Development of Steel Design Details and Selection Criteria for Cost Effective and Innovative Steel Bridges in Colorado

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Opinions expressed in this report are, however, those of the writers and do not necessarily reflect those of CDOT, USDOT, or Colorado State University.

EXECUTIVE SUMMARY

This research focuses on finding a method for creating cost effective and innovative steel bridges in Colorado. The design method that was discovered to create this cost efficiency was designing the beams as simply supported for non-composite dead loads, beam weight and wet concrete, and then making the beams continuous at the pier for composite dead loads and live loads. This method eliminates the need for an expensive field splice and simplifies design details at the interior support, creating cost savings. During the research, a software package was created at Colorado State University that takes user inputted data, such as span lengths, out to out width, number of girders, and overhang along with various other inputs and outputs the lightest wide flange shape that will satisfy the loading. The girders were designed using appropriate provisions from the AASHTO LRFD Bridge Design Specifications 4th edition 2007.

Once the program was completed, design charts and design tables were created for several one, two, and three span steel bridges. Each span arrangement for the design charts and tables was made using full widths of 39 ft, 44 ft, and 60 ft. Each chart and table depicted how the structural steel weight per square foot changes as the number of girders was increased as well as providing the lightest wide flange shape required to support the deck and traffic loads. These charts and tables also illustrate how the required amount of structural steel changes when different spans were used. The design charts will aid the bridge type selection process by giving designers an accurate measurement of minimum steel requirements for numerous one, two, and three span steel bridges. Finally, steel fabrication and erection cost were gathered from regional steel fabricators and bridge contractors. This cost information led to an accurate measurement of the cost per square foot for the structural steel of a bridge to be built in the state of Colorado. Overall, this research has provided CDOT and others who will use the software or design charts with a tool that will facilitate the construction of innovative steel girder bridges.

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1. INTRODUCTION

1.1 Background

Within the last 50 years in the midwestern United States, construction of short to medium span steel bridges has remained constant or declined, while prestressed concrete bridge construction has dominated the market (Azizinamini 2003). In Colorado the ratio of concrete to steel bridges is currently 20:1 (Wang 2006). One reason for this discrepancy is the lack of steel mills in the region combined with the strong presence of precast concrete companies in the state. In addition, a lack of readily available economical and innovative procedures to design and construct steel bridges has hindered the industry in certain areas, such as Colorado.

During the bidding process for design and construction of bridges, federal requirements mandate accurate bidding of both steel and concrete during the initial bidding process. The precast concrete industry has worked to develop tools to make this process easier and subsequently dominated the market in Colorado. These types of tools are not available for bidding steel bridges, thus the outcomes of type selection studies are routinely predominated by prestressed concrete.

1.2 Research Motivation

As previously stated, there has been a dearth of research on economical and rapid procedures to design short to medium span steel bridges. The purpose of this research is to provide the Colorado Department of Transportation (CDOT) with the most cost effective way to design and construct steel bridges using standard rolled steel sections readily available. With this result, CDOT will be able to choose the best alternative in the bridge type selection process.

1.3 Literature Review

An extensive literature review was conducted as part of this project to determine the most feasible options for the design of cost effective steel bridges in Colorado. Many publications were reviewed, including Transportation Research Board (TRB) annual meeting papers, National Cooperative Highway Research Program (NCHRP) reports, state Department of Transportation (DOT) structural design manuals, previous steel bridge studies, journal papers and various websites outlining steel bridge design and construction. The resource that proved to be most useful was Steel Bridge News journal reports from the National Steel Bridge Alliance. During the literature review, it was noted that the current method of constructing multi-span steel bridges is to build as continuous girders to distribute the load over all members. In this method, the rolled girders are fabricated and shipped to the job site. There they are assembled by the contractor using a bolted or welded field splice, usually between piers. In a recently developed method, simply supported beams are specified by the designer and beams are then made continuous at the piers by a concrete diaphragm or connection plate (Azizinamini 2005). In this setup, once the slab and diaphragm are poured, the simply supported beam accounts for its weight along with the wet concrete deck. As the concrete diaphragm hardens, making the girders continuous, all other loads (live, superimposed dead) are shared through the system of beams. This latter concept is called simple for dead load, continuous for live load, or simple made continuous (Azizinamini 2005). Some of the major advantages of the simple made continuous method over the field splice method (the field splice method is hereafter referred to as the "conventional method") are as follows (Azizinamini 2004):

- Eliminates the need for expensive field splices
- Reduces the negative moment at the pier, while increasing the positive moment at mid span
- Maintains a uniform cross section throughout span to reduce fabrication effort

- Requires minimum detailing of the steel beam
- Requires smaller cranes to assemble beam system
- Reduces erection time without the need for field splices
- Interrupts traffic minimally compared to conventional method

Several states have implemented this type of construction for some of their steel bridges. States that have built simple made continuous steel bridges include Colorado, New Mexico, Nebraska, Ohio, and Tennessee.

1.3.1 Nebraska

The Nebraska Department of Roads recently teamed with the University of Nebraska to identify/develop an economical solution for short-span (80-110 ft.) steel bridges (Azizinamini 2003). The two alternatives were to make the beam act as simple for the dead load and continuous for the live load, or to have the beam behave as continuous for both dead and live loading. Tests conducted for both alternatives show that the beam acting as continuous for the live load only produced a lower negative moment at the pier, while also generating a higher positive moment at mid-span (Azizinamini 2003). This is attractive because a uniform cross section could be specified throughout the length of the girder. After comparing the alternatives, the University of Nebraska recommended the development of simply supported beams for the dead load and continuous for live load. The initial detail designed for the connection at the pier can be seen in Figure 1.1.

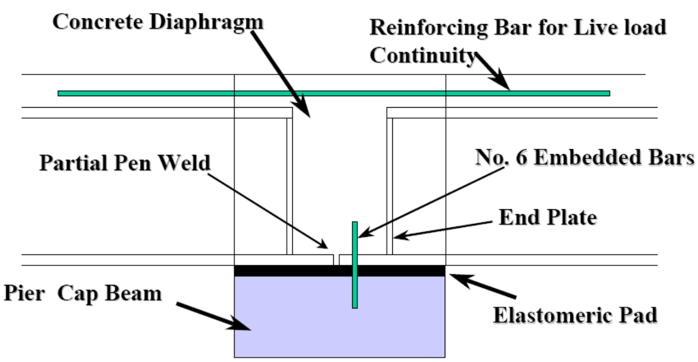


Figure 1.1 Detail of connection designed by the University of Nebraska [3].

A research bridge was constructed in Omaha, Nebraska using the principles developed by the University of Nebraska and National Bridge Research Organization. The new steel bridge replaced a four-span bridge over Interstate 680, with two 97-ft. spans (Azizinamini 2004). The rolled girder bridge, completed in August of 2004, uses four W40 x 249 grade 50W girders on its 32-ft. width, plus a 7-ft. cantilevered sidewalk. Girders are spaced at 10 ft. 4 in. on center. The bridge contains integral abutments, which allows for no bearings or expansion joints in the deck. On the pier, the girders sit on a 1.75 in. bearing pad surrounded by a sponge rubber joint filler. Simple bent plate cross frames are attached to the bearing stiffeners on the girders. The negative moment at the pier creates large compressive forces in the bottom flanges that could crush the concrete diaphragm. A 2 in. plate is welded to each bottom flange with no gaps to transfer the compressive forces through the steel instead of concrete. Reinforcing rods are also run laterally through the girders to give extra support for the concrete diaphragm cast around them (Azizinamini 2004). This bridge design calls for the concrete diaphragm to be poured two thirds full, making the beams partially continuous. The other third is filled in when the deck is poured, making the girders fully continuous. This process leads to stability in the deck during the pouring phase. Reinforcing rods are also placed in the deck slab above the piers to provided extra continuity. For this steel bridge, it is estimated that the simple made continuous design cut costs by a third compared to using field splices to connect the girders, i.e., the conventional method. The cost for in-place erected steel for this bridge amounted to only $0.52/lb., compared to a rule of thumb estimate of $0.75/lb. for rolled steel bridges having field splices (Azizinamini 2004). Figure 1.2 shows basic connection details for the research bridge spanning Interstate 680 in Omaha.

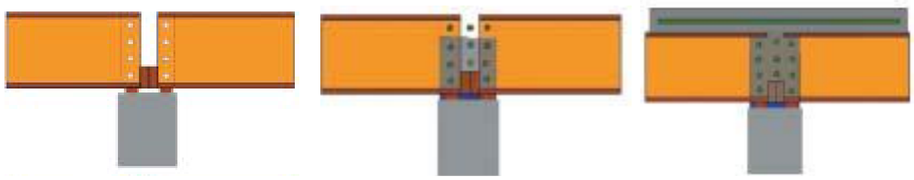


Figure 1.2 Making a continuous beam with concrete diaphragm [2].

1.3.2 Tennessee

The Tennessee Department of Transportation (TDOT) has also developed design details for steel girders with simple span for dead loads and continuous for all other loads. In one of the initial designs (Figure 1.3), continuity is achieved by a cast in place 3000 psi concrete diaphragm with steel reinforcement at the interior supports (Talbot 2005). A ½-in. plate welded at the end of the girder distributes the compression forces in the flanges.

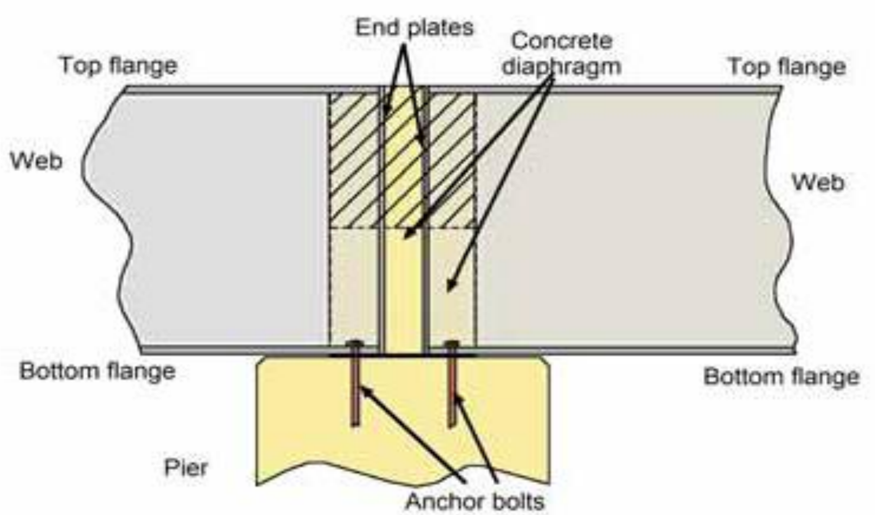


Figure 1.3 Initial Tennessee beam connection [17].

