COMPUTERS & STRUCTURES, INC.

STRUCTURAL AND EARTHQUAKE ENGINEERING SOFTWARE

CSiBRIDGE® 2017

Integrated 3-D Bridge Analysis, Design and Rating

Bridge Superstructure Design

SNiP 2.05.03-84

CSiBridge®

Bridge Superstructure Design

Russian Bridge Code SNiP 2.05.03-84

ISO BRG102816M13 Rev. 0
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Contents

Bridge Superstructure Design

9 Display Bridge Design Results

Bibliography

Chapter 1
Introduction

As the ultimate versatile, integrated tool for modeling, analysis, and design of bridge structures, CSiBridge can apply appropriate code-specific design processes to concrete box girder bridge design, design when the superstructure includes Precast Concrete Box bridges with a composite slab and steel I-beam bridges with composite slabs. The ease with which these tasks can be accomplished makes CSiBridge the most productive bridge design package in the industry.

Design using CSiBridge is based on load patterns, load cases, load combinations and design requests. The design output can then be displayed graphically and printed using a customized reporting format.

It should be noted that the design of bridge superstructure is a complex subject and the design codes cover many aspects of this process. CSiBridge is a tool to help the user with that process. Only the aspects of design documented in this manual are automated by the CSiBridge design capabilities. The user must check the results produced and address other aspects not covered by CSiBridge.

1.1 Organization

This manual is designed to help you become productive using CSiBridge design in accordance with the available codes when modeling concrete box girder bridges and precast concrete girder bridges. Chapter 2 describes code-specific design prerequisites. Chapter 3 describes Live Load Distribution Factors. Chapter 4 describes defining the design request, which includes the design request name, a bridge object name (i.e., the bridge model), check type (i.e., the type of design), station range (i.e., portion of the bridge to be designed), design parameters (i.e., overwrites for default parameters) and demand sets (i.e., loading combinations). Chapter 5 identifies code-specific algorithms used by CSiBridge in completing concrete box girder bridges. Chapter 6 provides code-specific algorithms used by CSiBridge in completing concrete box and multi-cell box girder bridges. Chapter 7 describes code-specific design parameters for precast I and U girder. Chapter 8 describes how to run a Design Request using an example that applies the AASHTO LRFD 2007 code, and Chapter 11 describes design output for the example in Chapter 9, which can be presented graphically as plots, in data tables, and in reports generated using the Advanced Report Writer feature.

1.2 Recommended Reading/Practice

It is strongly recommended that you read this manual and review any applicable "Watch & Learn" Series™ tutorials, which are found on our web site, http://www.csiamerica.com, before attempting to design a concrete box girder or precast concrete bridge using CSiBridge. Additional information can be found in the online Help facility available from within the software's main menu.

Chapter 2
Define Loads and Load Combinations

This chapter describes the steps that are necessary to define the loads and load combinations that the user intends to use in the design of the bridge superstructure. The user may define the load combinations manually. First, the user will need to select the Russian SNiP code using the **Design/Rating > Superstructure Design > Preference** command. Load pattern types can be defined using the **Loads > Load Patterns** command. CSiBridge contains a number of load pattern types that are shown below in Tables 2-1 and 2-2. Users may define and use any load pattern name.

2.1 Load Pattern Types

Tables 2-1 and 2-2 show the permanent and transient load pattern types that can be defined in CSiBridge. The tables also show the AASHTO abbreviation and the load pattern descriptions. Users may choose any name to identify a load pattern type.

Table 2-1 *PERMANENT* Load Pattern Types

CSiBridge Load Pattern Type	Description of Load Pattern
CREEP	Force effects due to creep
DOWNDRAG	Downdrag force
DEAD	Dead load of structural components and non-structural attachments

Table 2-1 *PERMANENT* Load Pattern Types

CSiBridge Load Pattern Type	Description of Load Pattern
SUPERDEAD	Superimposed dead load of wearing surfaces and utilities
BRAKING	Vehicle braking force
HORIZ. EARTH PR	Horizontal earth pressures
LOCKED IN	Misc. locked-in force effects resulting from the construction process
EARTH SURCHARGE	Earth surcharge loads
VERT. EARTH PR	Vertical earth pressure
PRESTRESS	Hyperstatic forces from post-tensioning

Table 2-2 *TRANSIENT* Load Pattern Types

CSiBridge Load Pattern Type	Description of Load Pattern
BRAKING	Vehicle braking force
CENTRIFUGAL	Vehicular centrifugal loads
VEHICLE COLLISION	Vehicular collision force
VESSEL COLLISION	Vessel collision force
QUAKE	Earthquake
FRICTION	Friction effects
ICE	Ice loads
-	Vehicle Dynamic Load Allowance
BRIDGE LL	Vehicular live load
LL SURCHARGE	Live load surcharge
PEDESTRIAN LL	Pedestrian live load
SETTLEMENT	Force effects due settlement
TEMP GRADIENT	Temperature gradient loads
TEMPERATURE	Uniform temperature effects
STEAM FLOW	Water load and steam pressure
WIND–LIVE LOAD	Wind on live load
WIND	Wind loads on structure

2.2 Design Load Combinations

Load combinations may be defined using the **Design/Rating>Load Combinations** command.

Chapter 3
Live Load Distribution

This chapter describes the algorithms used by CSiBridge that can be used to control assignment of live load demands to individual girders. An explanation is given with respect to how the distribution factors are applied in a shear, stress, and moment check.

Live load distribution factors can be used to control sharing of live load demands by individual girders in spine models that use single frame objects to model an entire cross-section. The use of live load distribution factors is also allowed on area and solid object models.

Legend:
Girder = beam + tributary area of composite slab or web + tributary area of top and bottom slab
Section Cut = all girders present in the cross-section at the cut location
LLD = Live Load Distribution

3.1 Methods for Determining Live Load Distribution

CSiBridge gives the user a choice of three methods to address distribution of live load to individual girders.

Method 1 – The LLD factors are specified directly by the user.

Method 2 – CSiBridge reads the calculated live load demands directly from individual girders (available only for Area or Solid models).

Method 3 – CSiBridge distributes the live load uniformly into all girders.

It is important to note that to obtain relevant results, the definition of a Moving Load case must be adjusted depending on which method is selected.

- When the LLD factors are user specified (Method 1), the number of loaded lanes and MultiLane Scale Factors included in the demand set combinations should correspond to the assumptions based on which the LLD factor was derived. (For example when factors based on AASHTO LRFD code are used only one lane with a MultiLane Scale Factor = 1 should be loaded into Moving Load cases included in the demand set combinations. The vehicle classes defined in the moving load case shall comprise the truck and lane load as defined in LRFD clause 5.7.1.2.1.2 or 5.7.1.4.1.2.)

- When CSiBridge reads the demands directly from individual girders (Method 2, applicable to area and solid models only) or when CSiBridge applies the LLD factors uniformly (Method 3), multiple traffic lanes with relevant Multilane Scale Factors should be loaded in accordance with code requirements.

3.2 Determination of Live Load Distribution Factors

The Russian SNiP code does not give specific guidance on how to calculate Live Load Distribution factors for exterior and interior beams. Other bridge codes, such as AASHTO LRFD or CAN/CSA S6, specify comprehensive methods for determining LLD factors for various types of cross-sections. The LLD factors typically are dependent on the following parameters:

- span length—the length of span for which moment or shear is being calculated.

- the number of girders

- girder designation—the first and last girders are designated as exterior girders and the other girders are classified as interior girders

- roadway width and spacing of girders

- overhang—consists of the horizontal distance from the centerline of the exterior web of the left exterior beam at deck level to the interior edge of the curb or traffic barrier
- the beams—includes the area, moment of inertia, torsion constant, center of gravity
- the thickness of the composite slab t1 and the thickness of concrete slab haunch t2
- the tributary area of the composite slab—which is bounded at the interior girder by the midway distances to neighboring girders and at the exterior girder; includes the entire overhang on one side, and is bounded by the midway distances to the neighboring girder on the other side
- Young's modulus for both the slab and the beams—angle of skew support.

If the live load demands are to be read by CSiBridge directly from the individual girders (Method 2; see the next subsection), the model type must be area or solid. This is the case because with the spine model option, CSiBridge models the entire cross-section as one frame element and there is no way to extract forces on individual girders. All other model types and LLD factor method permutations are allowed.

3.3 Apply LLD Factors

The application of live load distribution factors varies, depending on which method has been selected: user specified (Method 1); directly from individual girders (Method 2); or uniformly distributed onto all girders (Method 3).

3.3.1 User Specified (Method 1)

When this method is selected, CSiBridge reads the girder designations (i.e., exterior and interior) and assigns live load distribution factors to the individual girders accordingly.

3.3.2 Forces Read Directly from Girders (Method 2)

When this method is selected, CSiBridge sets the live load distribution factor for all girders to 1.

3.3.3 Uniformly Distributed to Girders (Method 3)

When this method is selected, the live load distribution factor is equal to 1/*n* where *n* is the number of girders in the section. All girders have identical LLD factors disregarding their designation (exterior, interior) and demand type (shear, moment).

3.4 Generate Virtual Combinations (Methods 1 and 3)

When the method for determining the live load distribution is user-specified or uniformly distributed (Methods 1 or 3), CSiBridge generates virtual load combination for every valid section cut selected for design. The virtual combinations are used during a stress check and check of the shear and moment to calculate the forces on the girders. After those forces have been calculated, the virtual combinations are deleted. The process is repeated for all section cuts selected for design.

Four virtual COMBO cases are generated for each COMBO that the user has specified in the Design Request (see Chapter 4). The program analyzes the design type of each load case present in the user specified COMBO and multiplies all non-moving load case types by 1/ *n* (where *n* is the number of girders) and the moving load case type by the section cut values of the LLD factors (exterior moment, exterior shear, interior moment and interior shear LLD factors). This ensures that dead load is shared evenly by all girders, while live load is distributed based on the LLD factors.

The program then completes a stress check and a check of the shear and the moment for each section cut selected for design.

3.4.1 Stress Check (Methods 1 and 3)

At the Section Cut being analyzed, the girder stresses at all stress output points are read from CSiBridge for every virtual COMBO generated. To ensure that live load demands are shared equally irrespective of lane eccentricity by all girders, CSiBridge uses averaging when calculating the girder stresses. It calculates the stresses on a beam by integrating axial and M3 moment demands on all the beams in the entire section cut and dividing the demands by the number of girders. Similarly, P and M3 forces in the composite slab are integrated and stresses are calculated in the individual tributary areas of the slab by dividing the total slab demand by the number of girders.

When stresses are read from analysis into design, the stresses are multiplied by *n* (where *n* is number of girders) to make up for the reduction applied in the Virtual Combinations.

3.4.2 Shear or Moment Check (Methods 1 and 3)

At the Section Cut being analyzed, the entire section cut forces are read from CSiBridge for every Virtual COMBO generated. The forces are assigned to individual girders based on their designation. (forces from two virtual Combinations — one for shear and one for moment—generated for exterior beam are assigned to both exterior beams, and similarly, Virtual Combinations for interior beams are assigned to interior beams.)

3.5 Read Forces/Stresses Directly from Girders (Method 2)

When the method for determining the live load distribution is based on forces read directly from the girders, the method varies based on which Design Check has been specified in the Design Request (see Chapter 4).

3.5.1 Stress Check (Method 2)

At the Section Cut being analyzed, the girder stresses at all stress output points are read from CSiBridge for every COMBO specified in the Design Request. CSiBridge calculates the stresses on a beam by integrating axial, M3 and M2 moment demands on the beam at the center of gravity of the beam. Similarly P, M3 and M2 demands in the composite slab are integrated at the center of gravity of the slab tributary area.

3.5.2 Shear or Moment Check (Method 2)

At the Section Cut being analyzed, the girder forces are read from CSiBridge for every COMBO specified in the Design Request (see Chapter 4). CSiBridge calculates the demands on a girder by integrating axial, M3 and M2 moment demands on the girder at the center of gravity of the girder.

Chapter 4
Define a Bridge Design Request

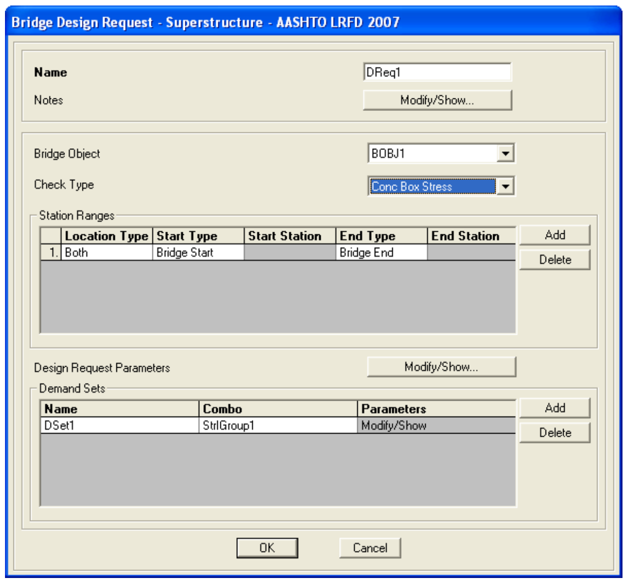
This chapter describes the Bridge Design Request, which is defined using the **Design/Rating > Superstructure Design > Design Requests** command.

Each Bridge Design Request is unique and specifies which bridge object is to be designed, the type of check to be performed (e.g., concrete box stress, precast composite stress, and so on), the station range (i.e., the particular zone or portion of the bridge that is to be designed), the design parameters (i.e., parameters that may be used to overwrite the default values automatically set by the program) and demand sets (i.e., the load combination[s] to be considered). Multiple Bridge Design Requests may be defined for the same bridge object.

Before defining a design request, the applicable code should be specified using the **Design/Rating > Superstructure > Preferences** command. Currently, the AASHTO STD 2002, AASHTO LRFD 2007, AASHTO LRFD 2012, CAN/CSA S6, EN 1992, Indian IRC, and SNiP codes are available for the design of a concrete box girder; the AASHTO 2007 LRFD, AASHTO LRFD 2012, CAN/CSA S6, EN 1992, Indian IRC, and SNiP codes are available for the design of a Precast I or U Beam with Composite Slab; the AASHTO LFRD 2007, AASHTO LRFD 2012, CAN/CSA S6, EN 1992-1-1, and SNiP are available for Steel I-Beam with Composite Slab superstructures; and the AASHTO LRFD 2012 is available for a U tub bridge with a composite slab.

Figure 4-1 shows the Bridge Design Request form when the bridge object is for a concrete box girder bridge, and the check type is concrete box stress. Figure 4-2 shows the Bridge Design Request form when the bridge object is for a Composite I or U girder bridge and the check type is precast composite stress. Figure 4-3 shows the Bridge Design Request form when the bridge object is for a Steel I-Beam bridge and the check type is composite strength.

Figure 4-1 Bridge Design Request - Concrete Box Girder Bridges



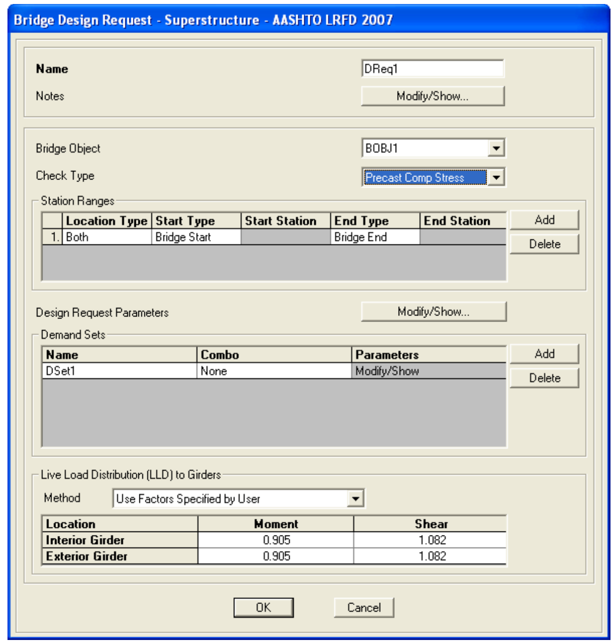


Figure 4-2 Bridge Design Request - Composite I or U Girder Bridges

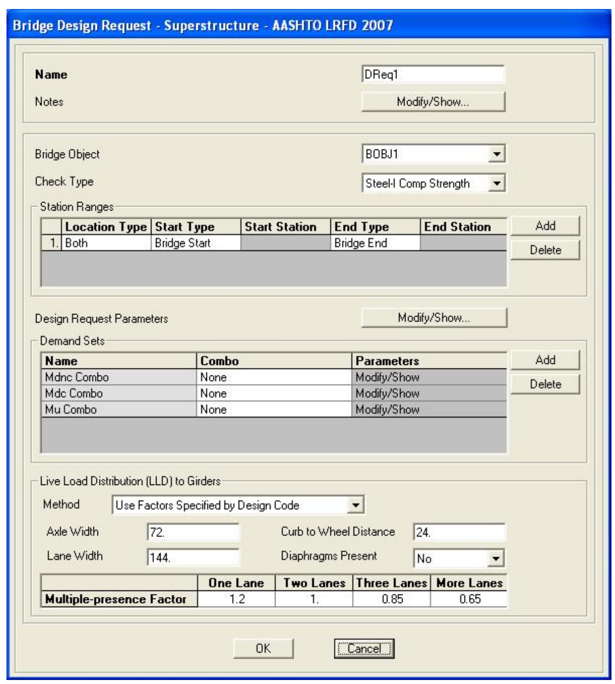


Figure 4-3 Bridge Design Request – Steel I Beam with Composite Slab

4.1 Name and Bridge Object

Each Bridge Design Request must have unique name. Any name can be used.

