5.6.3 Fabrication and Handling

A. Shop Plans

Fabricators of prestressed concrete girders are required to submit shop plans which show specific details for each girder. These shop plans are reviewed for conformance with the Contract Plans and specifications.

B. Special Problems for Fabricators

1. Strand Tensioning

The method selected for strand tensioning may affect the design of the girders. The strand arrangements shown in the office standard plans and included in the PGSuper computer program are satisfactory for tensioning methods used by fabricators in this state. Harped strands are normally tensioned by pulling them as straight strands to a partial tension. The strands are then deflected vertically as necessary to give the required harping angle and strand stress. In order to avoid overtensioning the harped strands by this procedure, the slope of the strands is limited to a maximum of 6:1 for 0.5″ ϕ strands and 8:1 for 0.6″ϕ strands. The straight strands are tensioned by straight jacking.

2. Hold Down Forces

Forces on the hold-down units are developed as the harped strands are raised. The hold-down device provided by the fabricator must be able to hold the vertical component of the harping forces. Normally a two or more hold-down unit is required. Standard commercial hold-down units have been preapproved for use with particular strand groups.

3. Numbers of Strands

Since the prestressing beds used by the girder fabricators can carry several girders in a line, it is desirable that girders have the same number of strands where practical. This allows several girders to be set up and cast at one time.

For pre-tensioned concrete girders, the number of permanent prestressing strands (straight and harped) shall be limited to 100 total 0.6″ϕ strands.

C. Handling of Prestressed Concrete Girders

1. In-Plant Handling

The maximum weight that can be handled by precasting plants in the Pacific Northwest is 252 kips. Pre-tensioning lines are normally long enough so that the weight of a girder governs capacity, rather than its length. Headroom is also not generally a concern for the deeper sections.

2. Lateral Stability During Handling

In order to ensure constructability, the designer shall specify the lifting embedment locations (centroid 3′ minimum from ends - see *Standard Specifications* Section 6-02.3(25)L), maximum midspan vertical deflection and the corresponding concrete strength at release that satisfies the stress limits from Section 5.2.1.C and provides an adequate factor of safety for lateral stability. The calculations shall conform to methods as described in *Standard Specifications* Section 6-02.3(25) and reference 26. Factors of safety of 1.0 against cracking and 1.5 against failure shall be used.

Biaxial stresses due to lateral bending at the girder tilt equilibrium condition shall consider the assumed lifting embedment transverse placement tolerance and the girder sweep tolerance. Stresses shall be evaluated for the girder tilt equilibrium condition for a hanging girder as described in Standard Specifications Section 6-02.3(25) and reference 26.

Lateral stability can be a concern when handling long, slender girders. Lateral bending failures are sudden, catastrophic, costly, pose a serious threat to workers and surroundings, and therefore shall be considered by designers. When the girder forms are stripped from the girder, the prestressing level is higher and the concrete strength is lower than at any other point in the life of the member. Lifting embedment/support misalignment, horizontal girder sweep and other girder imperfections can cause the girder to roll when handling, causing a component of the girder weight to be resisted by the weak axis.

Lateral stability may be improved using the following methods:

a. Move the lifting embedments away from the ends. This may increase the required concrete release strength, because decreasing the distance between lifting devices increases the concrete stresses at the harp point. Stresses at the support may also govern, depending on the exit location of the harped strands.

b. Select a girder section that is relatively wide and stiff about its vertical (weak) axis.

c. Add temporary prestressing in the top flange.

d. Brace the girder.

e. Raise the roll axis of the girder with a rigid yoke.

D. Shipping Prestressed Concrete Girders

1. General

The ability to ship girders can be influenced by a large number of variables, including mode of transportation, weight, length, height, and lateral stability. The ability to ship girders is also strongly site-dependent. For large or heavy girders, routes to the site shall be investigated during the preliminary design phase. To this end, on projects using large or heavy girders, WSDOT can place an advisory in their special provisions including shipping routes, estimated permit fees, escort vehicle requirements, Washington State Patrol requirements, and permit approval time.