The trial bridge in Tennessee was built with four spans (65, 71, 71, 45 ft.) of W36 x 150 grade 50W steel with eight girders spaced between 9.3 and 11.5 ft. The varied spacing is due to the deck width changing from 75 ft. to 87 ft. over the length. The unit weight of structural steel is 18.3 pounds per square foot at an in-place cost of $0.72 per pound. While the concrete diaphragm is a technical success, the economics still does not compete well with precast concrete bridges at other sites in Tennessee (Talbot 2005). TDOT developed another method to create a full length beam with the same cross section (prismatic) throughout the span to meet the demands of the maximum positive moment. This is done by using a single shear bolted connection in the top flange. The bottom compression flange is fitted with a welded cover plate. Two trapezoidal wedges are tightly fit in the gap between the bottom flanges, similar to the Nebraska detail. A 12 in. steel channel frame is run from exterior beam to exterior beam along with a concrete diaphragm. This design is used in a two span, (87', 76') 40 ft. wide steel bridge in New Johnsonville, TN. Six W33 x 240 grade 50W beams are constructed at 7.5 ft. on center. The unit weight of structural steel is

37.7 pounds per square foot. The price of the steel from the low bidder is $0.56/lb. in place, significantly lower than the previous design. Construction of the total bridge took only 90 days, without incentives. TDOT also designed two similar bridges, which contained integral abutments. Advantages of the integral abutments include being jointless, reduced maintenance, and dampened seismic motion. The first is a five span bridge, taking State Road 210 over Pond Creek. The substructure is skewed at 35 degrees carrying spans of 94, 103, 132, 132, and 118 ft. Five W40 x 248 grade 50W girders support the 42 ft. wide deck. The steel beams were set in 30 days. The second of the two was another large rolled beam bridge set for construction in 2006, carrying Church Ave. over Route 158 and 71. It consists of six spans measuring 80, 100, 100, 100, 93, and 90 ft. The 56 ft. wide deck is supported by seven lines of W30 x 173 grade 50W girders, spaced at 8 ft. 2 in. The engineers estimate for the bridge totals $80/sq. ft., totaling $2.82 million. The low contractor bid is $72.93/sq. ft., or $2.55 million (Talbot 2005). Details of the connection at the pier along with the span of the concrete diaphragm can be seen in Figure 1.4.

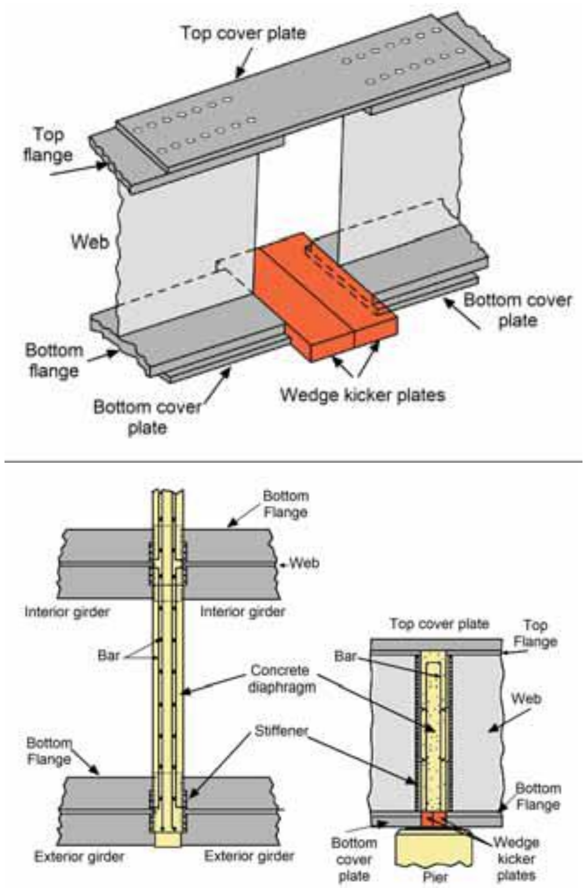


Figure 1.4 Tennessee design detail for continuity at pier [17].

1.3.3 Ohio

The Ohio Department of Transportation (ODOT) implemented a simple made continuous steel bridge as a replacement bridge in the summer of 2003. The existing structure was a six span (90’ approaches with 112’6” main spans) 29-foot wide steel stringer bridge crossing the Scioto River in Circleville on US 22 [Ohio DOT, 2003]. Because of time constraints, the state decided to make the project a design build fast track job. Five girders, spaced at 9 ft., are required to support the bridge, widened to 44 feet. High performance steel girders, M270 grade 50W, are designed as simply supported and are made continuous in the field by integral concrete diaphragms. The concrete diaphragm is 3 ft. wide and is cast across the pier comparable to the Nebraska and Tennessee diaphragms. The beams and diaphragm also sat on an elastomeric bearing pad and load plate. The beams are constructed as plate girders with a 54 in. web depth and 18 in. flanges. The total construction time of the US 22 Bridge, from demolition to the completed construction of the new bridge, was 48 days (Ohio DOT 2003). The bridge unit cost is $2.11 million, which equates to $75.6/sq. ft. Design details obtained from the state of Ohio can be seen in Figure 1.5.

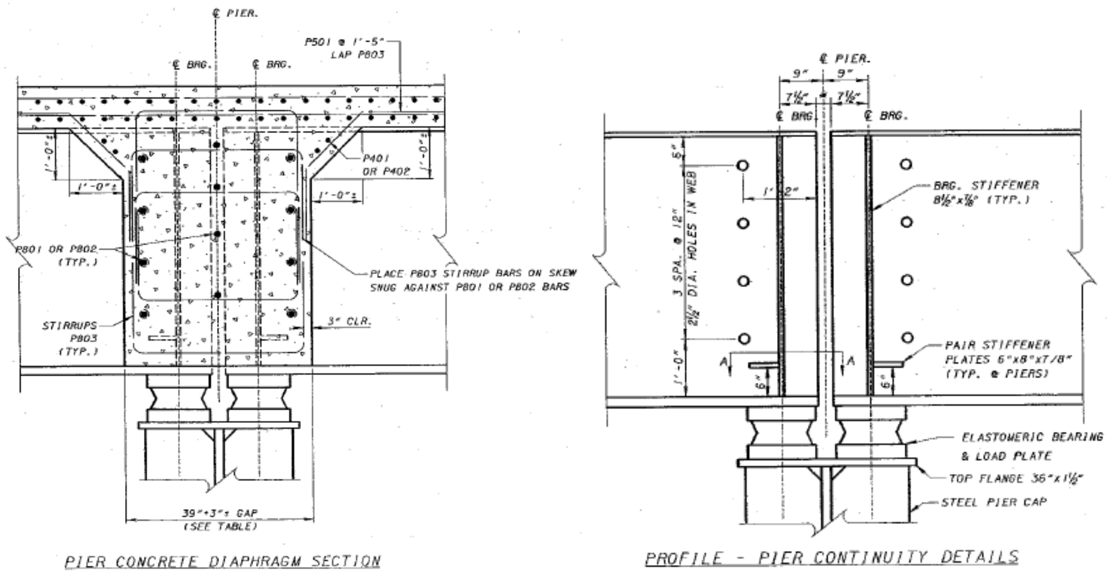


Figure 1.5 Concrete diaphragm details at pier on Scioto River Bridge [13].

1.3.4 New Mexico

New Mexico DOT used the simple for dead continuous for live method to design a five span 525 foot (105 ft./span), 34.5 foot wide replacement steel plate girder bridge (Barber 2006). The superstructure contains four lines of plate girders spaced at 7 ft. 6 in. The plate girder dimensions are a 54 in. web depth, 13.8 in. top flange, and 17.3 in. bottom flange (Barber 2006). That bridge crosses the Rio Grande River on NM 187 and was completed in the summer of 2005. On an earlier project, the simple-made continuous concept served in a dual-design analysis (steel vs. pre-stressed concrete) for a bridge on US 70 in southern New Mexico. A design consultant for the US 70 project, Parsons Brinckerhoff, Inc. bid the two alternatives at a difference of only 0.2 percent out of a total project construction cost of $21 million (Barber 2006). An innovative feature on this project is bolts placed outside of the concrete diaphragm to allow for tightening after the deck and diaphragms are poured. Reinforcing bars are added to the concrete diaphragm to achieve the required negative moment capacity. Bars are also added above the pier to alleviate stresses on the continuity connection plate and are shown in Figure 1.6. The cost of the bridge is $75 per sq. ft. Bids for precast concrete girder bridges of comparable square footage are $68 and $88 per sq. ft. each (Barber 2006).

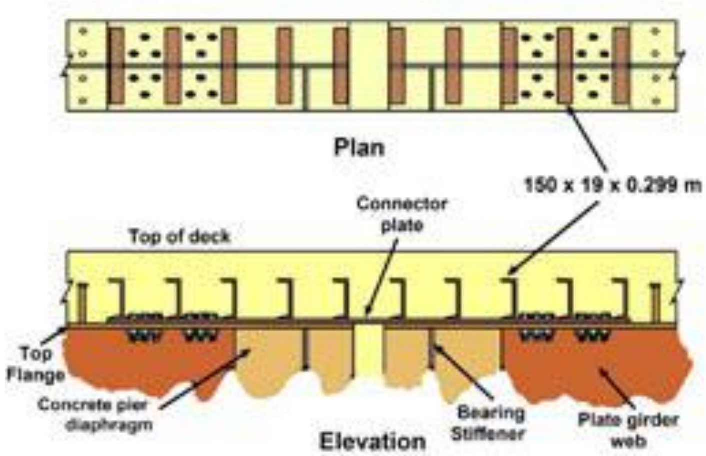


Figure 1.6 Detail of connection plate on top flanges on NM 187 bridge [5].