If multiple Bridge Objects are used to define a bridge model, select the bridge object to be designed for the Design Request. If a bridge model contains only a single bridge object, the name of that bridge object will be the only item available from the Bridge Object drop-down list.

4.2 Check Type

The Check Type refers to the type of design to be performed and the available options depend on the type of bridge deck being modeled.

For a **Concrete Box Girder** bridge, CSiBridge provides the following check type options:

AASHTO STD 2002

- Concrete **Box Stress**

AASHTO LRFD 2007

- Concrete **Box Stress**
- Concrete **Box Flexure**
- Concrete **Box Shear** and Torsion
- Concrete **Box Principal**

CAN/CSA S6, EN 1992-1-1, IRC: 112, and SNiP

- Concrete **Box Stress**
- Concrete **Box Flexure**
- Concrete **Box Shear**

For Multi-Cell Concrete Box Girder bridge, CSiBridge provides the following check type options:

AASHTO LRFD 2007, CAN/CSA S6, EN 1992-1-1, IRC: 112, and SNiP

- Concrete **Box Stress**
- Concrete **Box Flexure**
- Concrete **Box Shear**

For bridge models with **precast I or U Beams with Composite Slabs**, CSiBridge provides three check type options, as follows:

AASHTO LRFD 2007, CAN/CSA S6, EN 1992-1-1, IRC: 112, and SNiP

- **Precast Comp Stress**
- **Precast Comp Shear**
- **Precast Comp Flexure**

For bridge models with **steel I-beam with composite slab superstructures**, CSiBridge provides the following check type option:

AASHTO LRFD 2007 and 2012

- **Steel Comp Strength**
- **Steel Comp Service**
- **Steel Comp Fatigue**
- **Steel Comp Constructability Staged**
- **Steel Comp Constructability NonStaged**

EN 1994-2:2005 and SNiP

- **Steel Comp Ultimate**
- **Steel Comp Service Stresses**
- **Steel Comp Service Rebar**
- **Steel Comp Constructability Staged**

- **Steel Comp Constructability NonStaged**

The bold type denotes the name that appears in the check type drop-down list. A detailed description of the design algorithm can be found in Chapter 5 for concrete box girder bridges, in Chapter 6 for multi-cell box girder bridges, in Chapter 7 for precast I or U beam with composite slabs, and in Chapter 8 for steel I-beam with composite slab.

4.3 Station Range

The station range refers to the particular zone or portion of the bridge that is to be designed. The user may choose the entire length of the bridge, or specify specific zones using station ranges. Multiple zones (i.e., station ranges) may be specified as part of a single design request.

When defining a station range, the user specifies the Location Type, which determines if the superstructure forces are to be considered before or at a station point. The user may choose the location type as before the point, after the point, or both.

4.4 Design Parameters

Design parameters are overwrites that can be used to change the default values set automatically by the program. The parameters are specific to each code, deck type, and check type. Figure 4-4 shows the Superstructure Design Request Parameters form.

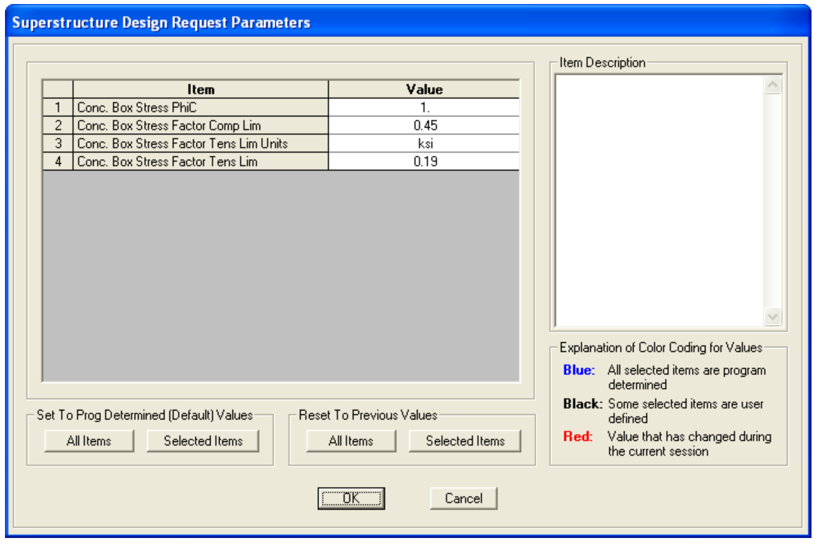


Figure 4-3 Superstructure Design Request Parameters form

Table 4-1 shows the parameters for concrete box girder bridges. Table 4-2 shows the parameters for multi-cell concrete box bridges. Table 4-3 shows the parameters applicable when the superstructure has a deck that includes precast I or U girders with composite slabs. Table 4-4 shows the parameters applicable when the superstructure has a deck that includes steel I-beams.

Table 4-1 Design Request Parameters for Concrete Box Girders

AASHTO STD 2002	
Concrete Box Stress	▪ Resistance Factor - multiplies both compression and tension stress limits ▪ Multiplier on f'_c to calculate the compression stress limit ▪ Multiplier on sqrt(f'_c) to calculate the tension stress limit, given in the units specified ▪ The tension limit factor may be specified using either MPa or ksi units for f'_c and the resulting tension limit

Table 4-1 Design Request Parameters for Concrete Box Girders

AASHTO LRFD 2007	
Concrete Box Stress	▪ Concrete Box Stress, *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits ▪ Concrete Box Stress Factor Compression Limit - Multiplier on f'_c to calculate the compression stress limit ▪ Concrete Box Stress Factor Tension Limit Units - Multiplier on sqrt(f'_c) to calculate the tension stress limit, given in the units specified ▪ Concrete Box Stress Factor Tension Limit - The tension limit factor may be specified using either MPa or ksi units for f'_c and the resulting tension limit
Concrete Box Shear	▪ Concrete Box Shear, *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits ▪ Concrete Box Shear, *PhiC*, *Lightweight* Resistance Factor that multiplies nominal shear resistance to obtain factored resistance for light-weight concrete ▪ Include Resal (Hunching-girder) shear effects – Yes or No. Specifies whether the component of inclined flexural compression or tension, in the direction of the applied shear, in variable depth members shall or shall not be considered when determining the design factored shear force in accordance with Article 5.8.6.2. ▪ Concrete Box Shear Rebar Material - A previously defined rebar material label that will be used to determine the area of shear rebar required ▪ Longitudinal Torsional Rebar Material - A previously defined rebar material that will be used to determine the area of longitudinal torsional rebar required
Concrete Box Flexure	▪ Concrete Box Flexure, *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits
Concrete Box Principal	▪ See the Box Stress design parameter specifications
CAN/CSA S6	
Concrete Box Stress	▪ Multi-Cell Concrete Box Stress Factor Compression Limit - Multiplier on f'_c to calculate the compression stress limit ▪ Multi-Cell Concrete Box Stress Factor Tension Limit - The tension limit factor may be specified using either MPa or ksi units for f'_c and the resulting tension limit
Concrete Box Shear	▪ Phi Concrete φ_c -- Resistance factor for concrete (see CSA

Table 4-1 Design Request Parameters for Concrete Box Girders

	Clause 8.4.6) ▪ Phi PT φ_p -- Resistance factor for tendons (see CSA Clause 8.4.6) ▪ Cracking Strength Factor – Multiplies sqrt(f'_c) to obtain cracking strength ▪ EpsilonX Negative Limit -- Longitudinal negative strain limit (see Clause 8.9.3.8) ▪ EpsilonX Positive Limit -- Longitudinal positive strain limit (see Clause 8.9.3.8) ▪ Tab slab rebar cover – Distance from the outside face of the top slab to the centerline of the exterior closed transverse torsion reinforcement ▪ Web rebar cover – Distance from the outside face of the web to the centerline of the exterior closed transverse torsion reinforcement ▪ Bottom Slab rebar cover – Distance from the outside face of the bottoms lab to the centerline of the exterior closed transverse torsion reinforcement ▪ Shear Rebar Material – A previously defined rebar material label that will be used to determine the required area of transverse rebar in the girder ▪ Longitudinal Rebar Material – A previously defined rebar material that will be used to determine the required area of longitudinal rebar in the girder
Concrete Box Flexure	▪ Phi Concrete φ_c -- Resistance factor for concrete (see CSA Clause 8.4.6) ▪ Phi Pt φ_p -- Resistance factor for tendons (see CSA Clause 8.4.6) ▪ Phi Rebar φ_s -- Resistance factor for reinforcing bars (see CSA Clause 8.4.6)
Eurocode EN 1992 and SNiP	
Concrete Box Stress	▪ Compression limit – Multiplier on $f_c k$ to calculate the compression stress limit ▪ Tension limit – Multiplier on $f_c k$ to calculate the tension stress limit
Concrete Box Shear	▪ Gamma C for Concrete – Partial factor for concrete. ▪ Gamma C for Rebar – Partial safety factor for reinforcing steel. ▪ Gamma C for PT – Partial safety factor for prestressing steel. ▪ Angle Theta – The angle between the concrete compression strut and the beam axis perpendicular to the shear force.

Table 4-1 Design Request Parameters for Concrete Box Girders

	The value must be between 21.8 degrees and 45 degrees. ▪ Factor for PT Duct Diameter – Factor that multiplies post-tensioning duct diameter when evaluating the nominal web thickness in accordance with Section 6.2.3(6) of the code. Typical values 0.5 to 1.2. ▪ Factor for PT Transmission Length – Factor for the transmission length of the post tensioning used in shear resistance equation 6.4 of the code. Typical value 1.0 for post tensioning. ▪ Inner Arm Method – The method used to calculate the inner lever arm "z" of the section (integer). ▪ Inner Arm Limit – Factor that multiplies the depth of the section to get the lower limit of the inner lever arm "z" of the section. ▪ Effective Depth Limit – Factor that multiplies the depth of the section to get the lower limit of the effective depth to the tensile reinforcement "d" of the section. ▪ Type of Section – Type of section for shear design. ▪ Determining Factor Nu1 – Method that will be used to calculate the η_1 factor. ▪ Factor Nu1 – η_1 factor ▪ Determining Factor AlphaCW – Method that will be used to calculate the α_{cw} factor. ▪ Factor AlphaCW – α_{cw} factor ▪ Factor Fywk – Multiplier of vertical shear rebar characteristic yield strength to obtain a stress limit in shear rebar used in 6.10.aN. Typical value 0.8 to 1.0. ▪ Shear Rebar Material – A previously defined material label that will be used to determine the required area of transverse rebar in the girder. ▪ Longitudinal Rebar Material – A previously defined material that will be used to determine the required area of longitudinal rebar in the girder.
Concrete Box Flexure	▪ Gamma c for Concrete – Partial safety factor for concrete. ▪ Gamma c for Rebar – Partial safety factor for reinforcing steel. ▪ Gamma c for PT – Partial safety factor for prestressing steel. ▪ PT pre-strain – Factor to estimate pre-strain in the post-tensioning. Multiplies f_pk to obtain the stress in the tendons after losses. Typical value between 0.4 and 0.9.

Table 4-2 Design Request Parameters for Multi-Cell Concrete Box

AASHTO LRFD 2007	
Multi-Cell Concrete Box Stress	▪ Multi-Cell Concrete Box Stress, *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits ▪ Multi-Cell Concrete Box Stress Factor Compression Limit - Multiplier on f'_c to calculate the compression stress limit ▪ Multi-Cell Concrete Box Stress Factor Tension Limit Units - Multiplier on $\text{sqrt}(f'_c)$ to calculate the tension stress limit, given in the units specified ▪ Multi-Cell Concrete Box Stress Factor Tension Limit - The tension limit factor may be specified using either MPa or ksi units for f'_c and the resulting tension limit
Multi-Cell Concrete Box Shear	▪ Multi-Cell Concrete Box Shear, *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits ▪ Multi-Cell Concrete Box Shear, *PhiC*, Lightweight Resistance Factor that multiplies nominal shear resistance to obtain factored resistance for light-weight concrete ▪ Negative limit on strain in nonprestressed longitudinal reinforcement – in accordance with Section 5.8.3.4.2; Default Value = $-0.4\text{x}10^{-3}$, Typical value(s): 0 to $-0.4\text{x}10^{-3}$ ▪ Positive limit on strain in nonprestressed longitudinal reinforcement - in accordance with Section 5.8.3.4.2; Default Value = $6.0\text{x}10^{-3}$, Typical value(s): $6.0\text{x}10^{-3}$ ▪ PhiC for Nu - Resistance Factor used in equation 5.8.3.5-1; Default Value = 1.0, Typical value(s): 0.75 to 1.0 ▪ Phif for Mu - Resistance Factor used in equation 5.8.3.5-1; Default Value = 0.9, Typical value(s): 0.9 to 1.0 ▪ Specifies which method for shear design will be used – either Modified Compression Field Theory (MCFT) in accordance with 5.8.3.4.2 or Vci Vcw method in accordance with 5.8.3.4.3. Currently only the MCFT option is available. ▪ A previously defined rebar material label that will be used to determine the required area of transverse rebar in the girder. ▪ A previously defined rebar material that will be used to determine the required area of longitudinal rebar in the girder
Multi-Cell Concrete Box Flexure	▪ Multi-Cell Concrete Box Flexure, *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits
CAN/CSA S6	

Table 4-2 Design Request Parameters for Multi-Cell Concrete Box

Multi-Cell Concrete Box Stress	▪ Multi-Cell Concrete Box Stress Factor Compression Limit - Multiplier on f'_c to calculate the compression stress limit ▪ Multi-Cell Concrete Box Stress Factor Tension Limit - The tension limit factor may be specified using either MPa or ksi units for f'_c and the resulting tension limit
Multi-Cell Concrete Box Shear	▪ Highway Class – The highway class shall be determined in accordance with CSA Clause 1.4.2.2, Table 1.1 for the average daily traffic and average daily truck traffic volumes for which the structure is designed ▪ Phi Concrete φ_c -- Resistance factor for concrete (see CSA Clause 8.4.6) ▪ Phi PT φ_p -- Resistance factor for tendons (see CSA Clause 8.4.6) ▪ Phi Rebar φ_s -- Resistance factor for reinforcing bars (see CSA Clause 8.4.6) ▪ Cracking Strength Factor -- Multiplies sqrt(f'_c) to obtain cracking strength ▪ EpsilonX Negative Limit -- Longitudinal negative strain limit (see Clause 8.9.3.8) ▪ EpsilonX Positive Limit -- Longitudinal positive strain limit (see Clause 8.9.3.8) ▪ Shear Rebar Material – A previously defined rebar material that will be used to determine the required area of transverse rebar in the girder ▪ Longitudinal Rebar Material – A previously defined rebar material that will be used to determine the required area of longitudinal rebar in the girder
Multi-Cell Concrete Box Flexure	▪ Highway Class – The highway class shall be determined in accordance with CSA Clause 1.4.2.2, Table 1.1 for the average daily traffic and average daily truck traffic volumes for which the structure is designed ▪ Phi Concrete φ_c -- Resistance factor for concrete (see CSA Clause 8.4.6) ▪ Phi PT φ_p -- Resistance factor for tendons (see CSA Clause 8.4.6) ▪ Phi Rebar φ_s -- Resistance factor for reinforcing bars (see CSA Clause 8.4.6)
Eurocode EN 1992 and SNiP	
Multi-Cell Concrete Box Stress	▪ Compression limit – Multiplier on $f_c k$ to calculate the compression stress limit

Table 4-2 Design Request Parameters for Multi-Cell Concrete Box

	▪ Tension limit – Multiplier on $f_c k$ to calculate the tension stress limit
Multi-Cell Concrete Box Shear	▪ Gamma C for Concrete – Partial factor for concrete. ▪ Gamma C for Rebar – Partial safety factor for reinforcing steel. ▪ Gamma C for PT – Partial safety factor for prestressing steel. ▪ Angle Theta – The angle between the concrete compression strut and the beam axis perpendicular to the shear force. The value must be between 21.8 degrees and 45 degrees. ▪ Factor for PT Duct Diameter – Factor that multiplies post-tensioning duct diameter when evaluating the nominal web thickness in accordance with Section 6.2.3(6) of the code. Typical values 0.5 to 1.2. ▪ Factor for PT Transmission Length – Factor for the transmission length of the post tensioning used in shear resistance equation 6.4 of the code. Typical value 1.0 for post tensioning. ▪ Inner Arm Method – The method used to calculate the inner lever arm "z" of the section (integer). ▪ Inner Arm Limit – Factor that multiplies the depth of the section to get the lower limit of the inner lever arm "z" of the section. ▪ Effective Depth Limit – Factor that multiplies the depth of the section to get the lower limit of the effective depth to the tensile reinforcement "d" of the section. ▪ Type of Section – Type of section for shear design. ▪ Determining Factor Nu1 – Method that will be used to calculate the η_1 factor. ▪ Factor Nu1 – η_1 factor ▪ Determining Factor AlphaCW – Method that will be used to calculate the α_{cw} factor. ▪ Factor AlphaCW – α_{cw} factor ▪ Factor Fywk – Multiplier of vertical shear rebar characteristic yield strength to obtain a stress limit in shear rebar used in 6.10.aN. Typical value 0.8 to 1.0. ▪ Shear Rebar Material – A previously defined material label that will be used to determine the required area of transverse rebar in the girder. ▪ Longitudinal Rebar Material – A previously defined material that will be used to determine the required area of longitudinal rebar in the girder.