2. Mode of Transportation

Three modes of transportation are commonly used in the industry: truck, rail, and barge. In Washington State, an overwhelming percentage of girders are transported by truck, so discussion in subsequent sections will be confined to this mode. However, on specific projects, it may be appropriate to consider rail or barge transportation.

Standard rail cars can usually accommodate larger loads than a standard truck. Rail cars range in capacity from approximately 120 to 200 kips. However, unless the rail system runs directly from the precasting plant to the jobsite, members must be trucked for at least some of the route, and weight may be restricted by the trucking limitations.

For a project where a large number of girders are required, barge transportation may be the most economical. Product weights and dimensions are generally not limited by barge delivery, but by the handling equipment on either end. In most cases, if a product can be made and handled in the plant, it can be shipped by barge.

3. **Weight Limitations**

The net weight limitation with trucking equipment currently available in Washington State is approximately 190 kips, if a reasonable delivery rate (number of pieces per day) is to be maintained. Product weights of up to 252 kips can be hauled with currently available equipment at a limited rate. The hauling of heavier girders may be possible with coordination with hauling subcontractors. Hauling subcontractors should be consulted on the feasibility of shipping large or heavy girders on specific projects.

4. **Support Locations**

The designer shall provide shipping support locations in the plans to ensure adequate girder stability. Shipping support locations shall be no closer than the girder depth to the ends of the girder at the girder centerline. The overhangs at the leading and trailing ends of the girders should be minimized and equal if possible. Generally, the leading end overhang should not exceed 15′ to avoid interference with trucking equipment. Local carriers should be consulted if a larger leading end overhang is required. Shipping support locations shall maintain the concrete stresses within allowable limits.

Length between shipping support locations may be governed by turning radii on the route to the jobsite. Potential problems can be circumvented by moving the support points closer together (away from the ends of the girder), or by selecting alternate routes. Up to 130′ between supports is typically acceptable for most projects.

5. **Height Limitations**

The height of a deep girder section sitting on a jeep and steerable trailer is of concern when considering overhead obstructions on the route to the jobsite. The height of the support is approximately 6′ above the roadway surface. When adding the depth of the girder, including camber, the overall height from the roadway surface to the top of concrete can rapidly approach 14′. Overhead obstructions along the route should be investigated for adequate clearance in the preliminary design phase. Obstructions without adequate clearance must be bypassed by selecting alternate routes.

Expectations are that, in some cases, overhead clearance will not accommodate the vertical stirrup projection on deeper WSDOT standard girder sections. Alternate stirrup configurations can be used to attain adequate clearance, depending on the route from the plant to the jobsite.

6. Lateral Stability During Shipping

In order to ensure constructability, the designer shall specify concrete strengths, shipping support locations, minimum shipping support rotational spring constants, shipping support center-to-center wheel spacing, maximum midspan vertical deflection at shipping and temporary top strand configurations in the Plans that satisfy the stress limits from Section 5.2.1.C and provide adequate factors of safety for lateral stability during shipping. The calculations shall conform to methods described in *Standard Specifications* Section 6-02.3(25) and reference 26. Factors of safety of 1.0 against cracking and 1.5 against failure and rollover shall be used. The maximum midspan vertical deflection at shipping used to evaluate stability shall be shown in the plans. In order to minimize the need for re-analysis under contract, this value may be conservatively determined using losses at 10 days, camber at 90 days, and a span length equal to the girder length.

The rotational stiffness and center-to-center wheel spacing used in design shall be taken from Table 5.6.3-1. Design the girder for transportation with the least stiff support system as possible while achieving recommended factors of safety.

Table 5.6.3-1 Shipping Support Parameters

Shipping Support Rotational Spring Constant, K_θ (Kip-in/radian)	Shipping Support Center-to-Center Wheel Spacing, W_{cc}
40,000	72
50,000	72
60,000	72 or 96
70,000	96
80,000	96

Design for shipping should not preclude the contractor from making modifications under contract that consider actual conditions, such as fabrication tolerances and the haul route, but the Engineer should confirm that any proposed changes are structurally acceptable in the final in-service structure.