1.3.5 Colorado

The Colorado Department of Transportation (CDOT) recently designed and completed its first simple made continuous steel bridge. The steel bridge, which was completed in July 2006, replaced an old bridge on US 36 that crossed Box Elder Creek outside of Denver (Modern Steel Construction 2006). The new superstructure is 470 feet long with six equal spans, 77 ft./span. The 44 ft. wide concrete deck is supported by six lines of W33 x 152 grade 50W rolled beam girders spaced at 7 ft. 4 in. The beams were supplied to the site in pairs with W27 x 84 diaphragms connected to the bearing stiffeners. These cross frames are spaced at 19 ft. on the interior girders and 12 ft. 4 in. on the exterior girders and provided stability during erection. Similar steel diaphragms also run over the pier cap from exterior to exterior girder. The girders sit six inches apart on a ¾-inch elastometric pad along with a 30x14x1 compression plate. The bottom flanges of each girder are welded to the compression plate to make the system continuous. A reinforcing rod is placed within the deck above the pier to handle the tension of the negative moment. The total cost of the superstructure amounts to $1.1 million. This equates to just $53 per square foot, or $.97 per pound of erected steel (Modern Steel Construction 2006). Details of the pier cap connections can be seen in Figure 1.7.

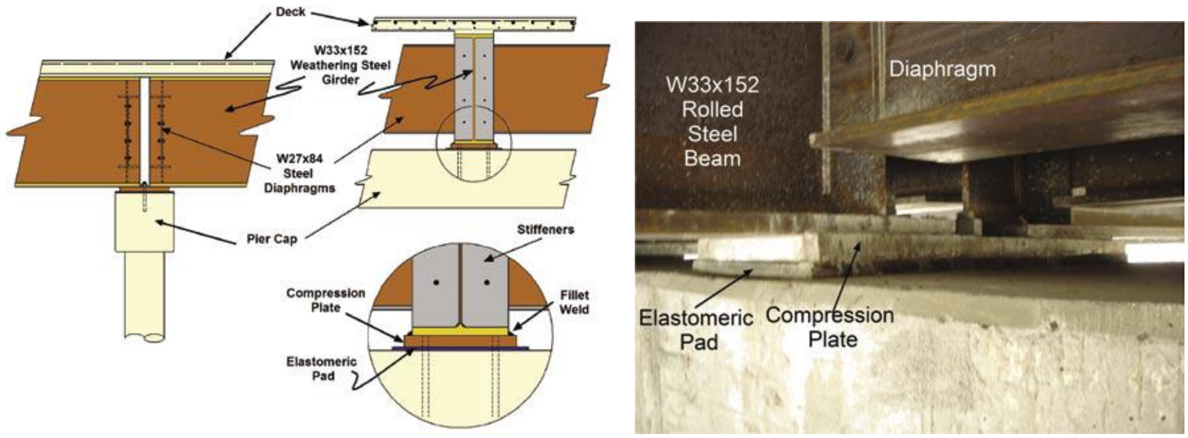


Figure 1.7 Colorado beam continuity connection above pier cap [16].

1.3.6 Comparison Between States

Table 1.1 outlines information about steel bridges constructed in different states using the simple made continuous method with rolled beams. General information on the bridge, along with beam size and cost is included.

Table 1.1 Rolled Girder Cost Chart

Location	General Bridge Information	Beam Used	Cost
Tennessee State Route 35 Maryville, TN	Four spans (65, 71, 71, 45 ft) width varies from 75 to 87 ft 8 girders	W36 x 150	18.3 lbs/ft^2 $.72/lb in place
Dupont Rd New Johnsonville, TN	Two spans (87, 76 ft) 40 ft wide 6 girders	W33 x 240	37.7 lbs/ft^2 $.56/lb in place
Church Ave over Route 158 Knox County	Six spans (80, 3@100, 2@90 ft) 56 ft wide 7 girders	W30 x 173	$73/sq ft
Nebraska Sprague St. Over I 680 Omaha,NE	Two spans (97, 97 ft) 32 ft wide 4 girders	W 40 x 249	$.52/lb in place
Colorado Box Elder Creek US 36 E. of Denver	Six spans (6@78 ft) 44 ft wide 6 girders	W 33 x 152	$1.1 million $53/sq ft deck $.97/lb erected

Although each of these steel bridges is constructed using the simple for dead load, continuous for live load method, the bridges have similarities and differences.

Similarities

- All use grade 50 weathering steel.
- Concrete diaphragms are cast from exterior to exterior beams to connect girders sitting on the pier cap, except in Colorado (steel diaphragm/welded connection plate).
- Integral abutments integrated in all bridges except initial designs in Tennessee.
- There are no expansion joints due to integral abutments.
- Sufficient reinforcement is placed in the deck above the pier in the negative moment section to provide extra continuity and take some of the tension force.
- Each state places an elastomeric pad along with a bearing plate between the pier cap and girders, except Tennessee.
- All designed used AASHTO LRFD Bridge Design Specifications.

Differences

- The bridges in Tennessee and Nebraska both utilize a plate between the girders to transfer the compressive forces, whereas the Ohio, New Mexico, and Colorado bridges do not.
- The cross frames vary from a wide flange section, to a bent plate, to a k-type cross frame.
- Tennessee uses a single shear bolted connection to connect the top flanges with a cover plate, along with a bottom plate, while New Mexico uses a continuity connection plate on the top flanges.
- Colorado welds the bottom flanges to the compression plate to create a continuous beam instead of using a concrete diaphragm.
- The concrete diaphragm in the Nebraska bridge is poured two-thirds full to make the beams partially continuous. The remaining third is filled when the deck is poured. This procedure is used to maintain the stability of the deck while it is cast.

1.4 Selection of Design Method

Based on the benefits of the simple made continuous method, this project focuses on this method as opposed to the conventional method. In addition, because cost is a major deciding factor in the selection process, the preferred material is standard size rolled steel beams. For short to medium spans, the rolled girders prove to be more cost effective than plate girders.

1.5 Objectives

The major objectives of this study are as follows:

- To establish/select a design detail for constructing simple span steel girders made continuous over piers.
- To create design charts that will aid in the optimal selection of rolled girders.
- To design a computer spreadsheet that will allow a user to input bridge data (spans, lengths, width, etc.) and automatically size a rolled girder system for applied loads.
- To produce costs associated with steel fabrication, transportation, and erection. This includes a cost per unit area of deck.
- To establish a procedure to update the design tables for changes in unit cost.

1.6 Report Organization

The first section of this report includes background information on the current state of bridges in Colorado along with an extensive literature review. Project objectives are also included. A review of different steel bridge design methods is contained in Section 2. Also, an overview of the simple made continuous design with detailed procedures of the design process can be found in Section 2. Section 3 contains the development of the software package. Creation of the design charts and descriptions of how they are used is in Section 4. A summary of the report along with recommendations makes up Section 5. Additionally, Appendix A includes sample calculations of a bridge design using the girder design software. Appendix B includes the design charts, while Appendix C contains the design tables. Appendix D illustrates design details for a simple made continuous bridge. Appendix E contains a User's Manual and Users Guide Examples for the software package. Finally, Appendix F includes a User's Manual for the software used to analyze a Colorado Permit Truck.

2. DESIGN OF A SIMPLE MADE CONTINUOUS STEEL BRIDGE GIRDER SYSTEM

2.1 Introduction

In this section, the girder design of a simple made continuous steel bridge is summarized. This is a continuous beam problem, which requires designing simple spans to be continuous across the negative moment. This includes references to the AASHTO LRFD Bridge Design Specifications 4th Edition 2007 and the steps taken to insure a given beam will support the applied loads. Throughout the section, article numbers or tables are assumed to be referenced by the AASHTO LRFD Bridge Design Specifications (AASHTO 2007).

2.2 Design Background

As is previously discussed in the previous section, steel bridge girders have historically been designed as a continuous beam with field splices at low stress points. Because of the labor involved in creating a field splice, the conventional method often is not cost effective when compared to precast concrete (Azizinamini 2003). A new design philosophy eliminates the costly field splices and minimizes the structural steel required.

2.3 Assumptions

Some of the major assumptions in the research project are that each designed bridge will satisfy the following:

- Standard size AISC rolled steel beams are used.
- Spans are between 50 and 120 feet.
- Pedestrian loads are negligible .
- Prismatic (same cross section) exists throughout the length of the bridge.
- Beam weight is greater than 124 lbs./ft. and less than 331 lbs./ft. for cost estimations.
- There is a minimum of four girders and a maximum of 12 girders.
- For the span ranges considered in this project, the use of the Colorado Permit Vehicle is excluded for both single and multiple lanes during the analysis and subsequent girder selection process.
- A deck pour analysis is not included in this study because the results of the study, i.e., preliminary girder selection, are intended at this stage.
- Fatigue stresses are not checked in the connection plates at the top and bottom when required.
- Load and resistance factor rating (LRFR) is not considered in the analysis.
- Optimized shear stud spacing is not considered in the analysis. The shear stud spacing is assumed or user specified since this is intended as a preliminary engineering procedure for cost estimation.
- Variable internal diaphragm spacing is not considered in the analysis to obtain the optimized girder section.
- Shear lag at the simple made continuous connection, i.e., the interior supports, are not considered due to the limited scope of work.

2.4 Design Steps

The first step in the steel bridge design process is defining basic data. These parameters include number of spans, span lengths, roadway width, slab thickness, number of girders, etc. Following inputted data, bridge loads are generated. Given the provided data and applied loads, flexure, shear, and subsequent stresses are all calculated to insure the selected beam will support the bridge.

2.5 Loads

Because the beams are designed as simple for dead load one and continuous for all other loads, it is important to distinguish between each. Dead load one includes the weight of the slab and self-weight of the beam. The self-weight is calculated from the volume of the girder multiplied by the density of steel, 490 lbs./ft.^{3} along with shear studs. Likewise, the slab weight is found by multiplying the volume of deck by 150 lbs./ft.^{3}. The 150 lbs./ft.^{3} does not include the effect of reinforcement, but the reinforcement weight is added to the dead load one. This is done due to the great amount of reinforcement put into bridge decks. The slab area is computed from the thickness multiplied by the centerline spacing of each girder. The long term composite dead load two includes barriers, a future wearing surface, and any additional items that may be added after the deck has cured. It is assumed that the each barrier weighed 482 lbs./ft. and the composite dead load is spread equally over all girders, but values can be modified in the design spreadsheet discussed in Section 3. The most critical load imposed on a steel bridge is the live load. All live load forces are calculated according to Section 3.6. The live load includes the design lane load and the larger of the design truck or design tandem. The design lane load is represented as a distributed load at 640 lbs./ft. It is determined that a HL-93 design truck will cause the greatest extreme forces that are under consideration in this research. According to Article 3.6.1.3, the extreme force effect is taken as the largest of one design truck with variable axle spacing combined with the lane load, or two design trucks spaced at least 50 feet apart combined with the lane load with a 10% reduction allowed in the negative moment region. For this design, Strength I and Service II load factors are applied to the appropriate loads (Table 3.4.1-1). Once all loads are defined, a software package created at Colorado State University is used to determine the extreme forces and critical sections.