Table 4-2 Design Request Parameters for Multi-Cell Concrete Box

Multi-Cell Concrete Box Flexure	▪ Gamma c for Concrete – Partial safety factor for concrete. ▪ Gamma c for Rebar – Partial safety factor for reinforcing steel. ▪ Gamma c for PT – Partial safety factor for prestressing steel. ▪ PT pre-strain – Factor to estimate pre-strain in the post-tensioning. Multiplies f_pk to obtain the stress in the tendons after losses. Typical value between 0.4 and 0.9.

Table 4-3 Design Request Parameters for Precast I or U Beams

AASHTO	
Precast Comp Stress	▪ Precast Comp Stress, *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits ▪ Precast Comp Stress Factor Compression Limit - Multiplier on f'_c to calculate the compression stress limit ▪ Precast Comp Stress Factor Tension Limit Units - Multiplier on sqrt(f'_c) to calculate the tension stress limit, given in the units specified ▪ Precast Comp Stress Factor Tension Limit - The tension limit factor may be specified using either MPa or ksi units for f'_c and the resulting tension limit
Precast Comp Shear	▪ *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits ▪ *PhiC*, *Lightweight* Resistance Factor that multiplies nominal shear resistance to obtain factored resistance for light-weight concrete ▪ Negative limit on strain in nonprestressed longitudinal reinforcement – in accordance with Section 5.8.3.4.2; Default Value = $-0.4x10^{-3}$, Typical value(s): 0 to $-0.4x10^{-3}$

Table 4-3 Design Request Parameters for Precast I or U Beams

	▪ Positive limit on strain in nonprestressed longitudinal reinforcement - in accordance with Section 5.8.3.4.2; Default Value = 6.0×10^{-3}, Typical value(s): 6.0×10^{-3} ▪ PhiC for Nu - Resistance Factor used in equation 5.8.3.5-1; Default Value = 1.0, Typical value(s): 0.75 to 1.0 ▪ Phif for Mu - Resistance Factor used in equation 5.8.3.5-1; Default Value = 0.9, Typical value(s): 0.9 to 1.0 ▪ Specifies what method for shear design will be used - either Modified Compression Field Theory (MCFT) in accordance with 5.8.3.4.2 or Vci Vcw method in accordance with 5.8.3.4.3 Currently only the MCFT option is available. ▪ A previously defined rebar material label that will be used to determine the required area of transverse rebar in the girder ▪ A previously defined rebar material that will be used to determine the required area of longitudinal rebar in the girder
Precast Comp Flexure	▪ Precast Comp Flexure, *PhiC*, - Resistance Factor that multiplies both compression and tension stress limits
CAN/CSA S6	
Precast Comp Stress	▪ Precast Comp Stress Factor Compression Limit - Multiplier on f'_c to calculate the compression stress limit ▪ Precast Comp Stress Factor Tension Limit - The tension limit factor may be specified using either MPa or ksi units for f'_c and the resulting tension limit
Precast Comp Shear	▪ Highway Class – The highway class shall be determined in accordance with CSA Clause 1.4.2.2, Table 1.1 for the average daily traffic and average daily truck traffic volumes for which the structure is designed ▪ Phi Concrete φ_c -- Resistance factor for concrete (see CSA Clause 8.4.6) ▪ Phi PT φ_p -- Resistance factor for tendons (see CSA Clause 8.4.6) ▪ Phi Rebar φ_s -- Resistance factor for reinforcing bars (see CSA Clause 8.4.6) ▪ Cracking Strength Factor -- Multiplies sqrt(f'_c) to obtain cracking strength ▪ EpsilonX Negative Limit -- Longitudinal negative strain limit (see Clause 8.9.3.8) ▪ EpsilonX Positive Limit -- Longitudinal positive strain limit (see Clause 8.9.3.8) ▪ Shear Rebar Material – A previously defined rebar material label that will be used to determine the required area of transverse rebar in the girder.

Table 4-3 Design Request Parameters for Precast I or U Beams

	▪ Longitudinal Rebar Material – A previously defined rebar material that will be used to determine the required area of longitudinal rebar n the girder
Precast Comp Flexure	▪ Highway Class – The highway class shall be determined in accordance with CSA Clause 1.4.2.2, Table 1.1 for the average daily traffic and average daily truck traffic volumes for which the structure is designed ▪ Phi Concrete φ_c -- Resistance factor for concrete (see CSA Clause 8.4.6) ▪ Phi PT φ_p -- Resistance factor for tendons (see CSA Clause 8.4.6) ▪ Phi Rebar φ_s -- Resistance factor for reinforcing bars (see CSA Clause 8.4.6)
Eurocode EN 1992 and SNiP	
Precast Comp Stress	▪ Compression limit – Multiplier on $f_c k$ to calculate the compression stress limit ▪ Tension limit – Multiplier on $f_c k$ to calculate the tension stress limit
Precast Comp Shear	▪ Gamma C for Concrete – Partial factor for concrete. ▪ Gamma C for Rebar – Partial safety factor for reinforcing steel. ▪ Gamma C for PT – Partial safety factor for prestressing steel. ▪ Angle Theta – The angle between the concrete compression strut and the beam axis perpendicular to the shear force. The value must be between 21.8 degrees and 45 degrees. ▪ Factor for PT Transmission Length – Factor for the transmission length of the post tensioning used in shear resistance equation 6.4 of the code. Typical value 1.0 for post tensioning. ▪ Inner Arm Method – The method used to calculate the inner lever arm "z" of the section (integer). ▪ Inner Arm Limit – Factor that multiplies the depth of the section to get the lower limit of the inner lever arm "z" of the section. ▪ Effective Depth Limit – Factor that multiplies the depth of the section to get the lower limit of the effective depth to the tensile reinforcement "d" of the section. ▪ Type of Section – Type of section for shear design. ▪ Determining Factor Nu1 – Method that will be used to calculate the η_1 factor. ▪ Factor Nu1 – η_1 factor

Table 4-3 Design Request Parameters for Precast I or U Beams

	▪ Determining Factor AlphaCW – Method that will be used to calculate the α_{cw} factor. ▪ Factor AlphaCW – α_{cw} factor ▪ Factor Fywk – Multiplier of vertical shear rebar characteristic yield strength to obtain a stress limit in shear rebar used in 6.10.aN. Typical value 0.8 to 1.0. ▪ Shear Rebar Material – A previously defined material label that will be used to determine the required area of transverse rebar in the girder. ▪ Longitudinal Rebar Material – A previously defined material that will be used to determine the required area of longitudinal rebar in the girder.
Precast Comp Flexure	▪ Gamma c for Concrete – Partial safety factor for concrete. ▪ Gamma c for Rebar – Partial safety factor for reinforcing steel. ▪ Gamma c for PT – Partial safety factor for prestressing steel. ▪ PT pre-strain – Factor to estimate pre-strain in the post-tensioning. Multiplies $f_p k$ to obtain the stress in the tendons after losses. Typical value between 0.4 and 0.9.

Table 4-4 Design Request Parameters for Steel I-Beam

AASHTO LRFD 2007	
Steel I-Beam - Strength	▪ Resistance factor Phi for flexure ▪ Resistance factor Phi for shear ▪ Do webs have longitudinal stiffeners? ▪ Use Stage Analysis load case to determine stresses on composite section? ▪ Multiplies short term modular ratio (Es/Ec) to obtain long-term modular ratio ▪ Use AASHTO, Appendix A to determine resistance in negative moment regions?
Steel I Beam Comp - Service	▪ Use Stage Analysis load case to determine stresses on composite section? ▪ Shored Construction? ▪ Does concrete slab resist tension? ▪ Multiplies short term modular ratio (Es/Ec) to obtain long-term modular ratio

Table 4-4 Design Request Parameters for Steel I-Beam

Steel-I Comp - Fatigue	▪ There are no user defined design request parameters for fatigue
Steel I Comp Construct Stgd	▪ Resistance factor Phi for flexure ▪ Resistance factor Phi for shear ▪ Resistance factor Phi for Concrete in Tension ▪ Do webs have longitudinal stiffeners? ▪ Concrete modulus of rupture factor in accordance with AASHTO LRFD Section 5.4.2.6, factor that multiplies sqrt of f'_c to obtain modulus of rupture, default value 0.24 (ksi) or 0.63 (MPa), must be > 0 ▪ The modulus of rupture factor may be specified using either MPa or ksi units
Steel I Comp Construct Non Stgd	▪ Resistance factor Phi for flexure ▪ Resistance factor Phi for shear ▪ Resistance factor Phi for Concrete in Tension ▪ Do webs have longitudinal stiffeners? ▪ Concrete modulus of rupture factor in accordance with AASHTO LRFD Section 5.4.2.6, factor that multiplies sqrt of f'_c to obtain modulus of rupture, default value 0.24 (ksi) or 0.63 (MPa), must be > 0 ▪ The modulus of rupture factor may be specified using either MPa or ksi units

4.5 Demand Sets

A demand set name is required for each load combination that is to be considered in a design request. The load combinations may be selected from a list of user defined or default load combinations that are program determined (see Chapter 2).

4.6 Live Load Distribution Factors

When the superstructure has a deck that includes precast I or U girders with composite slabs or multi-cell boxes, Live Load Distribution Factors can be specified. LLD factors are described in Chapter 3.

Chapter 5
Design Concrete Box Girder Bridges

This chapter describes the algorithms applied in accordance with the Russian SNiP 2.05.03-84 for design and stress check of the superstructure of a concrete box type bridge deck section.

When interim revisions of the codes are published by the relevant authorities, and (when applicable) they are subsequently incorporated into CSiBridge, the program gives the user an option to select what type of interims shall be used for the design. The interims can be selected by clicking on the Code Preferences button.

In CSiBridge, when distributing loads for concrete box design, the section is always treated as one beam; all load demands (permanent and transient) are distributed evenly to the webs for stress and flexure and proportionally to the slope of the web for shear. Torsion effects are always considered and assigned to the outer webs and the top and bottom slabs.

With respect to shear and torsion check, in accordance with AASHTO Article 5.8.6, CSA Clause 8.9, and EN 1992-1-1 Section 6.3 torsion is considered.

5.1 Stress Design

The following design parameters are defined by the user in the Design Request (see Chapter 4):

FactorCompLim – R_b multiplier; Default Value = 1.0. The R_b is multiplied by the *FactorCompLim* to obtain the concrete compression limit.

FactorTensLim - f_{ctk} multiplier; Default Value = 1.0. The R_{bt} is multiplied by the *FactorTensLim* to obtain the concrete tension limit.

The stresses are evaluated at three points at the top fiber of the top slab and three points at the bottom fiber of the bottom slab: the left corner, the centerline web, and the right corner of the relevant slab tributary area. The locations are labeled in the output plots and tables.

Concrete compressive and tensile strengths are read at every point, and compression and tension limits are evaluated using the *FactorCompLim* – R_b multiplier and the *FactorTensLim* – R_{bt} multiplier.

The stresses are evaluated for each demand set (Chapter 4). If the demand set contains live load, the program positions the load to capture extreme stress at each of the evaluation points.

Extremes are found for each point and the controlling demand set name is recorded.

5.2 Flexure Design

The following design parameters are defined by the user in the Design Request (see Chapter 4):

m_b– Operation condition factor for concrete, multiplies R_b in the moment resistance equation; Default Value = 1.0.

m_{as} – Reinforcement work coefficient, multiplies R_s in the moment resistance equation; Default Value = 1.0.

m_{ap} – Prestressing work coefficient, multiplies R_p in the moment resistance equation; Default Value = 1.0.

ε_{prePT} – Factor to estimate pre-strain in PT. Multiplies R_p to obtain stress in tendons after losses. Typical values are between 0.4 and 0.9

5.2.1 Design Process

The derivation of the moment resistance of the section is based on assumptions specified in Section 3.56 of the code:

- Plane sections remain plane.
- The strain in bonded reinforcement or bonded prestressing tendons, whether in tension or in compression, is the same as that in the surrounding concrete.
- The tensile strength of the concrete is ignored.
- The stresses in the concrete in compression are limited by stresses equal to R_b and equally distributed within the limits of the conditional compression region of the concrete.
- The tensile stresses in the reinforcement is limited by the the tensile strength in non-prestressed (R_s) and prestressed (R_p) reinforcement
- The factor ξ_y, defining the effective height of the compression zone follow from SNiP 3.61:

$$\xi_y = \frac{\omega}{1 + \frac{\sigma_1}{\sigma_2}(1 - \frac{\omega}{1.1})}$$

where:

- $\omega = 0.85 - 0.008R_b$ for elements with ordinary reinforcement;
- the stresses in the reinforcement σ_1, MPa, are set equal to Rs for non-prestressed reinforcement, $Rp + 500 - \sigma_p$ for prestressed reinforcement. The amount of prestressing in prestressing tendons σ_p is taken into account when assessing the stresses in the tendons. CSiBridge de-

termines the initial amount of prestressing by multiplying the prestressing steel tensile strength R_p by the user-specified factor ε_{prePT}.

- the stress σ_2 is the ultimate stress in the reinforcement of the compression region are set equal to 500 MPa

5.2.2 Algorithms

At each section:

- The equivalent slab thickness is evaluated based on the slab area and the slab width assuming a rectangular shape.

$$t_{\text{slabeq}} = \frac{A_{\text{slab}}}{b_{\text{slab}}}$$

- The tendon and rebar locations, areas, and materials are read. Only bonded tendons are processed; unbonded tendons are ignored.
- The section properties are calculated for the section before skew, grade, and superelevation have been applied. This is consistent with the demands being reported in the section local axis. The entire top and bottom slabs are considered effective in compression.

The ultimate moment resistance of a section is determined using the formula in SNiP 3.62.

The height of the compression zone x is determined as follows:

$$x = \min\left(\xi_y h_0, \frac{m_{ap} R_p A_p + m_{as} R_s A_s}{m_b R_b b}\right)$$

If the depth of compression zone is smaller than the flange depth h_f the moment resistance is calculated as follows:

$$M_r = m_b R_b x(h_0 - 0.5x)$$

otherwise

$$x = \min\left(\xi_y h_0, \frac{m_{ap} R_p A_p + m_{as} R_s A_s - m_b R_b \left(b_f - b\right) h_f}{m_b R_b b}\right)$$

$$M_r = m_b R_b x(h_0 - 0.5x) + m_b R_b (b_f - b) h_f (h_0 - 0.5h_f)$$

The resistance is evaluated for bending about horizontal axis 3 only. Separate capacity is calculated for positive and negative moment. The capacity is based on bonded tendons and mild steel located in the tension zone as defined in the Bridge Object. Tendons and mild steel reinforcement located in the compression zone are not considered. It is assumed that all defined tendons in a section, stressed or not, will reach stress R_p. If a certain tendon should not be considered for the flexural capacity calculation, its area must be set to zero.