E. Erection and Bridge Deck Construction

A variety of methods are used to erect prestressed concrete girders, depending on the weight, length, available crane capacity, and site access. Lifting girders during erection is not as critical as when they are stripped from the forms, particularly when the same lifting devices are used for both. However, if a separate set of erection devices are used, the girder shall be checked for stresses and lateral stability. In addition, once the girder is set in place, the free span between supports is usually increased. Wind can also pose a problem. Consequently, when girders are erected, they shall immediately be braced. The temporary bracing of the girders is the contractor's responsibility.

For tub girders, designers should consider web out-of-plane bending forces that will develop during construction (e.g. loading due to the deck finishing machine). These cases may govern the design of web stirrups.

F. Construction Sequence for Multi-Span Prestressed Concrete Girder Bridges

For multi-span prestressed concrete girder bridges, the sequence and timing of the superstructure construction has a significant impact on the performance and durability of the bridge. In order to maximize the performance and durability, the "construction sequence" details shown on the Bridge Standard Drawings website (www.wsdot.wa.gov/Bridge/Structures/StandardDrawings.htm) shall be followed for all new WSDOT multi-span prestressed concrete girder bridges. Particular attention shall be paid to the timing of casting the lower portion of the pier diaphragms/crossbeams (30 days minimum after girder fabrication) and the upper portion of the diaphragms/crossbeams (10 days minimum after placement of the deck slab). The requirements apply to multi-span prestressed concrete girder bridges with monolithic and hinge diaphragms/crossbeams.

5.6.4 Superstructure Optimization

A. Girder Selection

Cost of the girders is a major portion of the cost of prestressed concrete girder bridges. Much care is therefore warranted in the selection of girders and in optimizing their position within the structure. The following general guidelines should be considered.

1. Girder Series Selection

All girders in a bridge shall be of the same series unless approved otherwise by the Bridge and Structures Engineer. If vertical clearance is no problem, a larger girder series, utilizing fewer girder lines, may be a desirable solution.

Fewer girder lines may result in extra reinforcement and concrete but less forming cost. These items must also be considered.

2. Girder Concrete Strength

Higher girder concrete strengths should be specified where that strength can be effectively used to reduce the number of girder lines, see Section 5.1.1.A.2. When the bridge consists of a large number of spans, consideration should be given to using a more exact analysis than the usual design program in an attempt to reduce the number of girder lines. This analysis shall take into account actual live load, creep, and shrinkage stresses in the girders.

3. Girder Spacing

Consideration must be given to the deck slab cantilever length to determine the most economical girder spacing. This matter is discussed in Section 5.6.4.B. The deck slab cantilever length should be made a maximum if a line of girders can be saved. It is recommended that the overhang length, from edge of slab to center line of exterior girder, be less than 40 percent of girder spacing; then the exterior girder can use the same design as that of the interior girder. The following guidance is suggested.

i. **Tapered Spans**

On tapered roadways, the minimum number of girder lines should be determined as if all girder spaces were to be equally flared. As many girders as possible, within the limitations of girder capacity should be placed.

Washington State
Department of Transportation

Bridge Design Manual (LRFD)

M 23-50.19

July 2019

Engineering and Regional Operations
Bridge and Structures Office

Americans with Disabilities Act (ADA) Information

English

Title VI Notice to Public It is the Washington State Department of Transportation's (WSDOT) policy to assure that no person shall, on the grounds of race, color, national origin or sex, as provided by Title VI of the Civil Rights Act of 1964, be excluded from participation in, be denied the benefits of, or be otherwise discriminated against under any of its federally funded programs and activities. Any person who believes his/her Title VI protection has been violated, may file a complaint with WSDOT's Office of Equal Opportunity (OEO). For additional information regarding Title VI complaint procedures and/or information regarding our non-discrimination obligations, please contact OEO's Title VI Coordinator at 360-705-7090.