In addition, it is important to understand the properties that are used for each part of the design, i.e., section and related stiffness. For the positive moment capacity, for DL-1 the I_x of the selected beam is used; for DL-2 the long term composite section I_x from the elastic section properties is used; and for the LL+I the short term composite section I_x from the elastic section properties is used. The long term composite section carries a factor of 3*n* (modular ratio) and the short term section has a factor of *n*. For the negative moment capacity, for DL-1 the I_x of the selected beam is used as it is for the positive moment; for both DL-2 and LL+I the I_x of the selected beam plus the top and bottom reinforcement in the slab is used.

2.5.1 Live Load Moment and Shear Distribution

The next step in the design process is reducing the live load moments and shears according to the tables in Section 4.6.2.2. First, the distribution of live loads per lane for moments in interior beams (Table 4.6.2.2.2b-1) is calculated for one lane loaded and two or more lanes loaded.

One Design Lane Loaded: $DF = 0.06 + \left(\frac{S}{14\,ft}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12Lt_s^{\,3}}\right)^{0.1}$

Two or More Design Lanes Loaded: $DF = 0.075 + \left(\frac{S}{9.5\,ft}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12Lt_s^{\,3}}\right)^{0.1}$

Where: $K_g = n(I_x + Ae_g^{\,2})$ and $e_g = \frac{D}{2} + \frac{t_s}{2} + t_h$

After the interior moment distribution is calculated, the exterior moment distribution is found using Table 4.6.2.2.2d-1.

One Design Lane Loaded: Lever Rule

Two or More Design Lanes Loaded: $g = eg_{\text{interior}}$

Where: $e = .77 + \frac{d_e}{9.1}$

Special analysis on the exterior girder is also considered following C4.6.2.2.2d. This distribution factor is important because the other reductions do not factor in diaphragms or cross frames.

$$R = \frac{N_L}{N_b} + \frac{N_{ext}\sum e}{\sum x^2}$$

Where:
R = reaction on exterior beam
N_L = number of loaded lanes
e = eccentricity of a design truck from the center of gravity of the girders
x = horizontal distance from the center of gravity of the pattern of girders to each girder
N_{ext} = horizontal distance from the center of gravity of the pattern of girders to the exterior girder
N_b = number of beams

The shear distribution factors are calculated next for both interior and exterior girders according to Tables 4.6.2.2.3a-1 and 4.2.2.3b-1, respectively.

Interior:

One Design Lane Loaded: $VDF = 0.36 + \left(\frac{S}{25\,ft}\right)$

Two or More Design Lanes Loaded: $VDF = 0.075 + \left(\frac{S}{12\,ft}\right) - \left(\frac{S}{35\,ft}\right)$

Exterior:

One Design Lane Loaded: Lever Rule

Two or More Design Lanes Loaded: $g = eg_{\text{interior}}$

Where: $e = 0.6 + \frac{d_e}{10}$

Once each distribution factor is calculated, the appropriate factor is applied to the maximum calculated moment in both positive and negative sections. Also, multiple lane presence factors are considered according Article 3.6.1.1.2-1.

2.6 Flexure

Once the distribution factors are determined, the first design step is to determine if the selected beam can support the loads. When checking to see if the beam flexure criteria is satisfied, it is necessary to find the neutral axis location and plastic moment. In the positive flexure region, there are three possibilities for neutral axis location; in the concrete deck, in the top flange, or in the web. Each of these cases is checked according to equations found in Appendix D6.1.

2.6.1 Positive Moment Flexure (Composite Only)

Case 1 (Neutral Axis in the web): If $P_t + P_w \geq P_c + P_s$

Then: $Y = \left(\frac{D_w}{2}\right) * \left[\frac{P_t - P_c - P_s}{P_w} + 1\right]$ from bottom of top flange

And: $M_p = \left(\frac{P_c}{2D_w}\right) * \left[Y^2 + (D_w - Y)^2\right] + \left[P_s d_s + P_c d_c + P_t d_t\right]$

Case 2 (Neutral Axis in the top flange): If $P_t + P_w + P_c \geq P_s$

Then: $Y = \left(\frac{t_c}{2}\right) * \left[\frac{P_w + P_t - P_s}{P_c} + 1\right]$ from top of top flange

And: $M_p = \left(\frac{P_c}{2t_c}\right) * \left[Y^2 + (t_c - Y)^2\right] + \left[P_s d_s + P_w d_w + P_t d_t\right]$

Case 3 (Neutral Axis in the deck): If $P_t + P_w + P_c \geq \left(\frac{c_{rb}}{t_s}\right) P_s$

Then: $Y = (t_c) * \left[\frac{P_c + P_w + P_t}{P_s}\right]$ from top of deck

And: $M_p = \left(\frac{Y^2 P_s}{2t_s}\right) + \left[P_c d_c + P_w d_w + P_t d_t\right]$

Where: $P_s = 0.85 f_c' b_s t_s$

$P_c = f_{yc} b_c t_c$

$P_w = f_{yw} D t_w$

$P_t = f_{yt} b_t t_t$

Longitudinal reinforcement in the positive region is conservatively neglected.

Once the neutral axis and plastic moment are determined, the nominal flexural resistance is found using Article 6.10.7.1.2.

Nominal Positive Moment Resistance:

$M_n = M_p \quad if \quad D_p \leq .1(D + t_s + t_h)$

Otherwise: $M_n = M_p \left(1.07 - \frac{.7D_p}{D + t_s + t_h}\right)$

The yield moment is then calculated following Appendix D6.2

Yield Moment:

$$M_y = \left[f_y - \frac{M_{DL1}}{S_x} + \frac{M_{DL2}}{S_{Bot\_II}} \right] S_{Bot\_III} + M_{DL1} + M_{DL2}$$

$m_n \leq 1.3 m_y$ Article 6.10.7.1.2

After the beam resistance is found, it is compared to the maximum factored moment created by the applied loads using Strength I load factors. Recall that the moment M_{DC1} is from the simply supported dead load one and all others are calculated as a continuous beam.

$$M_u = 1.25 M_{DC1} + 1.25 M_{DC2} + 1.5 M_{DW} + 1.75 M_{LL}$$

$$M_u < \phi M_n$$

Where: $\Phi = 1.0$

If the nominal moment is greater than the imposed ultimate moment, the beam satisfy positive moment flexure.

2.6.2 Negative Moment Flexure (At Pier Bearing Location Only)

The negative flexure check is very similar to the positive region check. Again, the location of the neutral axis is found to determine the plastic moment capacity, and therefore nominal moment resistance. There are two cases for the location of the neutral axis; in the top flange or in the web.

Case 1 (Neutral Axis in the web): If $P_c + P_w \geq P_t + P_{rb} + P_{rt}$

Then: $Y = \left(\frac{D_w}{2} \right) * \left[\frac{P_c - P_t - P_{rt} - P_{rb}}{P_w} + 1 \right]$ from bottom of top flange

And: $M_p = \left(\frac{P_w}{2D_w} \right) * \left[Y^2 + (D_w - Y)^2 \right] + \left[P_{rt} d_{rt} + P_{rb} d_{rb} + P_t d_t + P_c d_c \right]$

Case 2 (Neutral Axis in the top flange): If $P_c + P_w + P_t \geq P_{rb} + P_{rt}$

Then: $Y = \left(\frac{t_t}{2} \right) * \left[\frac{P_w + P_c - P_{rt} - P_{rb}}{P_t} + 1 \right]$ from top of top flange

And: $M_p = \left(\frac{P_t}{2t_t} \right) * \left[Y^2 + (t_t - Y)^2 \right] + \left[P_{rt} d_{rt} + P_w d_w + P_c d_c \right]$

Nominal Negative Moment Resistance:

$$M_n = M_p$$

$$M_u < \phi M_n$$

Where: $\Phi = 1.0$

Again, the nominal resistance is compared to the maximum factored (negative) moment generated by the applied loads using Strength I load factors, to determine if the beam was satisfactory. In the negative section, there is no flexure from dead load one.

2.7 Shear

The next design step is to check the shear capacity of the girder compared to the shear created by the applied loads. When looking at the shear capacity of the web, it is concluded that all logical rolled beam sections within the specified span lengths are compact, and therefore C_v in the following equation will equal 1.

Nominal Shear Strength of an Unstiffened Web: (Article 6.10.9.2)

$$V_n = 0.58 F_y A_w C_v$$

The nominal shear strength is then compared to the shear of the live, composite, and non-composite dead loads with Strength I load factors to verify the beam will pass the shear check.

$$V_u < \phi V_n$$

Where: $\Phi = 1.0$

To assure the web will be satisfactory, various web properties are checked. These follow Appendix B6.2.1, respectively.

Web Proportions:

$$\frac{2D_p}{t_w} \le 6.8\sqrt{\frac{E}{f_{yc}}}$$

$$\frac{D}{t_w} \le 150$$

$$D_{cp} \le .75D$$

Compression Flange Properties:

$$\frac{b_f}{2t_f} \le 0.38\sqrt{\frac{E}{F_y}}$$

$$b_f \le \frac{D}{4.25}$$

2.8 Stress

The final limit states evaluated are the stresses in the compression and tension flanges in both the positive and negative moment regions. Following Article 6.10.4.2, the permanent deflections of each flange are calculated. To calculate the resulting stresses, it is necessary to find elastic section properties for the selected beam. A sample calculation for finding elastic section properties is found in Appendix A, Sample Calculations. The following equations hold true for both the positive and negative stress regions.

Tension Flange:

$$f_{DL1} = \frac{M_{Dl1}}{S_x} \qquad f_{DL2} = \frac{M_{DL2}}{S_{LongTerm}} \qquad f_{LL} = \frac{M_{LL}}{S_{ShortTerm}}$$

Compression Flange:

$$f_{DL1} = \frac{M_{Dl1}}{S_x} \qquad f_{DL2} = \frac{M_{DL2}}{S_{LongTerm}} \qquad f_{LL} = \frac{M_{LL}}{S_{ShortTerm}}$$

After all flange stresses are determined, they are compared to 95% of the yield strength, 47.5 ksi. In most cases, the bottom flange controls the design in either the positive or negative moment region.