5.3 Shear Design

The following design parameter is defined by the user in the Design Request (see Chapter 4):

- Effective depth limit – The factor that multiplies the depth of the section to get the lower limit of the effective depth to the tensile reinforcement h_0 of the section (h_0 = *Effective depth limit* * *Section Depth*).

5.3.1 Variables

A_0 Area enclosed by the centerlines of the connecting exterior webs and top and bottom slabs, including inner hollow area

A_{sw} Area of transverse shear reinforcement per unit

b Web width

h_0 Effective section depth

d_{girder} Depth of girder

d_{PTBot} Distance from the top fiber to the center of prestressing steel near the bottom fiber

d_{PTTop} Distance from the bottom fiber to the center of prestressing steel near the top fiber

T_u Ultimate design torsion per section cut

V_u Ultimate design shear force demand excluding the force in the tendons

V_p Component in the direction of the applied shear of the effective prestressing force; if V_p has the same sign as V_{Ed}, the component is resisting the applied shear.

V_t Shear in web resulting from torsion

5.3.2 Design Process

The shear resistance is determined in accordance with SNiP, Clause 3.77. The procedure assumes that the concrete shear stresses are distributed uniformly over an area *b* wide and *d* deep, that the direction of principal compressive stresses remains constant over *d*, and that the shear strength of the section can be determined by considering the biaxial stress conditions at just one location in the web. For design, the user should select only those sections that comply with these assumptions by defining appropriate station ranges in the Design Request (see Chapter 4).

The Shear and Torsion Design is completed on a per web basis. The D/C ratio is calculated as a fraction of applied shear over resistance. The section design shear force is distributed into individual webs assuming that the vertical shear that is carried by a web decreases with increased inclination of the web from vertical. Section torsion moments are assigned to external webs and slabs.

5.3.3 Algorithm

- All section properties and demands are converted from CSiBridge model units to N, mm.

- For every COMBO specified in the Design Request that contains envelopes, a new force demand set is generated. The new force demand set is built up from the maximum tension values of P and the maximum absolute values of V*2* and M3 of the two StepTypes (Max and Min) present in the envelope COMBO case. The StepType of this new force demand set is named ABS and the signs of the P, V2, and M3 are preserved. The ABS case follows the industry practice where sections are designed for extreme shear and moments that are not necessarily corresponding to the same design vehicle position. The section cut is designed for all three StepTypes in the COMBO—Max, Min and ABS—and the controlling StepType is reported.

- On the basis of the location and inclination of each web, the per-web demand values are evaluated as shown in the following table:

Location	**Outer Web**		**Inner Web**	
	V_{Ed}	**T_{Ed}**	**V_{Ed}**	**T_{Ed}**
Shear and Torsion Check	$\frac{V_{2c}\kappa_{web}}{\cos\alpha_{web}}$	T_{Ed}	$\frac{V_{2c}\kappa_{web}}{\cos\alpha_{web}}$	0

where $\kappa_{web} = \dfrac{\cos(|\alpha_{web}|)}{\sum_1^{n\text{web}} \cos(|\alpha_{web}|)}$

- The component in the direction of the applied shear of the effective prestressing force, positive if resisting the applied shear, is evaluated:

$$V_p = \frac{\left(V_{2c} - V_{2\text{tot}}\right)\kappa_{web}}{\cos\alpha_{web}}$$

- The component of shear due to torsion in the external webs is calculated as follows:

$V_t = \frac{T_u d_s}{2A_0}$ where d_s is the web height measured between mid-depths of top and bottom slab

- The effective depth of section h_0 of prestressed sections is determined as follows:

If $M_{Ed} > 0$, h_0 = max(Effective depth limit * d_{girder} , d_{PTbot})
If $M_{Ed} < 0$, h_0 = max(Effective depth limit * d_{girder} , d_{PTtop})

  - The effective depth of section h_0 of non-prestressed sections is determined as follows:

    If $M_{Ed} > 0$, then h_0 = max(Effective depth limit * d_{girder} , $d_{rebarbot}$)
    If $M_{Ed} < 0$, then h_0 = max(Effective depth limit * d_{girder}, $d_{rebartop}$)

When section contains both non-prestressed and prestressed reinforcement the effective depth of section h_0 of sections is calculated based on resultant of forces in the non-prestressed A_s*R_s and pre-stressed reinforecement A_p*R_p and verified against the minimum *Effective depth limit* * d_{girder}

The shear resistance of the web is calculated per SNiP Section 3.77

$$V_r = 0.3\varphi_{wl}\varphi_{bl}R_b b h_0$$

where:

$$\varphi_{wl} = \min(1 + \eta n_1 \mu_w, 1.3)$$

$\eta = 5$ (stirrups positioned normal to the longitudinal axis of the element)

$$n_1 = \frac{E_s}{E_c}$$

$$\mu_w = \frac{A_{sw}}{b s_w}$$

A_{sw} = area of vertical shear reinforcement (stirrups)
s_w = distance between stirrups
b = web width

The area of vertical transverse reinforcement specified in the Bridge Object is used to calculate the coefficient μ_w. The density (area per unit length) of provided transverse reinforcement in a given girder is based on values specified in the Bridge Object within distance $0.5*h_0$ measured downstation and upstation from a given section cut.

$$\varphi_{bl} = 1 - 0.01R_b$$

The demand over capacity ratio is evaluated as:

$$DoverC = \frac{\left|V_u - V_p\right| + V_t}{V_r}$$

Chapter 6
Design Multi-Cell Concrete Box Bridges using AMA

This chapter describes the algorithms used by CSiBridge for design checks when the superstructure has a deck that includes cast-in-place multi-cell concrete box design and uses the Approximate Method of Analysis, as described in the Russian SNiP 2.05.03-84.

When interim revisions of the codes are published by the relevant authorities, and (when applicable) they are subsequently incorporated into CSiBridge, the program gives the user an option to select what type of interims shall be used for the design. The interims can be selected by clicking on the Code Preferences button.

For MulticellConcBox design in CSiBridge, each web and its tributary slabs are designed separately. Moments and shears due to live load are distributed to individual webs in accordance with the live load distribution method specified in the Design Request (Chapter 4). Torsion effects are ignored.

6.1 Stress Design

The following design parameters are defined by the user in the Design Request (see Chapter 4):

– *FactorCompLim* – R_b multiplier; Default Value = 1.0. The R_b is multiplied by the *FactorCompLim* to obtain the concrete compression limit.

– *FactorTensLim* - f_{ctk} multiplier; Default Value = 1.0. The R_{bt} is multiplied by the *FactorTensLim* to obtain the concrete tension limit.

The stresses are evaluated at three points at the top fiber of the top slab and three points at the bottom fiber of the bottom slab: the left corner, the centerline web, and the right corner of the relevant slab tributary area. The locations are labeled in the output plots and tables.

Concrete compressive and tensile strengths are read at every point, and compression and tension limits are evaluated using the *FactorCompLim* – R_b multiplier and the *FactorTensLim* – R_{bt} multiplier.

The stresses assume linear distribution and take into account axial (P) and either both bending moments (M2 and M3) or only P and M3, depending on which method for determining LLDF has been specified in the design request (see Chapters 3 and 4).

The stresses are evaluated for each demand set (Chapter 4). If the demand set contains live load, the program positions the load to capture extreme stress at each of the evaluation points.

Extremes are found for each point and the controlling demand set name is recorded.

6.2 Flexure Design

The following design parameters are defined by the user in the Design Request (see Chapter 4):

– m_b– Operation condition factor for concrete, multiplies R_b in the moment resistance equation; Default Value = 1.0.

– m_{as} – Reinforcement work coefficient, multiplies R_s in the moment resistance equation; Default Value = 1.0.

– m_{ap} – Prestressing work coefficient, multiplies R_p in the moment resistance equation; Default Value = 1.0.

– ε_{prePT} – Factor to estimate pre-strain in PT. Multiplies R_p to obtain stress in tendons after losses. Typical values are between 0.4 and 0.9

6.2.1 Design Process

The derivation of the moment resistance of the section is based on assumptions specified in Section 3.56 of the code:

- Plane sections remain plane.
- The strain in bonded reinforcement or bonded prestressing tendons, whether in tension or in compression, is the same as that in the surrounding concrete.
- The tensile strength of the concrete is ignored.
- The stresses in the concrete in compression are limited by stresses equal to Rb and equally distributed within the limits of the conditional compression region of the concrete.
- The tensile stresses in the reinforcement is limited by the the tensile strength in non-prestressed (Rs) and prestressed (Rp) reinforcement
- The factor ξy, defining the effective height of the compression zone follow from SNiP 3.61:

$$\xi_y = \frac{\omega}{1 + \frac{\sigma_1}{\sigma_2}\left(1 - \frac{\omega}{1.1}\right)}$$

where:

- $\omega = 0.85 - 0.008R_b$ for elements with ordinary reinforcement;
- the stresses in the reinforcement σ_1, MPa, are set equal to *Rs* for non-prestressed reinforcement, $Rp + 500 - \sigma_p$ for prestressed reinforcement. The amount of prestressing in prestressing tendons σ_p is taken into account when assessing the stresses in the tendons. CSiBridge determines the initial amount of prestressing by multiplying the prestressing steel tensile strength R_p by the user-specified factor ε_{prePT}.
    - the stress σ_2 is the ultimate stress in the reinforcement of the compression region are set equal to 500 MPa

6.2.2 Algorithms

At each section:

- The equivalent slab thickness is evaluated based on the slab area and the slab width assuming a rectangular shape.

$$t_{\text{slabeq}} = \frac{A_{\text{slab}}}{b_{\text{slab}}}$$

- The tendon and rebar locations, areas, and materials are read. Only bonded tendons are processed; unbonded tendons are ignored.
- The section properties are calculated for the section before skew, grade, and superelevation have been applied. This is consistent with the demands being reported in the section local axis. The entire top and bottom slabs are considered effective in compression.

The ultimate moment resistance of a section is determined using the formula in SNiP 3.62.

The height of the compression zone x is determined as follows:

$$x = \min\left(\xi_y h_0, \frac{m_{ap}R_pA_p + m_{as}R_sA_s}{m_bR_bb}\right)$$

If the depth of compression zone is smaller than the flange depth h_f the moment resistance is calculated as follows:

$$M_r = m_bR_bx(h_0 - 0.5x)$$

otherwise

$$x = \min\left(\xi_y h_0, \frac{m_{ap}R_pA_p + m_{as}R_sA_s - m_bR_b(b_f - b)h_f}{m_bR_bb}\right)$$

$$M_r = m_bR_bx(h_0 - 0.5x) + m_bR_b\left(b_f - b\right)h_f\left(h_0 - 0.5h_f\right)$$

The resistance is evaluated for bending about horizontal axis 3 only. Separate capacity is calculated for positive and negative moment. The capacity is based on bonded tendons and mild steel located in the tension zone as defined in the Bridge Object. Tendons and mild steel reinforcement located in the compression zone are not considered. It is assumed that all defined tendons in a section, stressed or not, will reach stress R_p. If a certain tendon should not be considered for the flexural capacity calculation, its area must be set to zero.

6.3 Shear Design

The following design parameters are defined by the user in the Design Request (see Chapter 4):

– Effective depth limit – The factor that multiplies the depth of the section to get the lower limit of the effective depth to the tensile reinforcement h_0 of the section (h_0 = *Effective depth limit * Section Depth*).

6.3.1 Variables

A_0 Area enclosed by the centerlines of the connecting exterior webs and top and bottom slabs, including inner hollow area

A_{sw} Area of transverse shear reinforcement per unit

b Web width

h_0 Effective section depth

d_{girder} Depth of girder

d_{PTBot} Distance from the top fiber to the center of prestressing steel near the bottom fiber

d_{PTTop} Distance from the bottom fiber to the center of prestressing steel near the top fiber

V_u Ultimate design shear force demand excluding the force in the tendons

V_p Component in the direction of the applied shear of the effective prestressing force; if V_p has the same sign as V_{Ed}, the component is resisting the applied shear.

6.3.2 Design Process

The shear resistance is determined in accordance with SNiP, clause 3.77. The procedure assumes that the concrete shear stresses are distributed uniformly over an area *b* wide and *d* deep, that the direction of principal compressive stresses remains constant over *d*, and that the shear strength of the section can be determined by considering the biaxial stress conditions at just one location in the web. For design, the user should select only those sections that comply with these assumptions by defining appropriate station ranges in the Design Request (see Chapter 4).

The Shear Design is completed on a per web basis. The D/C ratio is calculated for each web. For a description of distribution of live and other loads into individual webs, please refer to Chapter 3. Section torsion moments are ignored.

6.3.3 Algorithm

- All section properties and demands are converted from CSiBridge model units to N, mm.
- For every COMBO specified in the Design Request that contains envelopes, a new force demand set is generated. The new force demand set is built up from the maximum tension values of P and the maximum absolute values of V*2* and M3 of the two StepTypes (Max and Min) present in the envelope COMBO case. The StepType of this new force demand set is named ABS and the signs of the P, V2, and M3 are preserved. The ABS case follows the industry practice where sections are designed for extreme shear and moments that are not necessarily corresponding to the same design vehicle position. The section cut is designed for all three StepTypes in the COMBO—Max, Min and ABS—and the controlling StepType is reported.
- The component in the direction of the applied shear of the effective prestressing force, positive if resisting the applied shear, is evaluated:

$$V_p = \frac{V_{2c} - V_{2\text{tot}}}{n_{\text{web}}}$$

- The effective depth of section h_0 of prestressed sections is determined as follows:

If $M_{Ed} > 0$, h_0 = max(Effective depth limit * d_{girder} , d_{PTbot})
If $M_{Ed} < 0$, h_0 = max(Effective depth limit * d_{girder} , d_{PTtop})

- The effective depth of section h_0 of non-prestressed sections is determined as follows:

If $M_{Ed} > 0$, then h_0 = max(Effective depth limit * d_{girder} , $d_{rebarbot}$)
If $M_{Ed} < 0$, then h_0 = max(Effective depth limit * d_{girder}, $d_{rebartop}$)

When section contains both non-prestressed and prestressed reinforcement the effective depth of section h_0 of sections is calculated based on resultant of forces in the non-prestressed A_s*R_s and pre-stressed reinforecement A_p*R_p and verified against the minimum *Effective depth limit* * d_{girder} Effective depth limit * d_{girder}

- The shear resistance of the web is calculated per SNiP section 3.77

$$V_r = 0.3\varphi_{wl}\varphi_{bl}R_b b h_0$$

where:

$$\varphi_{wl} = \min(1 + \eta n_1 \mu_w, 1.3)$$

$\eta = 5$ (stirrups positioned normal to the longitudinal axis of the element)

$$n_1 = \frac{E_s}{E_c}$$

$$\mu_w = \frac{A_{sw}}{b s_w}$$

A_{sw} = area of vertical shear reinforcement (stirrups)
s_w= distance between stirrups
b= web width

The area of vertical transverse reinforcement specified in the Bridge Object is used to calculate the coefficient μ_w. The density (area per unit length) of provided transverse reinforcement in a given girder is based on values specified in the Bridge Object within distance *0.5*h_0 measured downstation and upstation from a given section cut.

$$\varphi_{bl} = 1 - 0.01R_b$$

The demand over capacity ratio is evaluated as:

$$DoverC = \frac{\left|V_u - V_p\right|}{V_r}$$

Chapter 7
Design Precast Concrete Girder Bridges

This chapter describes the algorithms used by CSiBridge for design and stress check when the superstructure has a deck that includes precast I or U girders with composite slabs in accordance with the Russian SNiP 2.05.03-84.

When interim revisions of the codes are published by the relevant authorities, and (when applicable) they are subsequently incorporated into CSiBridge, the program gives the user an option to select what type of interims shall be used for the design. The interims can be selected by clicking on the Code Preferences button.

For PrecastComp design in CSiBridge each beam and its tributary composite slab is designed separately. Moments and shears due to live load are distributed to individual beans in accordance with the live load distribution method specified in the Design Request. Torsion effects are ignored.