Americans with Disabilities Act (ADA) Information This material can be made available in an alternate format by emailing the Office of Equal Opportunity at wsdotada@wsdot.wa.gov or by calling toll free, 855-362-4ADA(4232). Persons who are deaf or hard of hearing may make a request by calling the Washington State Relay at 711.

Spanish

Notificación de Titulo VI al Público Es la póliza de el Departamento de Transportes del Estado de Washington de asegurar que ninguna persona sea excluida de participación o sea negado los beneficios, o sea discriminado bajo cualquiera de sus programas y actividades financiado con fondos federales sobre la base de raza, color, origen nacional o sexo, como proveído por el Título VI de el Acto de Derechos Civiles de 1964. Cualquier persona que cree que sus protecciones de Titulo VI han sido violadas, puede hacer una queja con la Oficina de Igualdad de Oportunidades (OEO). Para información adicional con respecto a procedimientos de quejas de Titulo VI y/o información con respecto a nuestras obligaciones sin discriminación, por favor de comunicarse con el Coordinador de Titulo VI de la Oficina de Igualdad de Oportunidades (OEO) 360-705-7090.

Información del Acta Americans with Disabilities Act (ADA)
Este material es disponible en un formato alternative. Envie su petición por correo electrónico al equipo de Oficina de Igualdad de Oportunidades (OEO) en wsdotada@wsdot.wa.gov o llamando gratis, 855-362-4ADA (4232). Personas sordas o con problemas de audición pueden solicitar llamando el relé de estado de Washington al 711. For public events (like Open Houses, etc) English Accommodation requests for people with disabilities can be made by contacting the WSDOT Diversity/ADA Affairs team at wsdotada@wsdot.wa.gov or by calling toll-free, 855-362-4ADA (4232). Persons who are deaf or hard of hearing may make a request by calling the Washington State Relay at 711. Spanish Solicitudes de alojamiento para personas con discapacidad pueden hacer comunicándose con el equipo de Asuntos de diversidad/ADA WSDOT en wsdotada@wsdot.wa.gov o llamando al número gratuito, 855-362-4ADA (4232). Personas sordas o con problemas de audición pueden solicitar llamando el relé del estado de Washington al 711.

To get the latest information on WSDOT publications, sign up for individual email updates at www.wsdot.wa.gov/publications/manuals.

Washington State Department of Transportation
Bridge and Structures Office
PO Box 47340
Olympia, WA 98504-7340

Phone: 360-705-7753
Email: sargenw@wsdot.wa.gov
www.wsdot.wa.gov/eesc/bridge/index.cfm?fuseaction=home

Foreword

This manual has been prepared to provide Washington State Department of Transportation (WSDOT) bridge design engineers with a guide to the design criteria, analysis methods, and detailing procedures for the preparation of highway bridge and structure construction plans, specifications, and estimates.

It is not intended to be a textbook on structural engineering. It is a guide to acceptable WSDOT practice. This manual does not cover all conceivable problems that may arise, but is intended to be sufficiently comprehensive to along with sound engineering judgment, provide a safe guide for bridge engineering.

A thorough knowledge of the contents of this manual is essential for a high degree of efficiency in the engineering of WSDOT highway structures.

This loose leaf form of this manual facilitates modifications and additions. New provisions and revisions will be issued fro time to time to keep this guide current. Suggestions for improvement and updating the manual are always welcome.

All manual modifications be approved by the Bridge Design Engineer.

The Federal Highway Administration has agreed to approve designs that follow the guidance in the *Bridge Design Manual*; therefore, following the guidance is mandatory for state highway projects. When proposed designs meet the requirements contained in the *Bridge Design Manual*, little additional documentation is required.

The electronic version of this document is available at:
www.wsdot.wa.gov/publications/manusl/m23-50.htm

Tom Baker, P.E. Bridge and Structures Engineer	Debbie Lehmann, P.E. FHWA Washington Division Bridge Engineer