2.9 Summary

In the design process described in this paper, three main limit states are checked: flexure, shear, and stress. Each limit state is calculated to verify that a given rolled steel girder will carry its self-weight, deck, composite dead loads, and traffic loads. The lightest beam, measured by weight per linear foot, satisfies all conditions and is used in this paper's subsequent calculations.

3. DEVELOPMENT OF DESIGN SOFTWARE

3.1 Introduction

This section outlines how the rolled girder design software package in this study is created. An Excel spreadsheet is developed to take a user's input of bridge data, span length, width, number of girders, slab thickness, etc, and output the lightest shape required to support the loads. The girder selected from the automated process is subjected to all design steps outlined in Section 2.

3.2 Assumptions

As mentioned in the simple made continuous design summary in Section 2 of this report, due to the limited scope of this project and report, the following issues are not considered/included:

- For the span ranges considered in this project, the use of the Colorado Permit Vehicle is excluded for both single and multiple lanes during the analysis and subsequent girder selection process.
- A deck pour analysis is not included in this study because the results of the study, i.e., girder selection, are intended at this stage for preliminary engineering.
- Fatigue stresses are not checked in the connection plates at the top and bottom when required.
- Load and resistance factor rating (LRFR) is not considered in the analysis.
- Optimized shear stud spacing is not considered in the analysis. The shear stud spacing is assumed or user specified since this is intended as a preliminary engineering procedure for cost estimation.
- Variable internal diaphragm spacing is not considered in the analysis to obtain the optimized girder section.
- Shear lag at the simple made continuous connection, i.e., the interior supports, are not considered due to the limited scope of work.

3.3 Data Input

Gathering general information about the bridge is the first step in the design of the girder selection design software. Some of the major design criteria required for the calculations include the longest span length, full width, number of lanes available to traffic, slab thickness, overhang length, and the number of girders. Refer to Figure 3.1 for an example of the basic input data.

9						
10		**Input Data**	Denotes Required Field			
11						
12		Longest Span Length	L	90	ft	
13	CDOT Spec.	Full Width	w	44	ft	
14	Subsection 8.	Slab Thickness	t_s	9	in	
15		Haunch Thickness	t_h	0.75	in	
16		FW Surface Thicknes:	t_w	4	in	
17		Yield Strength Conc.	f'_c	4.5	ksi	
18		Yield Strength Beam	f_y	50	ksi	
19		Yield Strength Rebar	$f_{y,rb}$	60	ksi	
20		No. of girders	N_b	4		
21		Girder spacing	S	13.00	ft	
22		Overhang	d_e	2.5	ft	OK
23		# of rails		2		
24		Rail Width		1.5	ft	
25		Area Rebar in Top Sla	A_{st}	3.5	in^2	
26		Area Rebar in Bottom	A_{sb}	4	in^2	
27		Dist from top conc to top rebar		2.5	in	
28		Dist from top conc to bot rebar		7	in	
29		E_s		29000	ksi	
30	Article	Number of Lanes Loaded		2		
31	4.6.2.6.1	Avg Daily Traffic	ADT	6500		
32		Int Diaphragm Spacing		18	ft	
33		Ext Diaphragm Spacing		12	ft	
34		Barrier Weight		482	lbs/ft	
35		**End Input Data**				
36		Lane Load + DL2		1.51	kips/ft	
37		Modular Ratio	n	7.58		
38						
39		Total Length		468.0	ft	
40		Effective Flange Width		115.9	in	
41		**Additional Information**				
42		Diaphragms and Bearings		Channel diaphragms (C15 x		
43				Simple bearings		
44		Shear Studs in row		3		
45		Avg price of Nucor Yamato		$0.46		
46		W36 135 - 256 per pound				

Figure 3.1 Data input in girder selection design software.

The additional information section in the spreadsheet allows the user to select information that could affect cost, such as diaphragm type.

3.4 Girder Sizing

It is important to incorporate each AISC (American Institute of Steel Construction) wide flange beam into the software. This is true because every time the program is run, each cross section is subjected to all the design parameters described in Section 2.

3.5 Global Stiffness Analysis Program

After the bridge data is entered, the maximum and minimum shears and moments need to be determined using the extreme force effects stated in Article 3.6.1.3. An executable file, CSU-CBA.exe, is written using Delphi 7 to create a global stiffness analysis engine, which is linked to the spreadsheet. The global stiffness program was written by Thang Nguyen Dao, a Ph.D. candidate in the Department of Civil Engineering at Colorado State University. This program enables a user to freely create any number of spans and span lengths for the superstructure as displayed in Figure 3.2.

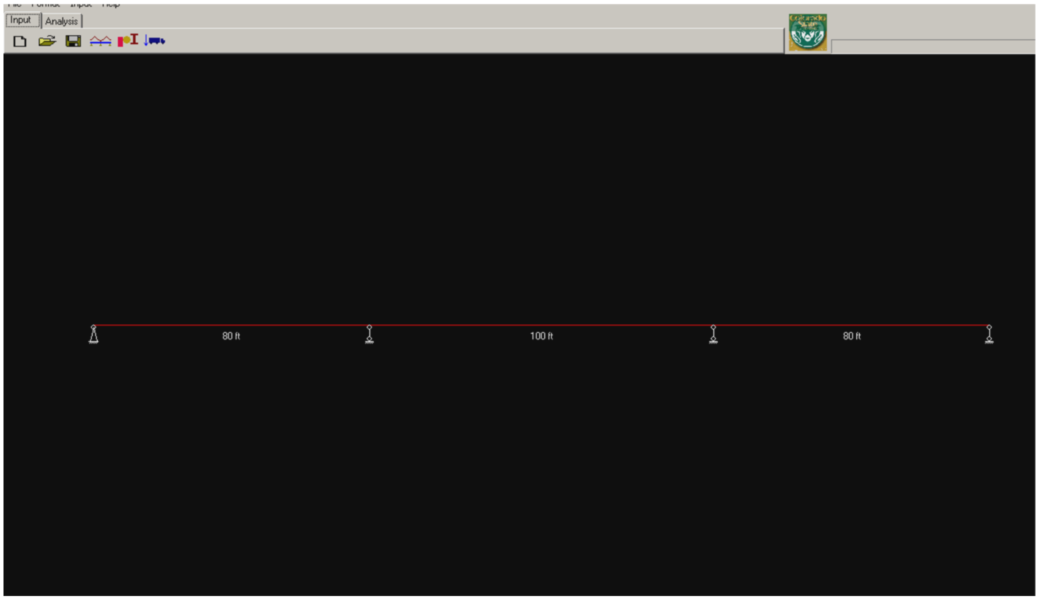


Figure 3.2 Global Stiffness Analysis Program CSU-CBA.

The program is designed to be as user-friendly as possible, while still allowing field professionals to find it useful. Some examples of this are different material choices, a variable distributed load (lane load plus composite dead loads), and point loads that are able to be changed based on HL-93 truck data. This includes input for multiple trucks to be run across with user specified spacing. For example, if the user wanted 50 foot spacing between the rear and front axels of two 28-foot trucks, 78 feet would be entered into the second truck position box.

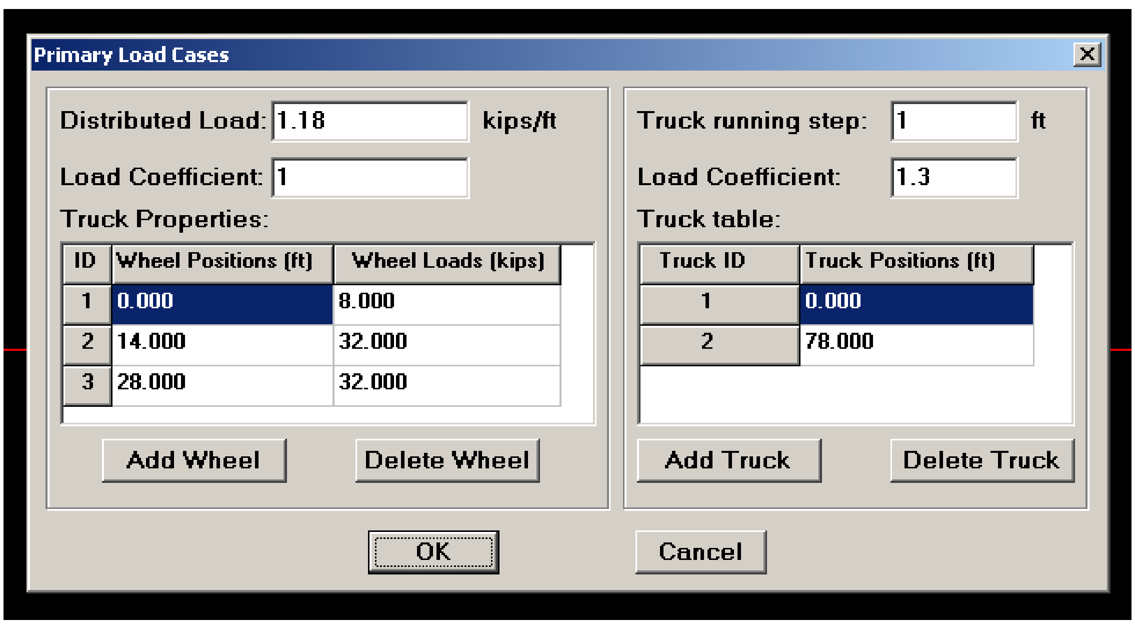


Figure 3.3 Live Loads into Global Stiffness Analysis Program.

Another advantage built into the program is the ability to change from US units to SI units, if desired by the user. The program defaults to US units, but any unit can be changed. For example, moments can be changed from kip-ft. to kip-in. to kN-m. It is important to note that the Excel program will only handle the default units of the global stiffness analysis program. However, the global stiffness routine is a stand-alone program and can be used without the spreadsheet.

Once all data is entered into the program, the user executes the program, and the maximum moments and shears are calculated for the loading conditions provided. Figure 3.4 shows what the moment and shear diagrams look like with simulated composite dead and live loads.