7.1 Stress Design

The following design parameters are defined by the user in the Design Request (see Chapter 4):

– *FactorCompLim* – R_b multiplier; Default Value = 1.0. The R_b is multiplied by the *FactorCompLim* to obtain the concrete compression limit.

– *FactorTensLim* - f_{ctk} multiplier; Default Value = 1.0. The R_{bt} is multiplied by the *FactorTensLim* to obtain the concrete tension limit.

The stresses are evaluated at three points at the top fiber of the composite slab: the left corner, the centerline beam, and the right corner of the composite slab tributary area. The locations of stress output points at the slab bottom fiber and beam top and bottom fibers depend on the type of precast beam present in the section cut. The locations are labeled in the output plots and tables.

Concrete compressive and tensile strengths are read at every point, and compression and tension limits are evaluated using the *FactorCompLim* – R_b multiplier and the *FactorTensLim* – R_{bt} multiplier.

The stresses assume linear distribution and take into account axial (P) and either both bending moments (M2 and M3) or only P and M3, depending on which method for determining LLDF has been specified in the design request (see Chapters 3 and 4).

The stresses are evaluated for each demand set (Chapter 4). If the demand set contains live load, the program positions the load to capture extreme stress at each of the evaluation points.

Extremes are found for each point and the controlling demand set name is recorded.

7.2 Flexure Design

The following design parameters are defined by the user in the Design Request (see Chapter 4):

– m_b– Operation condition factor for concrete, multiplies R_b in the moment resistance equation; Default Value = 1.0.

– m_{as} – Reinforcement work coefficient, multiplies R_s in the moment resistance equation; Default Value = 1.0.

– m_{ap} – Prestressing work coefficient, multiplies R_p in the moment resistance equation; Default Value = 1.0.

– ε_{prePT} – Factor to estimate pre-strain in PT. Multiplies R_p to obtain stress in tendons after losses. Typical values are between 0.4 and 0.9

7.2.1 Design Process

The derivation of the moment resistance of the section is based on assumptions specified in Section 3.56 of the code:

- Plane sections remain plane.
- The strain in bonded reinforcement or bonded prestressing tendons, whether in tension or in compression, is the same as that in the surrounding concrete.
- The tensile strength of the concrete is ignored.
- The stresses in the concrete in compression are limited by stresses equal to Rb and equally distributed within the limits of the conditional compression region of the concrete.
- For positive bending when the compression region contains the composite slab and precast beam the area of the prestressed beam is adjusted in proportion to the concrete strength of the composite slab and the precast beam.
- The tensile stresses in the reinforcement is limited by the the tensile strength in non-prestressed (Rs) and prestressed (Rp) reinforcement
- The factor ξy, defining the effective height of the compression zone follow from SNiP 3.61:

$$\xi_y = \frac{\omega}{1 + \frac{\sigma_1}{\sigma_2}(1 - \frac{\omega}{1.1})}$$

where:

- $\omega = 0.85 - 0.008R_b$ for elements with ordinary reinforcement;
- the stresses in the reinforcement σ_1, MPa, are set equal to Rs for non-prestressed reinforcement, $Rp + 500 - \sigma_p$ for prestressed reinforcement. The amount of prestressing in prestressing tendons σ_p is taken into account when assessing the stresses in the tendons. CSiBridge determines the initial amount

of prestressing by multiplying the prestressing steel tensile strength R_p by the user-specified factor ε_{prePT}.

- the stress σ_2 is the ultimate stress in the reinforcement of the compression region are set equal to 500 MPa

7.2.2 Algorithms

At each section:

- The equivalent slab thickness is evaluated based on the slab area and the slab width assuming a rectangular shape.

$$t_{\text{slabeq}} = \frac{A_{\text{slab}}}{b_{\text{slab}}}$$

- The tendon and rebar locations, areas, and materials are read. Only bonded tendons are processed; unbonded tendons are ignored.

- The section properties are calculated for the section before skew, grade, and superelevation have been applied. This is consistent with the demands being reported in the section local axis. The entire top and bottom slabs are considered effective in compression.

- The ultimate moment resistance of a section is determined using the formula in SNiP 3.62.

- The height of the compression zone x is determined as follows:

$$x = \min\left(\xi_y h_0, \frac{m_{ap} R_p A_p + m_{as} R_s A_s}{m_b R_b b}\right)$$

- If the depth of compression zone is smaller than the flange depth h_f the moment resistance is calculated as follows:

$$M_r = m_b R_b x(h_0 - 0.5x)$$

otherwise

$$x = \min\left(\xi_y h_0, \frac{m_{ap} R_p A_p + m_{as} R_s A_s - m_b R_b \left(b_f - b\right) h_f}{m_b R_b b}\right)$$

$$M_r = m_b R_b x(h_0 - 0.5x) + m_b R_b (b_f - b) h_f (h_0 - 0.5 h_f)$$

The resistance is evaluated for bending about horizontal axis 3 only. Separate capacity is calculated for positive and negative moment. The capacity is based on bonded tendons and mild steel located in the tension zone as defined in the Bridge Object. Tendons and mild steel reinforcement located in the compression zone are not considered. It is assumed that all defined tendons in a section, stressed or not, will reach stress R_p. If a certain tendon should not be considered for the flexural capacity calculation, its area must be set to zero.

7.3 Shear Design

The following design parameters are defined by the user in the Design Request (see Chapter 4):

– Effective depth limit – The factor that multiplies the depth of the section to get the lower limit of the effective depth to the tensile reinforcement h_0 of the section (h_0 = *Effective depth limit* * *Section Depth*).

7.3.1 Variables

A_0 Area enclosed by the centerlines of the connecting exterior webs and top and bottom slabs, including inner hollow area

A_{sw} Area of transverse shear reinforcement per unit

b Web width

h_0 Effective section depth

d_{girder} Depth of girder

d_{PTBot} Distance from the top fiber to the center of prestressing steel near the bottom fiber

d_{PTTop} Distance from the bottom fiber to the center of prestressing steel near the top fiber

V_u Ultimate design shear force demand excluding the force in the tendons

V_p Component in the direction of the applied shear of the effective prestressing force; if V_p has the same sign as V_{Ed}, the component is resisting the applied shear.

7.3.2 Design Process

The shear resistance is determined in accordance with SNiP, clause 3.77. The procedure assumes that the concrete shear stresses are distributed uniformly over an area *b* wide and *d* deep, that the direction of principal compressive stresses remains constant over *d*, and that the shear strength of the section can be determined by considering the biaxial stress conditions at just one location in the web. For design, the user should select only those sections that comply with these assumptions by defining appropriate station ranges in the Design Request (see Chapter 4).

The Shear Design is completed on a per beam basis. The D/C ratio is calculated and the required area of rebar is reported for each beam. For a description of distribution of live and other loads into individual beams, please refer to Chapter 3. Section torsion moments are ignored.

7.3.3 Algorithm

All section properties and demands are converted from CSiBridge model units to N, mm.

- For every COMBO specified in the Design Request that contains envelopes, a new force demand set is generated. The new force demand set is built up from the maximum tension values of P and the maximum absolute values of V2 and M3 of the two StepTypes (Max and Min) present in the envelope COMBO case. The StepType of this new force demand set is named ABS and the signs of the P, V2, and M3 are preserved. The ABS case follows the industry practice where sections are designed for extreme shear and moments that are not necessarily corresponding to the same design vehicle position. The section cut is designed for all three StepTypes in the COMBO—Max, Min and ABS—and the controlling StepType is reported.

- The component in the direction of the applied shear of the effective prestressing force, positive if resisting the applied shear, is evaluated:

$$V_p = \frac{V_{2c} - V_{2\text{tot}}}{n_{\text{web}}}$$

- The effective depth of section h_0 of prestressed sections is determined as follows:

If $M_{Ed} > 0$, h_0 = max(Effective depth limit * d_{girder} , d_{PTbot})
If $M_{Ed} < 0$, h_0 = max(Effective depth limit * d_{girder} , d_{PTtop})

- The effective depth of section h_0 of non-prestressed sections is determined as follows:

If $M_{Ed} > 0$, then h_0 = max(Effective depth limit * d_{girder} , d_{rebarbot})
If $M_{Ed} < 0$, then h_0 = max(Effective depth limit * d_{girder}, d_{rebartop})

- When section contains both non-prestressed and prestressed reinforcement the effective depth of section h_0 of sections is calculated based on resultant of forces in the non-prestressed A_s*R_s and pre-stressed reinforecement A_p*R_p and verified against the minimum *Effective depth limit* * d_{girder} Effective depth limit * d_{girder}

- The shear resistance of the web is calculated per SNiP section 3.77

$$V_r = 0.3\varphi_{wl}\varphi_{bl}R_b b h_0$$

where:
$\varphi_{wl} = \min(1 + \eta n_1 \mu_w, 1.3)$

$\eta = 5$ (stirrups positioned normal to the longitudinal axis of the element)

$$n_1 = \frac{E_s}{E_c}$$

$$\mu_w = \frac{A_{sw}}{b s_w}$$

A_{sw} = area of vertical shear reinforcement (stirrups)
s_w = distance between stirrups
b = web width

The area of vertical transverse reinforcement specified in the Bridge Object is used to calculate the coefficient μ_w. The density (area per unit length) of provided transverse reinforcement in a given girder is based on values specified in the Bridge Object within distance $0.5*h_0$ measured downstation and upstation from a given section cut.

$$\varphi_{bl} = 1 - 0.01R_b$$

- The demand over capacity ratio is evaluated as:

$$DoverC = \frac{\left|V_u - V_p\right|}{V_r}$$

Chapter 8
Run a Bridge Design Request

This chapter identifies the steps involved in running a Bridge Design Request. (Chapter 4 explains how to define the Request.) Running the Request applies the following to the specified Bridge Object:

- Program defaults in accordance with the selected code—the Preferences
- Type of design to be performed—the check type (Section 4.2.1)
- Portion of the bridge to be designed—the station ranges (Section 4.1.3)
- Overwrites of the Preferences—the Design Request parameters (Section 4.1.4)
- Load combinations—the demand sets (Chapter 2)
- Live Load Distribution factors, where applicable (Chapter 3)

For this example, the AASHTO LRFD 2007 code is applied to the model of a concrete box-girder bridge shown in Figure 8-1.

It is assumed that the user is familiar with the steps that are necessary to create a CSiBridge model of a concrete box girder bridge. If additional assistance is needed to create the model, a 30-minute Watch and Learn™ video entitled, "Bridge – Bridge Information Modeler" is available at the CSI website www.csiamerica.com. The tutorial video guides the user through the creation of the bridge model referenced in this chapter.

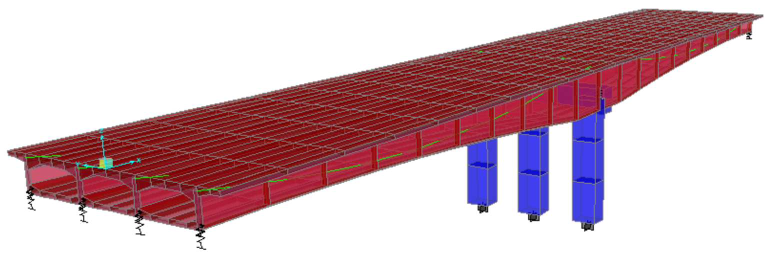


Figure 8-1 3D view of example concrete box girder bridge model

8.1 Description of Example Model

The example bridge is a two-span prestressed concrete box girder bridge with the following features:

Abutments: The abutments are skewed by 15 degrees and connected to the bottom of the box girder only.

Prestress: The concrete box girder bridge is prestressed with four 10-in^2 tendons (one in each girder) and a jacking force of 2160 kips per tendon.

Bents: The one interior bent has three 5-foot-square columns.

Deck: The concrete box girder has a nominal depth of 5 feet. The deck has a parabolic variation in depth from 5 feet at the abutments to a maximum of 10 feet at the interior bent support.

Spans: The two spans are each approximately 100 feet long.

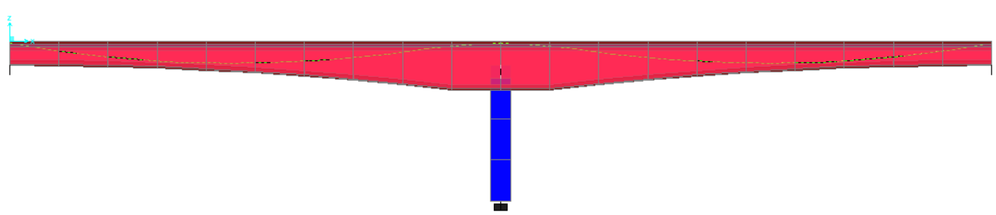


Figure 8-2 Elevation view of the example bridge

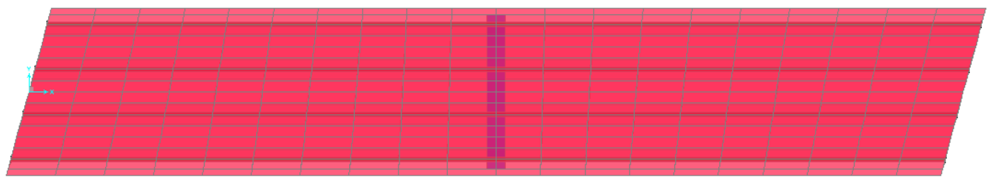


Figure 8-3 Plan view of the example bridge

8.2 Design Preferences

Use the **Design/Rating** > **Superstructure Design** > **Preferences** command to select the AASHTO LRFD 2007 design code. The Bridge Design Preferences form shown in Figure 8-4 displays.

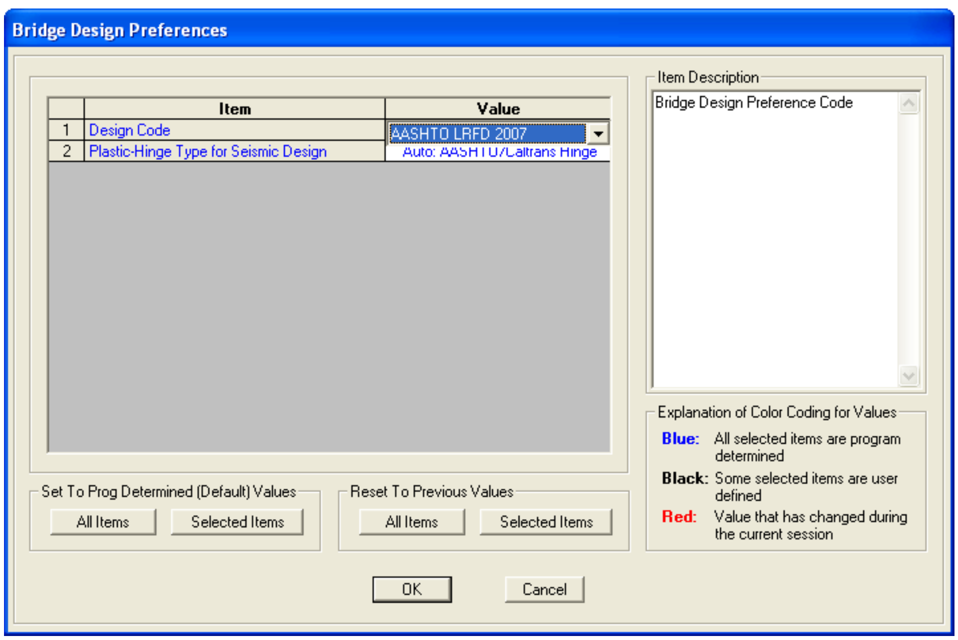


Figure 8-4 Bridge Design Preferences form

8.3 Load Combinations

For this example, the default design load combinations were activated using the **Design/Rating** > **Load Combinations** > **Add Defaults** command. After the *Bridge Design* option has been selected, the Code-Generated Load Combinations for Bridge Design form shown in Figure 8-5 displays. The form is used to specify the desired limit states. Only the Strength II limit state was selected for this example. Normally, several limit states would be selected.

