\text{Strength I} = \gamma_p \gamma_h DL \quad (2.4.1.1-2)$$

where:

- γ_h = dynamic dead load factor for handling of prefabricated elements.
- γ_p = dead load factor as specified in the *AASHTO LRFD Bridge Design Specifications*

The following values for γ_h are recommended:

1. Dead load factors for removal of precast elements from forms:

Form finish	γ_h
Flat, with removable side forms no false joints or reveals	1.3
Flat, with false joints and/or reveals	1.4
Fluted with proper draft (tees, channels, fluted panels)	1.6
Sculptured	1.7

2. Dead load factors for yard handling and erection:

$$\gamma_h = 1.2$$

3. Dead load factor for shipping:

$$\gamma_h = 1.5$$

The values contained herein are based on the *Precast/Prestressed Concrete Institute Design Handbook* MNL-120 (2010).

These values for handling, erection, and shipping account for dynamic effects during construction. They would be applicable to prefabricated elements fabricated with any material (concrete, steel, etc.).

2.4.2—BRIDGE SYSTEMS—SPMT INSTALLATION

Several load combinations shall be checked for the design of the bridge, falsework, and SPMTs to resist horizontal and vertical dynamic loads during installation.

The Designer is responsible for the checks on the beams and deck. The Contractor is responsible for the checks on the falsework and SPMTs.

2.4.2.1—Service Load Combination for the Bridge

The Service I Load Combination as specified in the *AASHTO LRFD Bridge Design Specifications* shall be checked to control cracking in the deck during the bridge move, cracking in prestressed concrete beams subjected to negative bending during the move, and the bridge falsework (if designed using working stress methods). The following load combination shall be used:

$$\text{Service I} = 1.0DL + 0.40(VDL) \quad (2.4.2.1-1)$$

where:

- DL = dead loads applied to the bridge, falsework, and SPMTs
- VDL = vertical dynamic loads applied to the bridge, falsework, and SPMTs

C2.4.2.1

This limit state can also be used to check the SPMTs for working limit loads.

Horizontal dynamic forces will not affect the design of the bridge since it is considered a rigid body. Therefore they are excluded from this check.

The basis of this provision is the document *Guidelines for Dynamic Effects during Bridge System Installations* (Culmo, et al., 2017), which is recommended for use in calculating dynamic effects during SPMT bridge moves.

Research conducted for the development of this document involved establishing the upper bound for vertical dynamic loads with a loaded SPMT traversing uneven ground at a travel speed of approximately 4 miles per hour. The vertical dynamic effects are a function of the square of the travel speed of the SPMT. The load factor of 0.40 accounts for a travel speed value of approximately 2.5 miles per hour ($2.5^2/4.0^2$), which is a more realistic safe maximum travel speed. Designers

Other applicable loads and load factors specified in the *AASHTO LRFD Bridge Design Specifications* for the Service I Load Combination shall also be applied.

2.4.2.2—Strength Load Combination for the Bridge

The Strength I Load Combination as specified in the *AASHTO LRFD Bridge Design Specifications* shall be used to check the flexural capacity of the beams and the bridge. The following combination shall be used:

$$\text{Strength Load} = \gamma_p DL + 1.0(VDL) \quad (2.4.2.2-1)$$

where:

- γ_p = dead load factor as specified in the *AASHTO LRFD Bridge Design Specifications*
- DL = dead loads applied to the bridge, falsework, and SPMTs
- VDL = vertical dynamic loads applied to the bridge, falsework, and SPMTs

Other applicable loads and load factors specified in the *AASHTO LRFD Bridge Design Specifications* for the Strength I Load Combination shall also be applied.

2.4.2.3—Load Combinations for Falsework and SPMTs

The falsework and SPMTs shall be designed according to the *AASHTO Guide Design Specifications for Temporary Works* (2017). The following load combination shall be used:

$$ASD_{SPMT} = 1.0DL + 0.75(HDL) + 0.40(VDL) \quad (2.4.2.3-1)$$

where:

- DL = dead loads applied to the bridge, falsework, and SPMTs
- HDL = horizontal dynamic loads applied to the bridge, falsework, and SPMTs
- VDL = vertical dynamic loads applied to the bridge, falsework, and SPMTs

Other applicable loads and load factors as specified in Load Combination ASD_{12} shall also be applied to the falsework and SPMTs.

and Owners may elect to specify lower travel speeds along with corresponding load factors. Project specifications should limit the travel speed to this level in order to provide adequate service limit state performance.

C2.4.2.2

The basis of this provision is the document *Guidelines for Dynamic Effects during Bridge System Installations* (Culmo, et al., 2017), which is recommended for use in calculating dynamic loads during SPMT bridge moves.

Horizontal dynamic forces will not affect the design of the bridge since it is considered a rigid body. Therefore they are excluded from the check.

The 0.40 factor for travel speed in Equation 2.4.2.1-1 is replaced with a load factor of 1.0 in this equation, since the loads calculated in Article 2.4.2.1 represent an upper bound for vertical forces.

C2.4.2.3

The basis of this provision is the document *Guidelines for Dynamic Effects during Bridge System Installations* (Culmo, et al. 2017), which is recommended for use in calculating dynamic loads during SPMT bridge moves.

The primary cause of horizontal dynamic load (HDL) is the acceleration and deceleration of the SPMT. An emergency stop would represent the largest horizontal dynamic force, which is the basis for the loads calculated in the cited guideline. This is similar to a seismic load; however the probability of occurrence is higher. Load Combination ASD_{12} of the *AASHTO Guide Design Specifications for Bridge Temporary Works* (2017) accounts for seismic forces. A load factor of 0.53 is specified for seismic loads. The load factor of 0.75 in this provision is an approximate value based on the anticipated probability of occurrence.

See Article C2.4.2.1 for discussion regarding the 0.40 factor for vertical dynamic load.

2.4.3—BRIDGE SYSTEMS—LATERAL SLIDE INSTALLATION

Dynamic effects on the bridge structure for lateral slide installations are not significant due to the relative speed of the move and the systems used for the sliding. The primary forces that need to be accounted for are the horizontal sliding forces and horizontal and vertical jacking forces. The horizontal forces consist of static friction and dynamic friction.

Vertical dynamic effects associated with lateral sliding may be ignored in the design of the bridge and falsework. Horizontal sliding forces and vertical jacking forces can be considered construction loads as specified in the *AASHTO LRFD Bridge Design Specifications*.

2.4.4—OWNER SPECIFIED CRITERIA

The Owner may choose to specify alternative load factors and load combination criteria for ABC or prefabricated bridge elements.

C2.4.3

The document *Guidelines for Dynamic Effects during Bridge System Installations* (Culmo, et al. 2017), is recommended for use in calculating static and dynamic forces during lateral slide installations.

C2.4.4

Several of the provisions in this section are based on the document *Guidelines for Dynamic Effects during Bridge System Installations* (Culmo, et al., 2017), which was developed under NCHRP project 12-98. This guideline document has not yet been adopted for use by AASHTO; therefore, AASHTO member states may not be in concurrence with the values presented, and choose to adopt different criteria. Designers and Contractors should verify the design criteria prior to start of design.

2.5—REFERENCES

AASHTO. *AASHTO LRFD Bridge Design Specifications*, Eighth Edition with 2018 Errata. LRFD-8. American Association of State Highway and Transportation Officials, Washington, DC, 2017.

AASHTO. *AASHTO Guide Design Specifications for Bridge Temporary Works*, Second Edition. GSBTW-2. American Association of State Highway and Transportation Officials, Washington, DC, 2017.

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