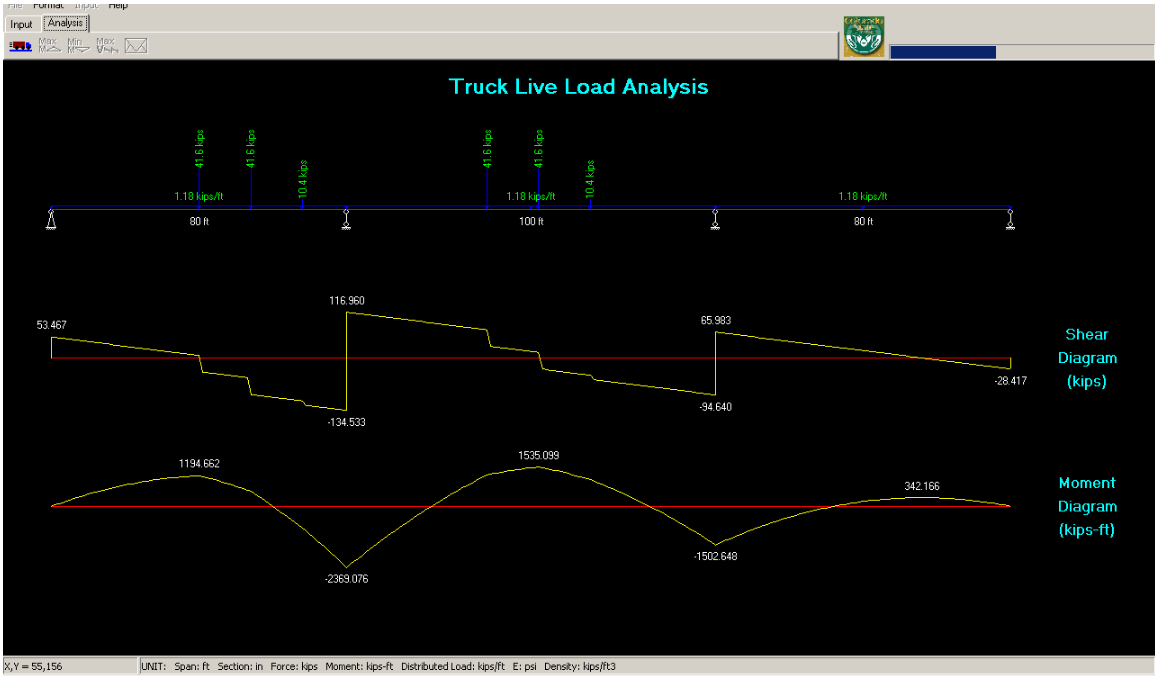
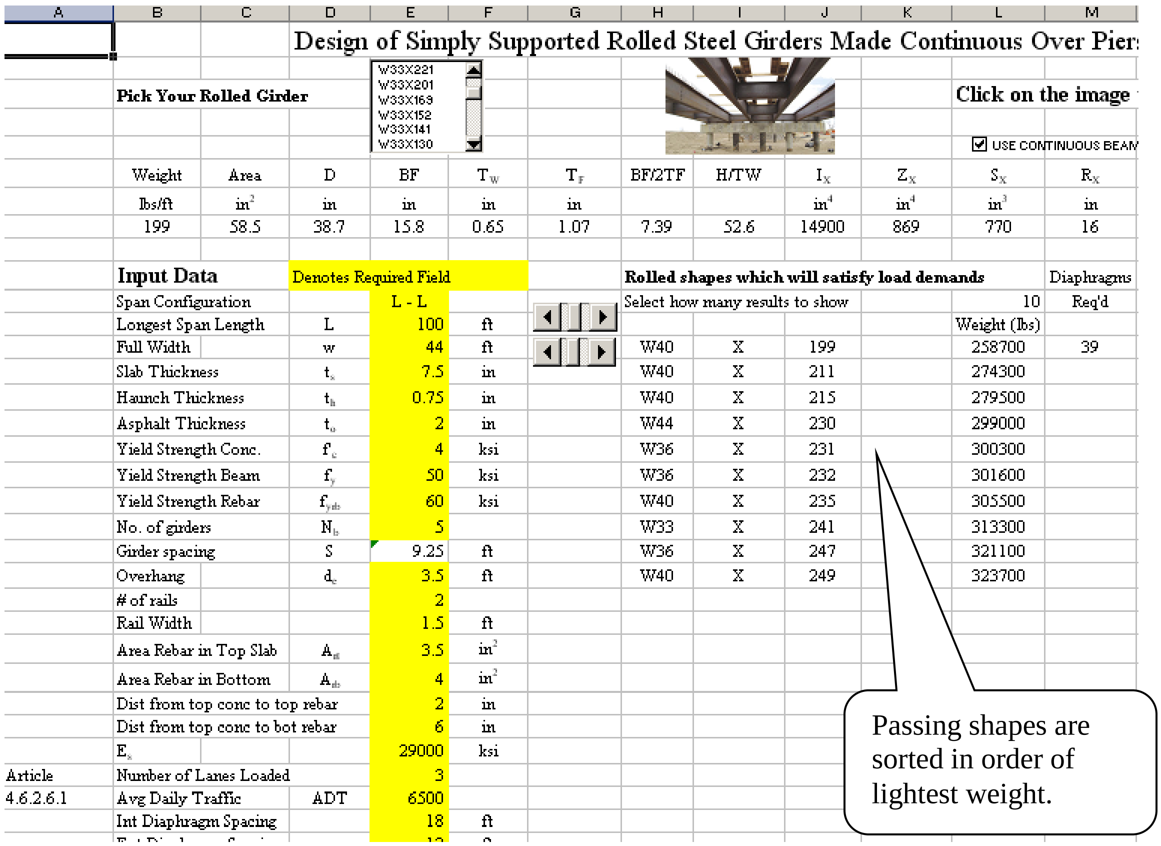


Figure 3.4 Shear and Moment Diagrams with Traffic and Dead Load Two Loads.

After the maximum and minimum moments and shears are determined, the user is able to save the data, and a file called “Results.txt” is automatically updated in the same directory. This text file is later imported into the Excel spreadsheet.

3.6 Excel Macro

This study revealed that the most efficient way to write a program to minimize bridge girder sizes in Excel is to create a macro. The macro is called when the image in the Beam Analysis tab is clicked. Once the macro is executed, it opens the global stiffness analysis program. The user inputs the data into the program and extreme values are found, as described in Section 3.4. After the CSU-CBA.exe file is closed, an import file textbox automatically appears in Excel. The user then selects the “Results.txt” file, from the directory where the CSU-CBA.exe file is located. Once the extreme force results are imported, the macro cycles through each AISC wide flange shape. Each shape is checked using all of the design parameters specified in Section 2. Every time a new shape is run through the macro, values such as nominal resistance moments, moment distribution factors, and neutral axis locations are recalculated. If the shape passes all design checks, it is saved on the spreadsheet. Conversely, if it fails one of the design parameters, it is discarded. Finally, after all shapes are tested, the macro sorts all passing shapes based on the lightest weight, as seen in Figure 3.5.


Design of Simply Supported Rolled Steel Girders Made Continuous Over Piers

Pick Your Rolled Girder: W33X221, W33X201, W33X169, W33X152, W33X141, W33X130

Click on the image

USE CONTINUOUS BEAM

Weight	Area	D	BF	T_W	T_F	BF/2TF	H/TW	I_X	Z_X	S_X	R_X
lbs/ft	in^2	in	in	in	in			in^4	in^4	in^3	in
199	58.5	38.7	15.8	0.65	1.07	7.39	52.6	14900	869	770	16

A	B	D	E	F	H	I	J	L	M
	Input Data	Denotes Required Field			**Rolled shapes which will satisfy load demands**				Diaphragms
	Span Configuration		L - L		Select how many results to show			10	Req'd
	Longest Span Length	L	100	ft				Weight (lbs)	
	Full Width	w	44	ft	W40	X	199	258700	39
	Slab Thickness	t_s	7.5	in	W40	X	211	274300	
	Haunch Thickness	t_h	0.75	in	W40	X	215	279500	
	Asphalt Thickness	t_a	2	in	W44	X	230	299000	
	Yield Strength Conc.	f'_c	4	ksi	W36	X	231	300300	
	Yield Strength Beam	f_y	50	ksi	W36	X	232	301600	
	Yield Strength Rebar	f_{yrb}	60	ksi	W40	X	235	305500	
	No. of girders	N_b	5		W33	X	241	313300	
	Girder spacing	S	9.25	ft	W36	X	247	321100	
	Overhang	d_e	3.5	ft	W40	X	249	323700	
	# of rails		2						
	Rail Width		1.5	ft					
	Area Rebar in Top Slab	A_{st}	3.5	in^2					
	Area Rebar in Bottom	A_{sb}	4	in^2					
	Dist from top conc to top rebar		2	in					
	Dist from top conc to bot rebar		6	in					
	E_s		29000	ksi					
Article	Number of Lanes Loaded		3						
4.6.2.6.1	Avg Daily Traffic	ADT	6500						
	Int Diaphragm Spacing		18	ft					

Figure 3.5 Output of Lightest Girders from Girder Selection Design Software.