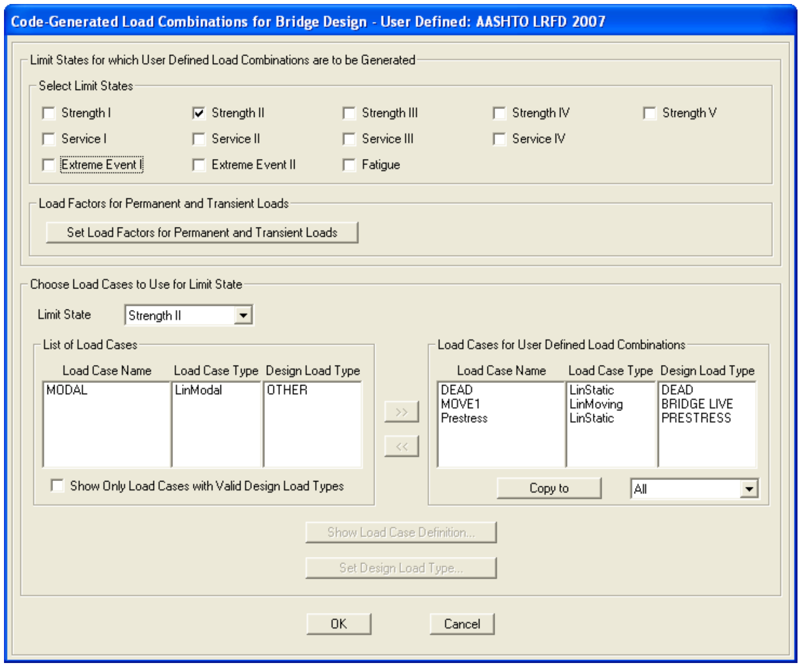


Figure 8-5 Code-Generated Load Combinations for Bridge Design form

The defined load combinations for this example are shown in Figure 8-6.

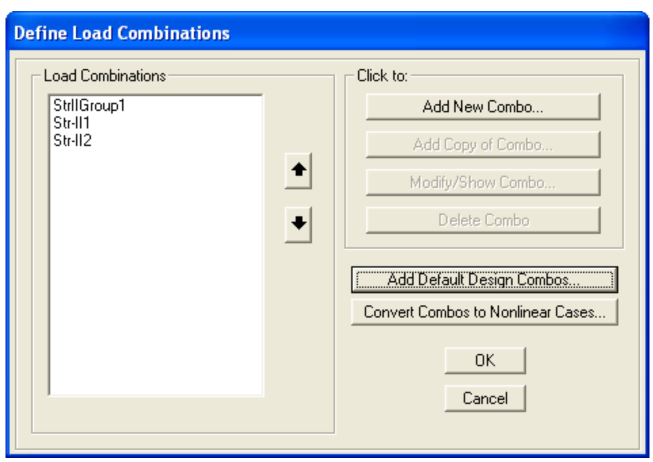


Figure 8-6 Define Load Combinations form

The Str-II1, Str-II2 and StrIIGroup1 designations for the load combinations are specified by the program and indicate that the limit state for the combinations is Strength Level II.

8.4 Bridge Design Request

After the **Design/Rating** > **Superstructure Design** > **Design Request** command has been used, the Bridge Design Request form shown in Figure 8-7 displays.

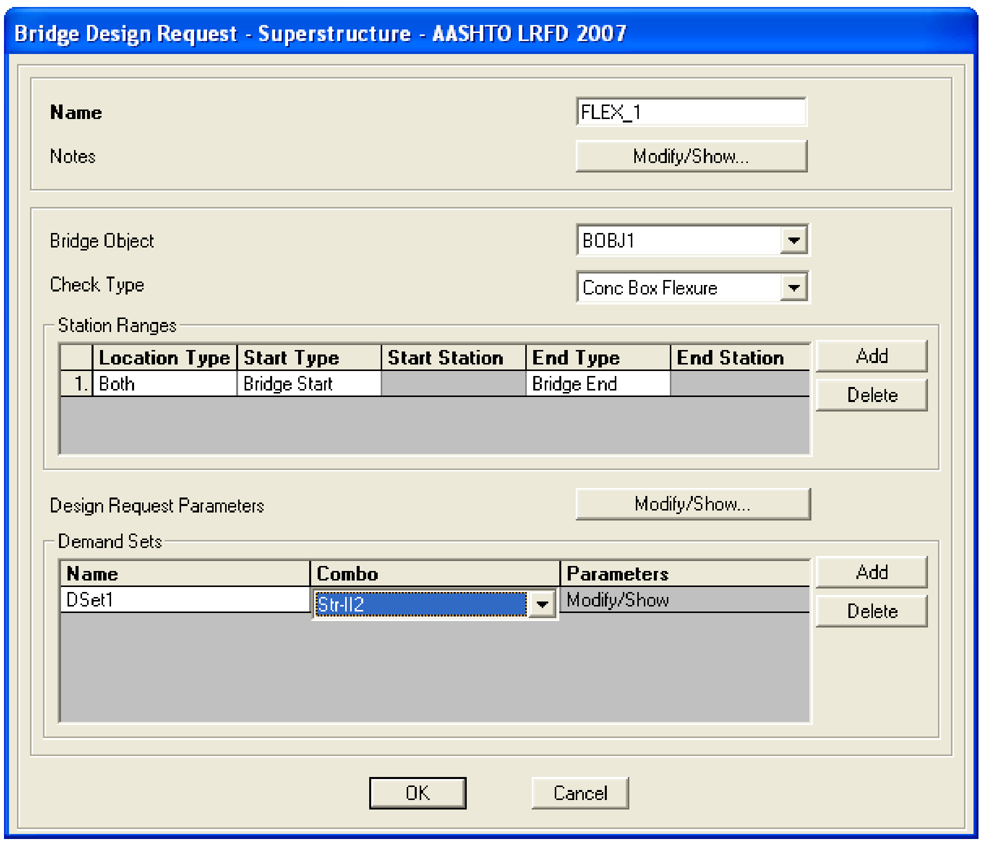


Figure 8-7 Define Load Combinations form

The name given to this example Design Request is **FLEX_1**, the Check Type is for **Concrete Box Flexure** and the Demand Set, DSet1, specifies the combination as **StrII** (Strength Level II**).**

The only Design Request Parameter option for a Concrete Box Flexural check type is for PhiC. A value of 0.9 for PhiC is used.

8.5 Start Design/Check of the Bridge

After an analysis has been run, the bridge model is ready for a design/check. Use the **Design/Rating > Superstructure Design > Run Super** command to start the design process. Select the design to be run using the Perform Bridge Design form shown in Figure 8-8:

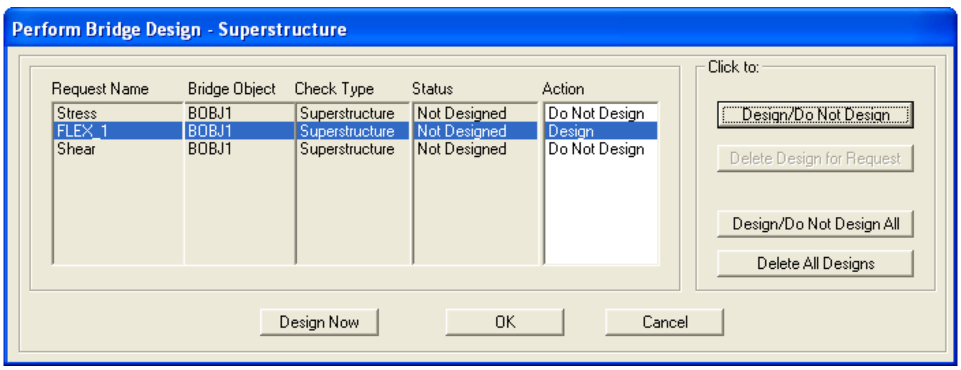


Figure 8-8 Perform Bridge Design - Superstructure

The user may select the desired Design Request(s) and click on the **Design Now** button. A plot of the bridge model, similar to that shown in Figure 8-9, will display.

If several Design Requests have been run, the individual Design Requests can be selected from the Design Check options drop-down list. This plot is described further in Chapter 9.

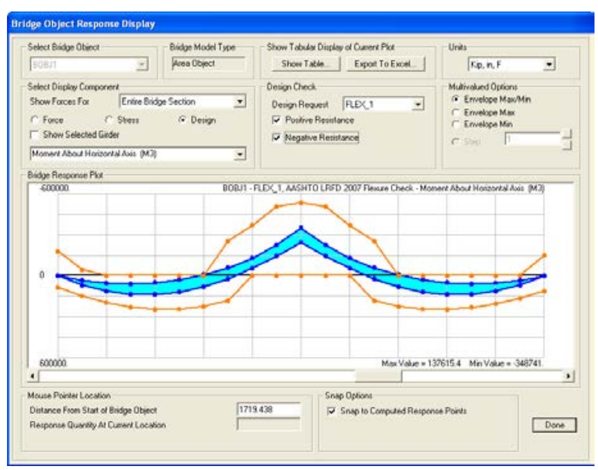


Figure 8-9 Plot of flexure check results

Chapter 9
Display Bridge Design Results

Bridge design results can be displayed on screen and as printed output. The on-screen display can depict the bridge response graphically as a plot or in data tables. The Advanced Report Writer can be used to create the printed output, which can include the graphical display as well as the database tables.

This chapter displays the results for the example used in Chapter 8. The model is a concrete box girder bridge and the code applied is AASHTO LRFD 2007. Creation of the model is shown in a 30-minute Watch and Learn™ video on the CSI website, www.csiamerica.com.

9.1 Display Results as a Plot

To view the forces, stresses, and design results graphically, click the **Home** > **Display** > **Show Bridge Superstructure Design Results** command, which will display the Bridge Object Response Display form shown in Figure 9-1.

The plot shows the design results for the FLEX_1 Design Request created using the process described in the preceding chapters. The demand moments are enveloped and shown in the blue region, and the negative capacity moments are shown with a brown line. If the demand moments do not exceed the capacity moments, the superstructure may be deemed adequate in response to the flexure Design Request. Move the mouse pointer onto the demand or capacity plot to view the values for each nodal point. Move the pointer to the capacity moment at station 1200 and 536981.722 kip-in is shown. A verification calculation that shows agreement with this CSiBridge result is provided in Section 11.4.

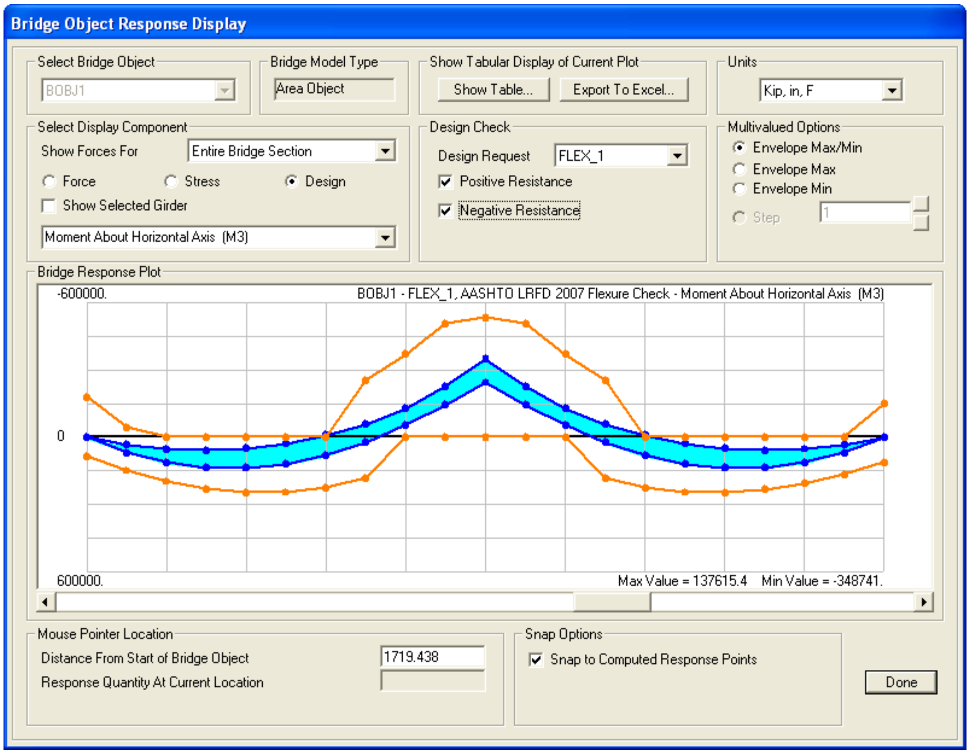


Figure 9-1 Plot of flexure check results for the example bridge design model

9.1.1 Additional Display Examples

Use the **Home > Display > Show Bridge Forces/Stresses** command to select, on the example form shown in Figure 9-2, the location along the top or bottom portions of a beam or slab for which stresses are to be displayed. Figures 9-3 through 9-9 illustrate the left, middle, and right portions as they apply to Multi-cell Concrete Box Sections. Location 1, as an example, refers to the top left selection option while location 5 would refer to the bottom center selection option. Locations 1, 2, and 3 refer to the top left, top center, and top right selection option while locations 4, 5, and 6 refer to the bottom left, bottom center, and bottom right selection options.

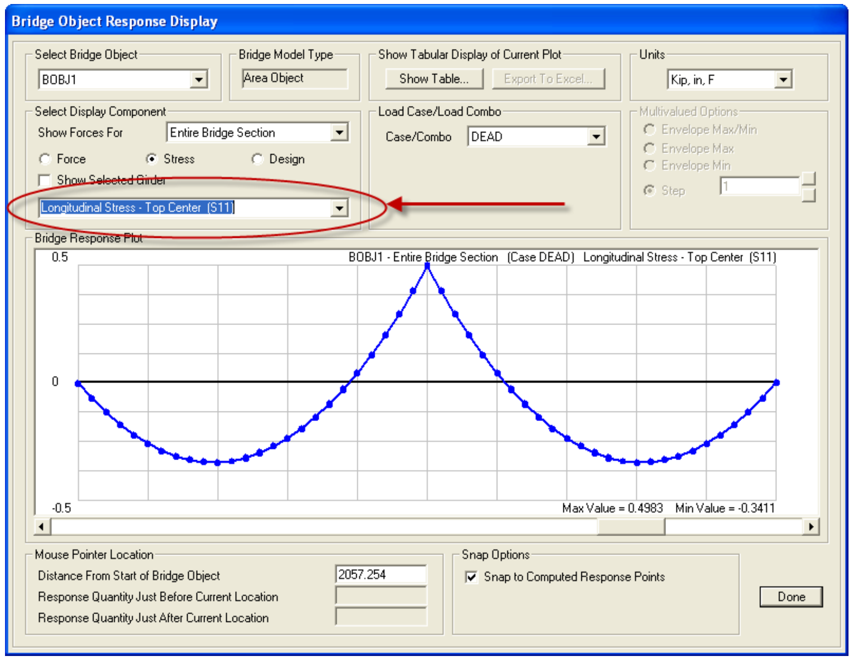


Figure 9-2 Select the location on the beam or slab for which results are to be displayed