3.7 Excel Design Calculations

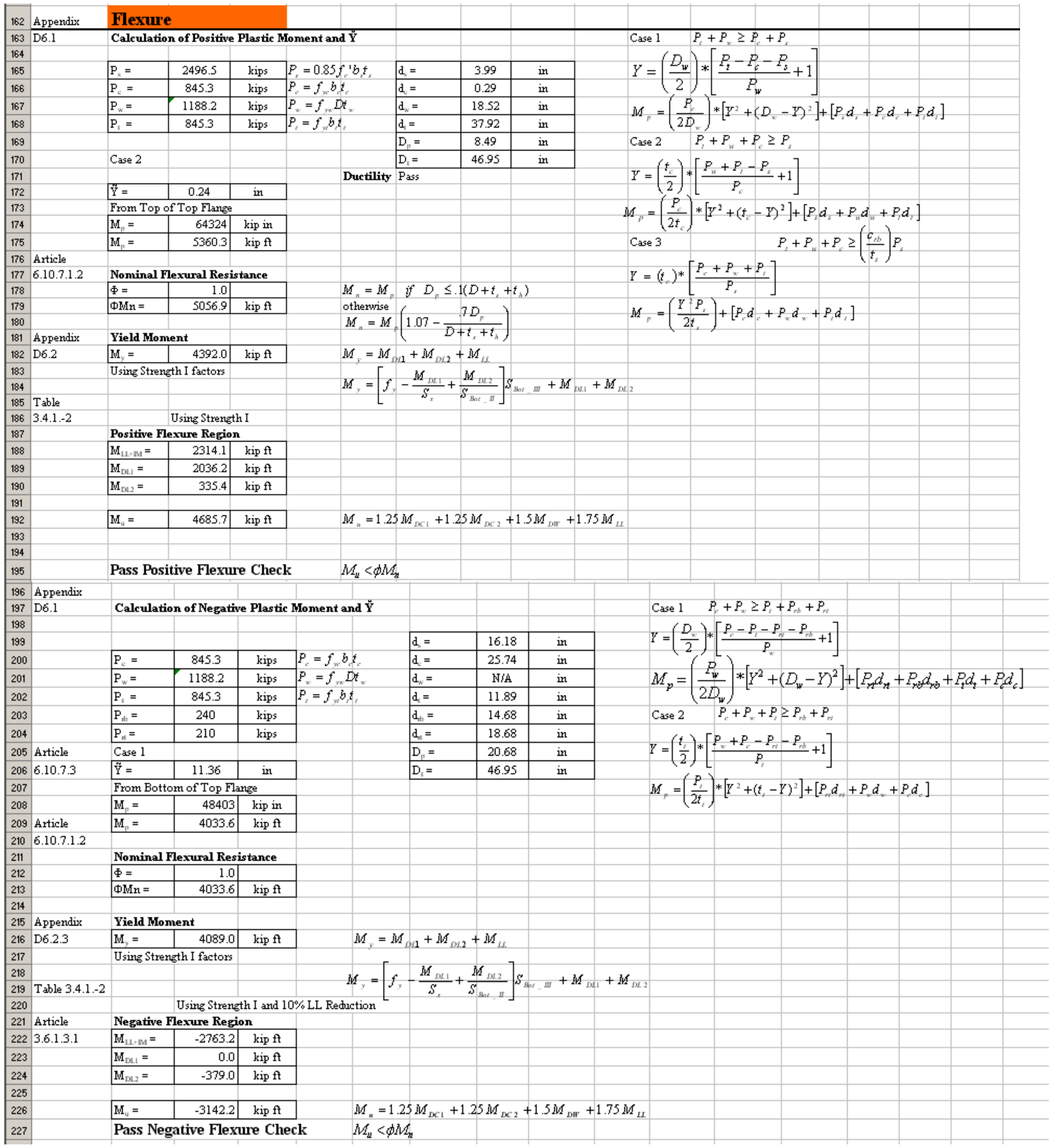
As is mentioned above, for a given bridge design, each AISC wide flange rolled beam section is put through the design parameters described in Section 2. In the Excel spreadsheet, the design is broken down to three basic categories: Flexure, Shear, and Stress. The following figures depict what the design section of the spreadsheet looks like on completion.

The calculations are based on the imported data from the global stiffness analysis program. This data is imported into the 'analysis results' section of the spreadsheet and broken into DL1, DL2, and LL components. Because the global stiffness analysis program takes the distributed load input as one parameter, when the distributed load moments and shears are imported they are broken down by ratios to the total continuity distributed load. In Figure 3.6, the factored moment seen in the right column is not necessarily the moment used in the flexure, shear, or stress calculations. This table is provided for the user to see the unfactored moments and the load factors that can be applied.

Article						
3.6.1.2.2		☑ Use IM Factor	☑ Use Service II Factors		☑ Use Strength I Factors	
	Unfactored Moment	**IM**	**Service II**	**Strength I**	**Moment Distribution Factor**	**Factored Moment**
Positive Moment	kip ft					kip ft
Truck Live Load	1084.87	1.33	1.3	1.75	0.704	2309.4
Live Lane Load	362.88	1	1.3	1.75	0.704	580.8
Dead Load II	89.62	1	1	1.25		112.0
Future Wearing Surface	199.55	1	1	1.5		299.3
Dead Load I	1277.36	1	1	1.25		1596.7
Shear						
Truck Live Load	72.51	1.33	1.3	1.75	0.704	154.4
Live Lane Load	36.00	1	1.3	1.75	0.704	57.6
Dead Load II	9.04	1	1	1.25		11.3
Future Wearing Surface	19.80	1	1	1.5		29.7
Dead Load I	56.77	1	1	1.25		70.96
Negative Moment						
Truck Live Load	-1187.13	1.33	1.3	1.75	0.704	-2527.1
Live Lane Load	-648.00	1	1.3	1.75	0.704	-1037.1
Dead Load II	-160.04	1	1	1.25		-200.0
Future Wearing Surface	-356.34	1	1	1.5		-534.5
Dead Load I	0.00	1	1	1.25		0.0

Figure 3.6 Extreme Results Data.

3.7.1 Flexure



Row	Reference	Item	Value	Unit	Formula	Item	Value	Unit
162	Appendix	**Flexure**						
163	D6.1	**Calculation of Positive Plastic Moment and Ÿ**						
164								
165		P_s =	2496.5	kips	$P_s = 0.85 f'_c b_s t_s$	d_s =	3.99	in
166		P_c =	845.3	kips	$P_c = f_{yc} b_c t_c$	d_c =	0.29	in
167		P_w =	1188.2	kips	$P_w = f_{yw} D t_w$	d_w =	18.52	in
168		P_t =	845.3	kips	$P_t = f_{yt} b_t t_t$	d_t =	37.92	in
169						D_p =	8.49	in
170		Case 2				D_t =	46.95	in
171					**Ductility**	Pass		
172		Ÿ =	0.24	in				
173		From Top of Top Flange						
174		M_p =	64324	kip in				
175		M_p =	5360.3	kip ft				
176	Article							
177	6.10.7.1.2	**Nominal Flexural Resistance**						
178		Φ =	1.0		$M_n = M_p \quad if \quad D_p \le .1(D + t_s + t_h)$			
179		ΦMn =	5056.9	kip ft	otherwise			
180					$M_n = M_p\left(1.07 - \frac{.7 D_p}{D + t_s + t_h}\right)$			
181	Appendix	**Yield Moment**						
182	D6.2	M_y =	4392.0	kip ft	$M_y = M_{DL1} + M_{DL2} + M_{LL}$			
183		Using Strength I factors						
184					$M_y = \left[f_y - \frac{M_{DL1}}{S_x} + \frac{M_{DL2}}{S_{Bot\_II}}\right] S_{Bot\_III} + M_{DL1} + M_{DL2}$			
185	Table							
186	3.4.1.-2	Using Strength I						
187		**Positive Flexure Region**						
188		M_{LL+IM} =	2314.1	kip ft				
189		M_{DL1} =	2036.2	kip ft				
190		M_{DL2} =	335.4	kip ft				
191								
192		M_u =	4685.7	kip ft	$M_u = 1.25 M_{DC1} + 1.25 M_{DC2} + 1.5 M_{DW} + 1.75 M_{LL}$			
193								
194								
195		Pass Positive Flexure Check			$M_u < \phi M_n$			
196	Appendix							
197	D6.1	**Calculation of Negative Plastic Moment and Ÿ**						
198								
199						d_s =	16.18	in
200		P_c =	845.3	kips	$P_c = f_{yc} b_c t_c$	d_c =	25.74	in
201		P_w =	1188.2	kips	$P_w = f_{yw} D t_w$	d_w =	N/A	in
202		P_t =	845.3	kips	$P_t = f_{yt} b_t t_t$	d_t =	11.89	in
203		P_{rb} =	240	kips		d_{rb} =	14.68	in
204		P_{rt} =	210	kips		d_{rt} =	18.68	in
205	Article	Case 1				D_p =	20.68	in
206	6.10.7.3	Ÿ =	11.36	in		D_t =	46.95	in
207		From Bottom of Top Flange						
208		M_p =	48403	kip in				
209	Article	M_p =	4033.6	kip ft				
210	6.10.7.1.2							
211		**Nominal Flexural Resistance**						
212		Φ =	1.0					
213		ΦMn =	4033.6	kip ft				
214								
215	Appendix	**Yield Moment**						
216	D6.2.3	M_y =	4089.0	kip ft	$M_y = M_{DL1} + M_{DL2} + M_{LL}$			
217		Using Strength I factors						
218					$M_y = \left[f_y - \frac{M_{DL1}}{S_x} + \frac{M_{DL2}}{S_{Bot\_II}}\right] S_{Bot\_III} + M_{DL1} + M_{DL2}$			
219	Table 3.4.1.-2							
220		Using Strength I and 10% LL Reduction						
221	Article	**Negative Flexure Region**						
222	3.6.1.3.1	M_{LL+IM} =	-2763.2	kip ft				
223		M_{DL1} =	0.0	kip ft				
224		M_{DL2} =	-379.0	kip ft				
225								
226		M_u =	-3142.2	kip ft	$M_u = 1.25 M_{DC1} + 1.25 M_{DC2} + 1.5 M_{DW} + 1.75 M_{LL}$			
227		Pass Negative Flexure Check			$M_u < \phi M_n$			

Positive plastic moment:

Case 1 $\quad P_t + P_w \ge P_c + P_s$

$$Y = \left(\frac{D_w}{2}\right) * \left[\frac{P_t - P_c - P_s}{P_w} + 1\right]$$

$$M_p = \left(\frac{P_w}{2D_w}\right) * \left[Y^2 + (D_w - Y)^2\right] + \left[P_s d_s + P_c d_c + P_t d_t\right]$$

Case 2 $\quad P_t + P_w + P_c \ge P_s$

$$Y = \left(\frac{t_c}{2}\right) * \left[\frac{P_w + P_t - P_s}{P_c} + 1\right]$$

$$M_p = \left(\frac{P_c}{2t_c}\right) * \left[Y^2 + (t_c - Y)^2\right] + \left[P_s d_s + P_w d_w + P_t d_t\right]$$

Case 3 $\quad P_t + P_w + P_c \ge \left(\frac{c_{rb}}{t_s}\right) P_s$

$$Y = (t_s) * \left[\frac{P_c + P_w + P_t}{P_s}\right]$$

$$M_p = \left(\frac{Y^2 P_s}{2t_s}\right) + \left[P_c d_c + P_w d_w + P_t d_t\right]$$

Negative plastic moment:

Case 1 $\quad P_c + P_w \ge P_t + P_{rb} + P_{rt}$

$$Y = \left(\frac{D_w}{2}\right) * \left[\frac{P_c - P_t - P_{rt} - P_{rb}}{P_w} + 1\right]$$

$$M_p = \left(\frac{P_w}{2D_w}\right) * \left[Y^2 + (D_w - Y)^2\right] + \left[P_{rt} d_{rt} + P_{rb} d_{rb} + P_t d_t + P_c d_c\right]$$

Case 2 $\quad P_c + P_w + P_t \ge P_{rb} + P_{rt}$

$$Y = \left(\frac{t_t}{2}\right) * \left[\frac{P_w + P_c - P_{rt} - P_{rb}}{P_t} + 1\right]$$

$$M_p = \left(\frac{P_t}{2t_t}\right) * \left[Y^2 + (t_t - Y)^2\right] + \left[P_{rt} d_{rt} + P_w d_w + P_c d_c\right]$$

Figure 3.7 Positive and Negative Flexural Check in Spreadsheet.