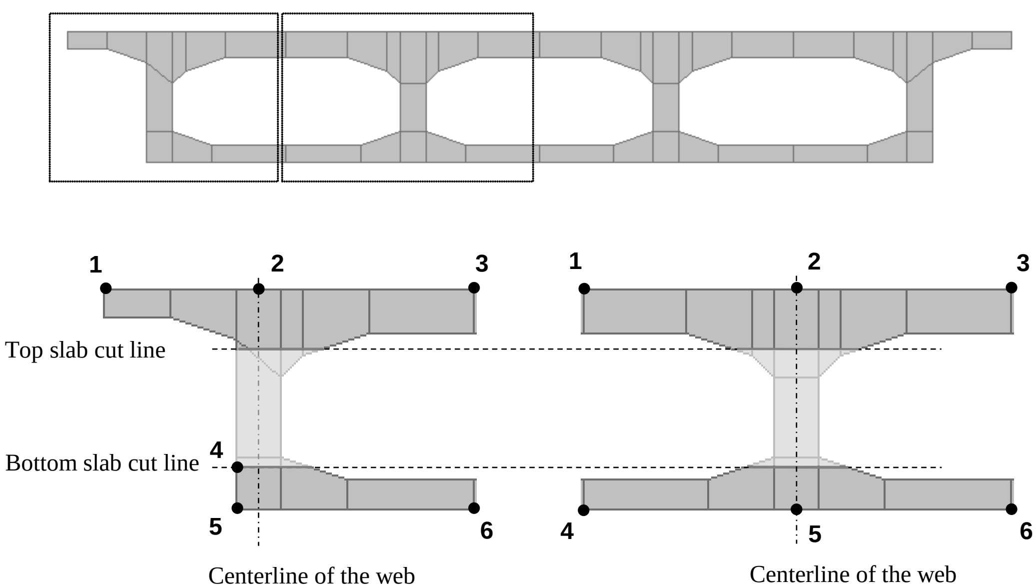


Figure 9-3 Bridge Concrete Box Deck Section - External Girders Vertical

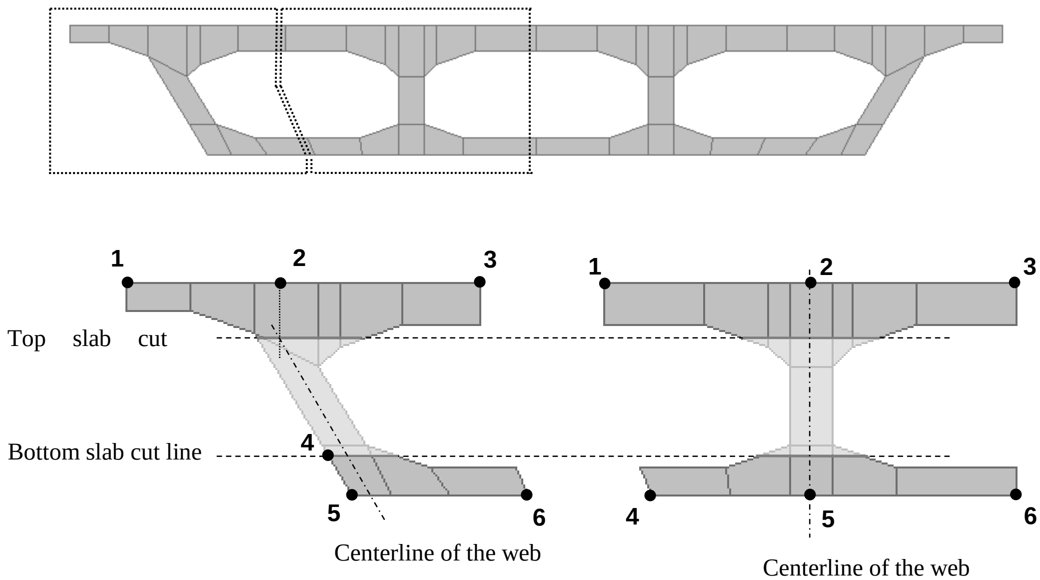


Figure 9-4 Bridge Concrete Box Deck Section - External Girders Sloped

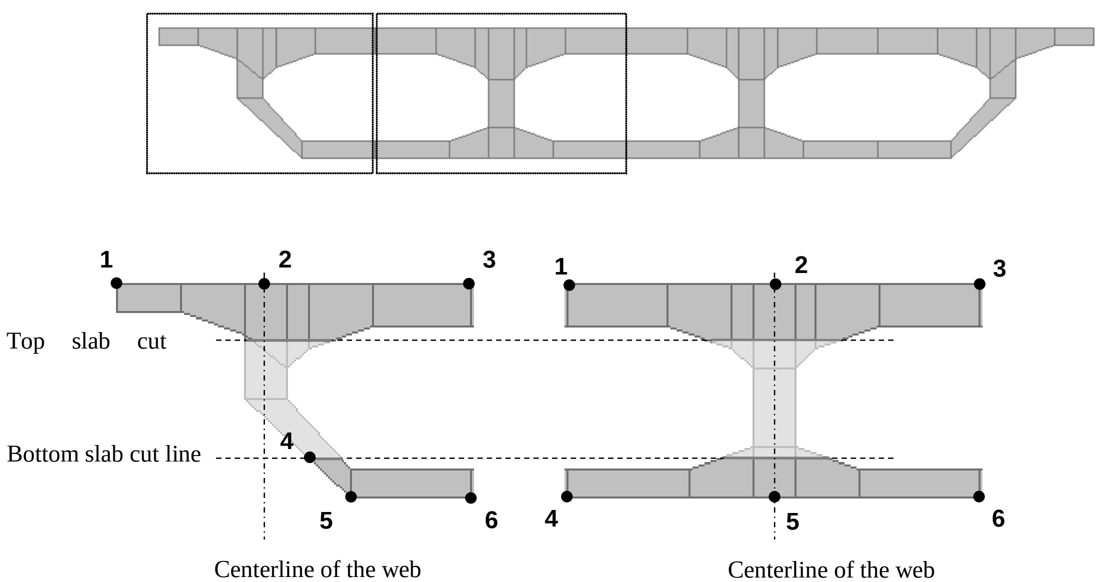


Figure 9-5 Bridge Concrete Box Deck Section - External Girders Clipped

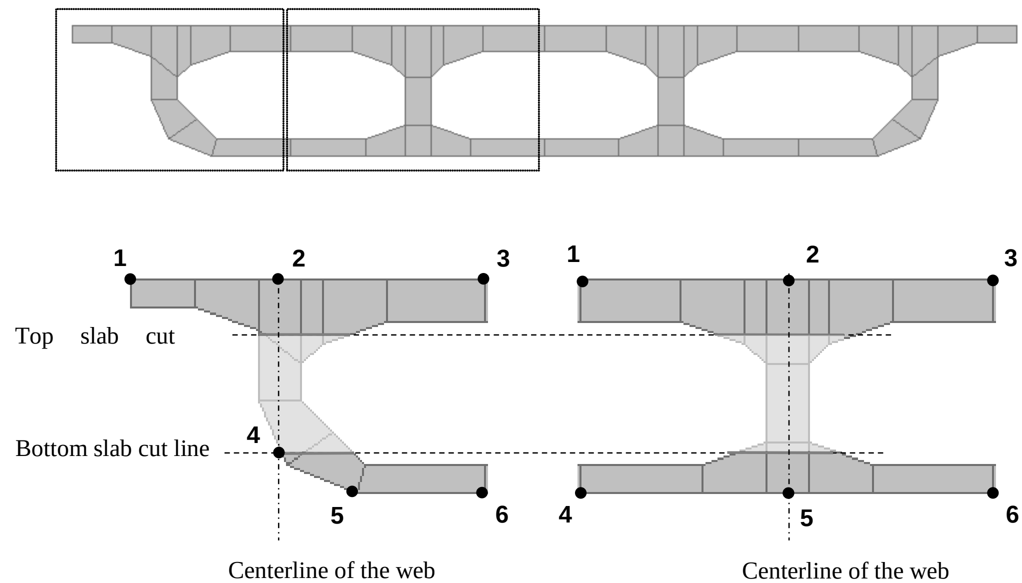


Figure 9-6 Bridge Concrete Box Deck Section - External Girders and Radius

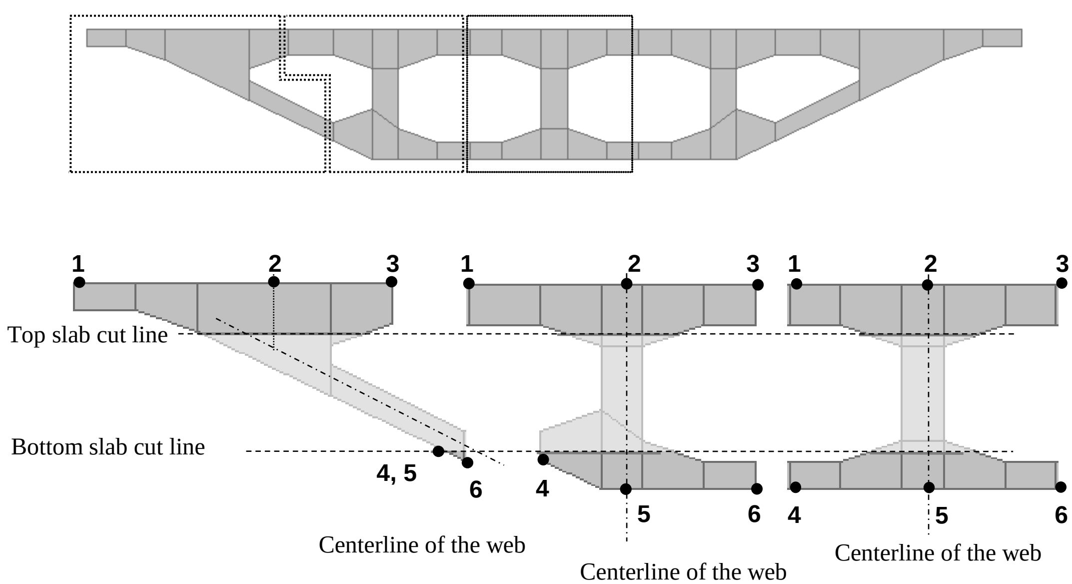


Figure 9-7 Bridge Concrete Box Deck Section - External Girders Sloped Max

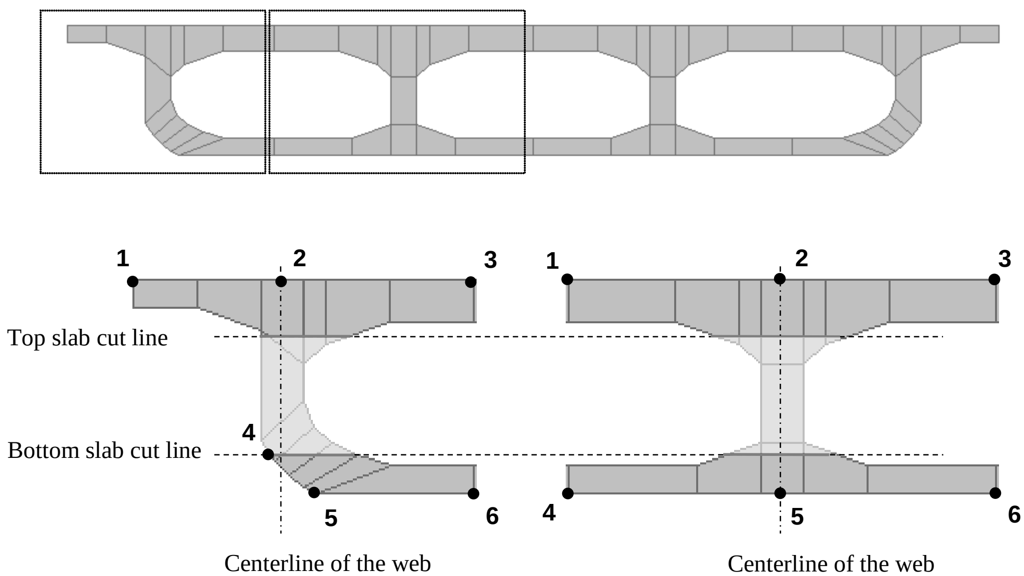


Figure 9-8 Bridge Concrete Box Deck Section - Advanced

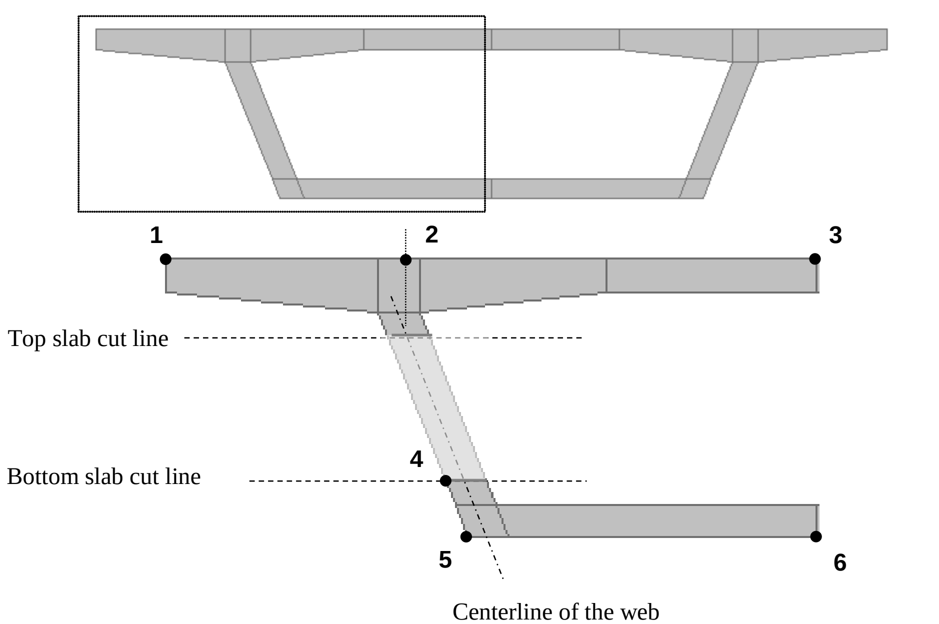


Figure 9-9 Bridge Concrete Box Deck Section - AASHTO - PCI - ASBI Standard

9.2 Display Data Tables

To view design results on screen in tables, click the **Home** > **Display** > **Show Tables** command, which will display the Choose Tables for Display form shown in Figure 9-10. Use the options on that form to select which data results are to be viewed. Multiple selection may be made.

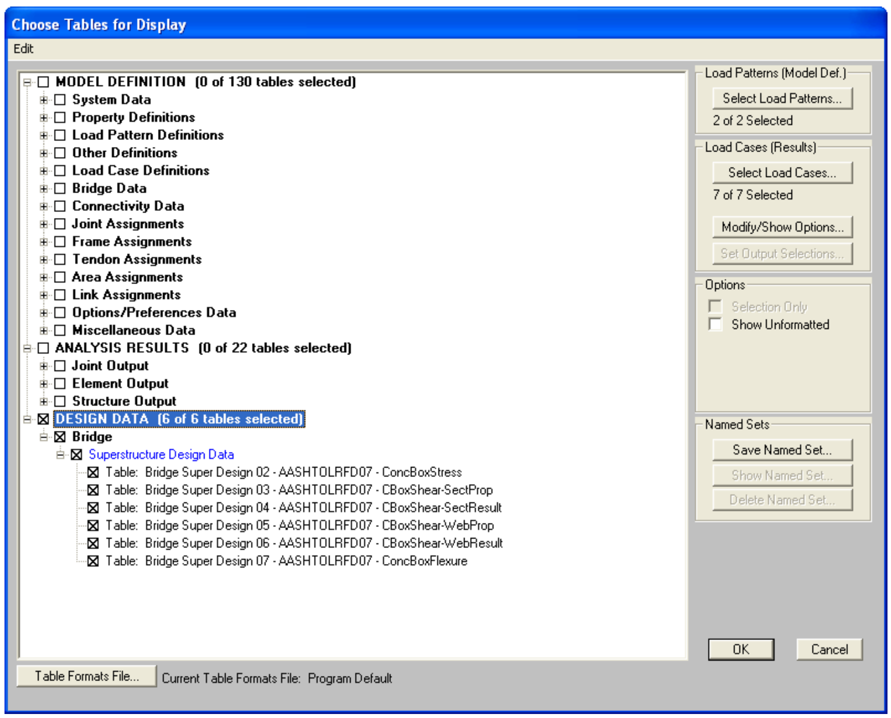
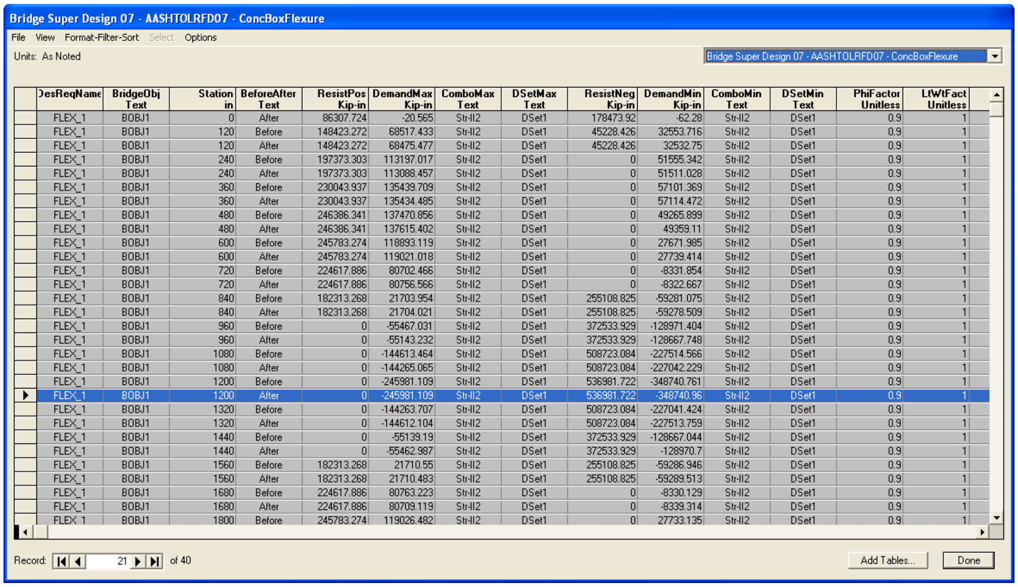


Figure 9-10 Choose Tables for Display form

When all selections have been made, click the **OK** button and a database table similar to that shown in Figure 9-11 will display. Note the drop-down list in the upper right-hand corner of the table. That drop-down list will include the various data tables that match the selections made on the Choose Tables for Display form. Select from that list to change to a different database table.



DesReqName	BridgeObj Text	Station in	BeforeAfter Text	ResistPos Kip-in	DemandMax Kip-in	ComboMax Text	DSetMax Text	ResistNeg Kip-in	DemandMin Kip-in	ComboMin Text	DSetMin Text	PhiFactor Unitless	LtWtFact Unitless
FLEX_1	BOBJ1	0	After	86307.724	-20.565	Str-II2	DSet1	178473.92	-62.28	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	120	Before	148423.272	68517.433	Str-II2	DSet1	45228.426	32553.716	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	120	After	148423.272	68475.477	Str-II2	DSet1	45228.426	32532.75	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	240	Before	197373.303	113197.017	Str-II2	DSet1	0	51555.342	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	240	After	197373.303	113088.457	Str-II2	DSet1	0	51511.028	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	360	Before	230043.937	135439.709	Str-II2	DSet1	0	57101.369	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	360	After	230043.937	135434.485	Str-II2	DSet1	0	57114.472	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	480	Before	246386.341	137470.856	Str-II2	DSet1	0	49265.899	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	480	After	246386.341	137615.402	Str-II2	DSet1	0	49359.11	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	600	Before	245783.274	118893.119	Str-II2	DSet1	0	27671.985	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	600	After	245783.274	119021.018	Str-II2	DSet1	0	27739.414	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	720	Before	224617.886	80702.466	Str-II2	DSet1	0	-8331.854	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	720	After	224617.886	80756.566	Str-II2	DSet1	0	-8322.667	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	840	Before	182313.268	21703.954	Str-II2	DSet1	255108.825	-59281.075	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	840	After	182313.268	21704.021	Str-II2	DSet1	255108.825	-59278.509	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	960	Before	0	-55467.031	Str-II2	DSet1	372533.929	-128971.404	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	960	After	0	-55143.232	Str-II2	DSet1	372533.929	-128667.748	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1080	Before	0	-144613.464	Str-II2	DSet1	508723.084	-227514.566	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1080	After	0	-144265.065	Str-II2	DSet1	508723.084	-227042.229	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1200	Before	0	-245981.109	Str-II2	DSet1	536981.722	-348740.761	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1200	After	0	-245981.109	Str-II2	DSet1	536981.722	-348740.96	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1320	Before	0	-144263.707	Str-II2	DSet1	508723.084	-227041.424	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1320	After	0	-144612.104	Str-II2	DSet1	508723.084	-227513.759	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1440	Before	0	-55139.19	Str-II2	DSet1	372533.929	-128667.044	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1440	After	0	-55462.987	Str-II2	DSet1	372533.929	-128970.7	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1560	Before	182313.268	21710.55	Str-II2	DSet1	255108.825	-59286.946	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1560	After	182313.268	21710.483	Str-II2	DSet1	255108.825	-59289.513	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1680	Before	224617.886	80763.223	Str-II2	DSet1	0	-8330.129	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1680	After	224617.886	80709.119	Str-II2	DSet1	0	-8339.314	Str-II2	DSet1	0.9	1
FLEX_1	BOBJ1	1800	Before	245783.274	119026.482	Str-II2	DSet1	0	27733.135	Str-II2	DSet1	0.9	1

Figure 9-11 Design database table for AASHTO LRFD 2007 flexure check

The scroll bar along the bottom of the form can be used to scroll to the right to view additional data columns.

9.3 Advanced Report Writer

The **File > Report > Create Report** command is a single button click output option but it may not be suitable for bridge structures because of the size of the document that is generated. Instead, the Advanced Report Writer feature within CSiBridge is a simple and easy way to produce a custom output report.

To create a custom report that includes input and output, first export the files using one of the **File > Export** command**s: Access**; **Excel**; or **Text**. When this command is executed, a form similar to that shown in Figure 9-12 displays.

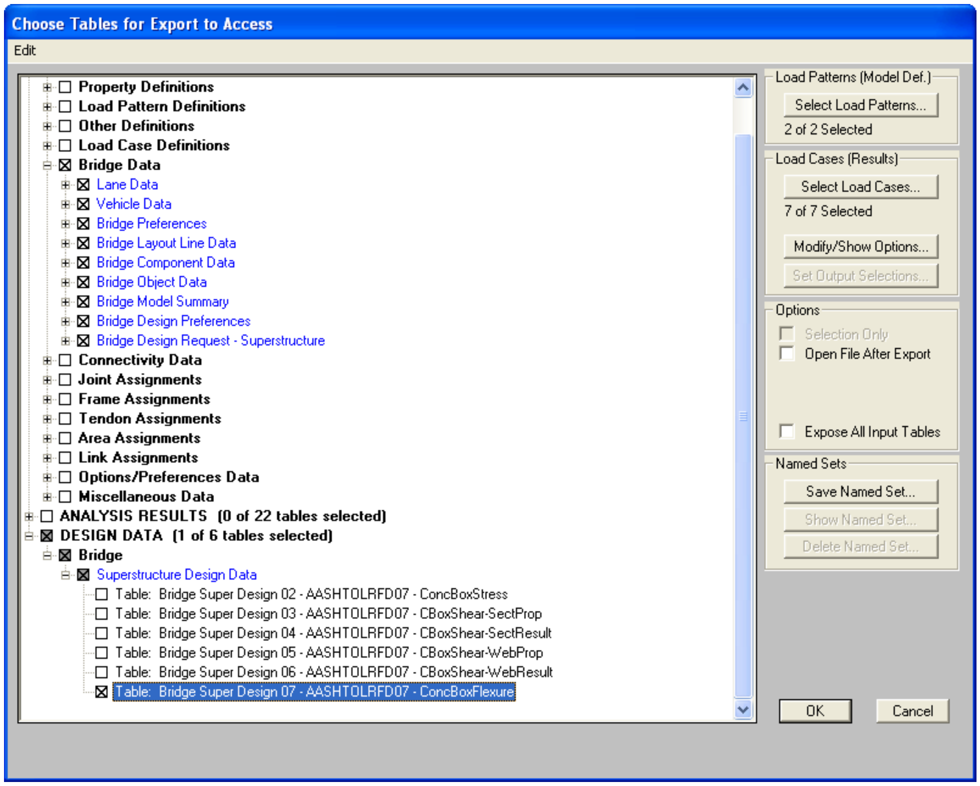


Figure 9-12 Choose Tables for Export to Access form

This important step allows control over the size of the report to be generated. Export only those tables to be included in the final report. However, it is possible to export larger quantities of data and then use the Advanced Report Writer to select only specific data sets for individual reports, thus creating multiple smaller reports. For this example, only the Bridge Data (input) and Concrete Box Flexure design (output) are exported.

After the data tables have been exported and saved to an appropriate location, click the **File** > **Report** > **Advanced Report Writer** command to display a form similar to that show in Figure 9-13. Click the appropriate button (e.g., Find existing DB File, Convert Excel File, Convert Text File) and locate the exported data tables. The tables within that Database, Excel, or Text file will be listed in the List of Tables in Current Database File display box.

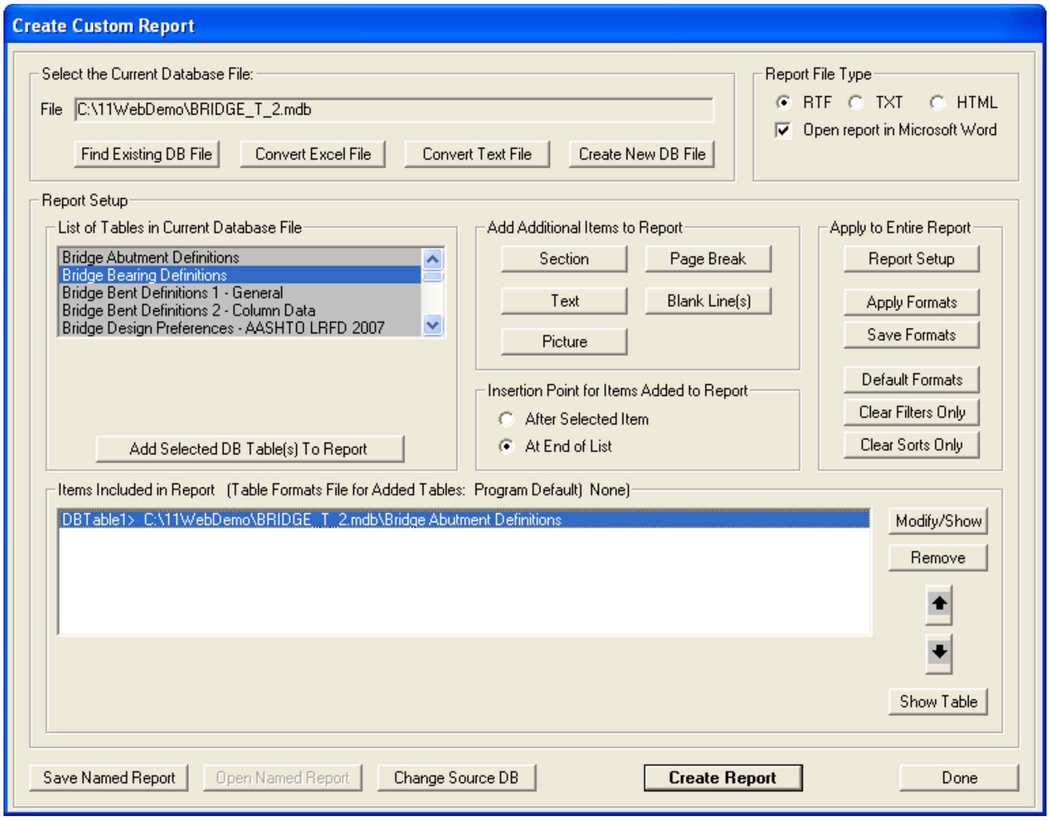


Figure 9-13 Create Custom Report form

Select the tables to be included in the report from that display box. The selected items will then display in the Items Included in Report display box. Use the various options on the form to control the order in which the selected tables appear in the report as well as the headers (i.e., Section names), page breaks, pictures, and blanks required for final output in .rft, .txt, or .html format.

After the tables have been selected and the headers, pictures, and other formatting items have been addressed, click the **Create Report** button to generate the report. The program will request a filename and the path to be used to store the report. Figure 9-14 shows an example of the printed output generated by the Report Writer.

Table: Bridge Super Design 07 - AASHTOLRFD07 - ConcBoxFlexure, Part 8 of 8

DesReqName	BridgeObj	Station	BeforeAfter	TSectForNeg	CDistForPos	CDistForNeg	EqFpsForPos	EqFpsForNeg
		in			in	in	Kip/in2	Kip/in2
FLEX_1	BOBJ1	0.0000	After	No	3.1396	5.0186	261.3115	261.0669
FLEX_1	BOBJ1	120.0000	Before	No	4.1819	1.2860	261.0506	267.5904
FLEX_1	BOBJ1	120.0000	After	No	4.1819	1.2860	261.0506	267.5904
FLEX_1	BOBJ1	240.0000	Before	No	4.2144	0.0000	263.0781	0.0000
FLEX_1	BOBJ1	240.0000	After	No	4.2144	0.0000	263.0781	0.0000
FLEX_1	BOBJ1	360.0000	Before	No	4.2289	0.0000	263.9863	0.0000
FLEX_1	BOBJ1	360.0000	After	No	4.2289	0.0000	263.9863	0.0000
FLEX_1	BOBJ1	480.0000	Before	No	4.2349	0.0000	264.3566	0.0000
FLEX_1	BOBJ1	480.0000	After	No	4.2349	0.0000	264.3566	0.0000
FLEX_1	BOBJ1	600.[illegible]	[illegible]	[illegible]	4.2346	0.0000	264.3437	0.0000
FLEX_1	BOBJ1	600.[illegible]	[illegible]	[illegible]	4.2346	0.0000	264.3437	0.0000
FLEX_1	BOBJ1	720.[illegible]	[illegible]	[illegible]	4.2268	0.0000	263.8524	0.0000
FLEX_1	BOBJ1	720.0000	After	No	4.2268	0.0000	263.8524	0.0000
FLEX_1	BOBJ1	840.0000	Before	No	4.2061	5.0660	262.5598	263.5331
FLEX_1	BOBJ1	840.0000	After	No	4.2061	5.0660	262.5598	263.5331
FLEX_1	BOBJ1	960.0000	Before	No	0.0000	5.1029	0.0000	265.4533
FLEX_1	BOBJ1	960.0000	After	No	0.0000	5.1029	0.0000	265.4533
FLEX_1	BOBJ1	1080.0000	Before	No	0.0000	5.1253	0.0000	266.6173
FLEX_1	BOBJ1	1080.0000	After	No	0.0000	5.1253	0.0000	266.6173
FLEX_1	BOBJ1	1200.0000	Before	No	0.0000	5.1286	0.0000	266.7879
FLEX_1	BOBJ1	1200.0000	After	No	0.0000	5.1286	0.0000	266.7879

Values used in the verification calculations.

Figure 9-14 An example of the printed output

9.4 Verification

As a verification check of the design results, the output at station 1200 is examined. The following output for negative bending has been pulled from the ConBoxFlexure data table, a portion of which is shown in Figure 9-10:

Demand moment,	"DemandMax" (kip-in)	=	–245973.481
Resisting moment,	"ResistingNeg" (kip-in)	=	536981.722
Total area of prestressing steel,	"AreaPTTop" (in^2)	=	20.0
Top *k* factor,	"kFactorTop"	=	0.2644444
Neutral axis depth, c,	"CDistForNeg" (in)	=	5.1286
Effective stress in prestressing, f_{ps},	"EqFpsForNeg" (kip/in^2)	=	266.7879

A hand calculation that verifies the results follows:

- For top *k* factor, from (eq. 5.7.3.1.1-2),

$$k = 2\left(1.04 - \frac{f_{PY}}{f_{PU}}\right) = 2\left(1.04 - \frac{245.1}{270}\right) = 0.26444 \text{ (Results match)}$$

- For neutral axis depth, from (AASHTO LRFD eq. 5.7.3.1.1-4),

$$c = \frac{A_{PT}\, f_{PU} - 0.85\, f'_c \left(b_{\text{slab}} - b_{\text{webeq}}\right) t_{\text{slabeq}}}{0.85\, f'_c \beta_1 b_{\text{webeq}} + kA_{PT}\, \dfrac{f_{PU}}{Y_{PT}}}, \text{ for a T-section}$$

$$c = \frac{A_{PT}\, f_{PU}}{0.85\, f'_c \beta_1 b_{\text{webeq}} + kA_{PT}\, \dfrac{f_{PU}}{Y_{PT}}}, \text{ when not a T-section}$$

$$c = \frac{20.0(270)}{0.85(4)(0.85)(360) + 0.26444(20)\left(\dfrac{270}{114}\right)} = 5.1286 \text{ (Results match)}$$

- For effective stress in prestressing, from (AASHTO LRFD eq. 5.7.3.1.1-1),

$$f_{PS} = f_{PU}\left(1 - k\frac{c}{Y_{PT}}\right) = 270\left(1 - 0.26444\frac{5.1286}{144}\right) = 266.788 \text{ (Results match)}$$

- For resisting moment, from (AASHTO LRFD eq. 5.7.3.2.2-1),

$$M_N = A_{PT}\, f_{PS}\left(Y_{PT} - \frac{c\beta_1}{2}\right) + 0.85\, f'_c \left(b_{\text{SLAB}} - b_{\text{webeq}}\right) t_{\text{slabeq}} \left(\frac{c\beta_1}{2} - \frac{t_{\text{slabeq}}}{2}\right)$$

$$M_N = A_{PT}\, f_{PS}\left(Y_{PT} - \frac{c\beta_1}{2}\right), \text{ when the box section is not a T-section}$$

$$M_N = 20.0(266.788)\left(144 - \frac{5.1286(0.85)}{2}\right) = 596646.5 \text{ kip-in}$$

$$M_R = \phi M_N = 0.85(596646.5) = 536981.8 \text{ kip-in (Results match)}$$

The preceding calculations are a check of the flexure design output. Other design results for concrete box stress, concrete box shear, and concrete box principal have not been included. The user is encouraged to perform a similar check of these designs and to review Chapters 5, 6, and 7 for detailed descriptions of the design algorithms.

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