When looking at both the positive and negative flexure sections in Figure 3-7, notice when the nominal flexural resistance is greater than the maximum factored moment, the spreadsheet reads “Pass Positive Flexure Check” and “Pass Negative Flexural Check.” The column on the left side of the spreadsheet references the appropriate section of the AASHTO LRFD Bridge Design Specifications. Supporting equations are also listed to the right side of each calculation.

3.7.2 Shear

Row										
241		**Shear**								
242		**Nominal Shear Strength of Unstiffened Web**								
243		*C_v will equal 1 for all shapes where k_v = 5				B6.2.1	**Web Properties**			$D_c = \left(\frac{-f_c}{-f_c+f_t}\right)d - t_{fc}$
244	Article				$V_n = 0.6F_yA_wC_v$	Elastic	D_c =	14.02		
245	6.10.9.2	ΦV_n =	689.2	kips		Plastic	D_{cp} =	0.00	NA above Web	$D_{cp} = \frac{D}{2}\left(\frac{F_{yt}A_t - F_{yc}A_c - .85f'_cA_s - F_{yrs}A_{rs}}{A_wf_{yw}}+1\right)$
246		Φ =	1				$\frac{2D_c}{t_w} \le 6.8\sqrt{\frac{E}{f_{yc}}}$	43.12	**OK**	
247								163.77		
248		**Maximum Shear from applied loads**					$\frac{D}{t_w} \le 150$	56.25	**OK**	
249		$V_{LL\text{-}IM}$ =	182.61	kips				150		
250		V_{DL1} =	89.84	kips			$D_{cp} \le .75D$	27.42	**OK**	
251		V_{DL2} =	46.25	kips						
252										
253		V_u =	318.70	kips	$V_u = 1.25V_{DC1} + 1.25V_{DC2} + 1.5V_{DW} + 1.75V_{LL}$					*if $V_u < .75\phi V_n$ stiffeners not required*
254										
255		**Pass Shear Check**			$V_u < \phi V_n$				**Bearing Stiffeners Not Required**	
256										

Figure 3.8 Shear Check in Spreadsheet.

The shear design takes the point of largest shear created by applied loads and compares it to the properties of the unstiffened web. As the macro cycles through each rolled shape, the nominal shear resistance changes. The spreadsheet outputs "Pass Shear Check" until the nominal shear resistance drops below the maximum factored shear. Web properties, such as web slenderness, are confirmed as "ok" according to Appendix B6.2.1. The program also determines if bearing stiffeners are required.

3.7.3 Stress

Row									
246		**Stress**							
247		**Elastic Section Properties**							
248	Article	**Positive Section**							
249	6.10.1.1.1	Long Term Composite Section 3n =		22.7					
250		Component	A (in²)	d (in)	Ad (in³)	Ad² (in⁴	I_o (in⁴)	I (in⁴)	
251		Steel Sect	58.5					14900	
252		Conc. Sect	32.4	23.85	771.8	18407.0	151.7	18558.7	
253			90.9					33458.7	
254							I_{NA} =	26903	in⁴
255		d_{3n} =	8.5	in					
256		d_{Top_II} =	10.9	in			S_{Top_II} =	2478.21	in³
257		d_{Bot_II} =	27.8	in			S_{Bot_II} =	966.198	in³
258									
259									
260		Short Term Composite Section n =		7.6					
261		Component	A (in²)	d (in)	Ad (in³)	Ad² (in⁴	I_o (in⁴)	I (in⁴)	
262		Steel Sect	58.5					14900	
263		Conc. Sect	97.1	23.85	2315.3	55220.9	455.1	55676.0	
264			155.6					70576	
265							I_{NA} =	36118.9	in⁴
266		d_{3n} =	14.9	in					
267		d_{Top_III} =	4.5	in			S_{Top_III} =	8084.03	in³
268		d_{Bot_III} =	34.2	in			S_{Bot_III} =	1055.12	in³
269									

Row									
247	**Elastic Section Properties**								
248	**Negative Section**								
250			A (in²)	d (in)	Ad (in³)	Ad² (in⁴	I_o (in⁴)	I (in⁴)	
251	Steel Section		58.5					14900	
252	Top Reinforcement		3.5	25.6	89.6	2293.8		2293.8	
253	Bottom Reinforcement		4.0	21.6	86.4	1866.2		1866.2	
254			66.0		176.0			19060.0	
255							I_{NA} =	18590.7	in⁴
256		d_{reinf} =	2.7	in					
257		d_{Top} =	16.7	in			S_{Top} =	1114.33	in³
258		d_{Bot} =	22.0	in			S_{Bot} =	844.391	in³

Figure 3.9 Elastic Section Properties for Long/Short Term and Negative Section.

Row						
269						
270	Appendix	**Permanent Deformations**			**Service II Loads**	
271	D6.2	Bottom Flange				
272		**Positive Section**				$f_{DL1} = \frac{M_{DL1}}{S_x}$
273		f_{DL1} =	25.4	ksi		
274		f_{DL2} =	2.26	ksi		$f_{DL2} = \frac{M_{DL2}}{S_{LongTerm}}$
275	Article	f_{LL+IM} =	19.6	ksi		
276	6.10.4.2					$f_{LL} = \frac{M_{LL}}{S_{ShortTerm}}$
277		$f_{bot\ flange}$ =	47.20	ksi	Tension	
278		$0.95F_y$ =	47.50	ksi		
279						$0.95F_y \ge f_{DC1} + f_{DC2} + 1.3f_{LL}$
280			**OK**			
281						
282		Top Flange				
283		f_{DL1} =	25.4	ksi		
284		f_{DL2} =	0.9	ksi		
285		f_{LL+IM} =	3.4	ksi		$f_{DL1} = \frac{M_{DL1}}{S_x}$
286						
287		$f_{top\ flange}$ =	29.7	ksi	Compression	$f_{DL2} = \frac{M_{DL2}}{S_{LongTerm}}$
288		$0.95F_y$ =	47.5	ksi		
289						$f_{LL} = \frac{M_{LL}}{S_{ShortTerm}}$
290			**OK**			
291						
292		**Pass Positive Stress Check**				$0.95F_y \ge f_{DC1} + f_{DC2} + 1.3f_{LL}$
293						
294						

Row					
272	**Negative Section**				$f_{DL1} = \frac{M_{DL1}}{S_x}$
273	f_{DL1} =	0.0	ksi		
274	f_{DL2} =	4.8	ksi		$f_{DL2} = \frac{M_{DL2}}{S_{LongTerm}}$
275	f_{LL+IM} =	32.4	ksi		
276					$f_{LL} = \frac{M_{LL}}{S_{ShortTerm}}$
277	$f_{bot\ flange}$ =	37.26	ksi	Compression	
278	$0.95F_y$ =	47.50	ksi		
279					$0.95F_y \ge f_{DC1} + f_{DC2} + 1.3f_{LL}$
280		**OK**			
282	Top Flange				
283	f_{DL1} =	0.0	ksi		
284	f_{DL2} =	3.7	ksi		
285	f_{LL+IM} =	24.6	ksi		
286					$f_{DL1} = \frac{M_{DL1}}{S_x}$
287	$f_{top\ flange}$ =	28.2	ksi	Tension	
288	$0.95F_y$ =	47.5	ksi		$f_{DL2} = \frac{M_{DL2}}{S_{LongTerm}}$
290		**OK**			$f_{LL} = \frac{M_{LL}}{S_{ShortTerm}}$
292	**Pass Negative Stress Check**				
293					$0.95F_y \ge f_{DC1} + f_{DC2} + 1.3f_{LL}$

Figure 3.10 Flange Stresses in Positive and Negative Sections.

To calculate the generated stresses, it is necessary to first find elastic section properties for the selected beam. A sample calculation for finding elastic section properties can be found in Appendix A, Sample Calculations. As seen in Figure 3.9, the elastic section properties are calculated for the short term composite, long term composite and negative sections. From the elastic section properties, the permanent deformations (flange stresses) are determined (Figure 3.10). The spreadsheet first determines the stress in the top and bottom flanges in both the positive and negative maximum moment sections. Each of these stresses is then compared to 95% of the steel yield stress, 47.5 ksi. If each flange stress is below 95% of the yield stress, a “Pass Positive Stress Check” and “Pass Negative Stress Check” appears on the spreadsheet.

3.8 Summary

During this project, a software package for the design of simple made continuous steel bridges is developed. The program is created in Microsoft Excel and utilizes a macro to output AISC wide flange shapes that satisfies the AASHTO LRFD Bridge Design Specification, based on user-inputted bridge data. For a complete design, the user may also utilize a separate program to check if a selected rolled beam will support a Colorado Permit Vehicle. Appendix F contains a user’s manual for this program.

4. DESIGN CHARTS

4.1 Introduction

This section describes how the design charts and design tables are created and how they are used to rapidly determine the rolled steel section type and erected cost of the bridge in Colorado. The design charts require assumptions that affect the results. It iss also important to find a way to update the steel cost data so the design chart can be updated routinely and not become obsolete.

4.2 Design Charts

Several different design charts are created in this study to outline the structural steel weight compared to number of girders used. The charts are made using a variety of span arrangements. These spans lengths range from 50 to 120 ft. with different ratios. Charts are created for simply supported, two span, and three span bridges. The longest span of 120 ft. is chosen because the simple for dead load, continuous for live load method using rolled sections becomes financially ineffective above this length, in large part because field splicing is required because of shipping limitations. Also, shipping a girder longer than 120 ft. may not be feasible in many parts of Colorado. The CDOT bridge design manual subsection 10.2 states that the maximum preferred length of a steel girder without a field splice is 100 ft., but several steel girders up to 122 ft. have been shipped (CDOT 2002). With this requirement in mind, any span longer than 100 ft. will most likely require a costly field splice. Because this project seeks the design resulting in the least expensive alternative, sections exceeding 100 ft. should be selected on a case-by-case basis because of their potential to be financially viable. Three different out to out widths are used for each of the span arrangements in the design charts. These widths are 39 ft., 44 ft., and 60 ft., based on recommendations from CDOT project study panel members. Each line on the chart depicts how the weight per sq. ft. changes as the number of girders increases. Span lengths can also be compared to determine if and how weight per square foot escalates as the span length is increased. An example of a two span design chart can be seen in Figure 4.1. All other design charts can be seen in Appendix B.

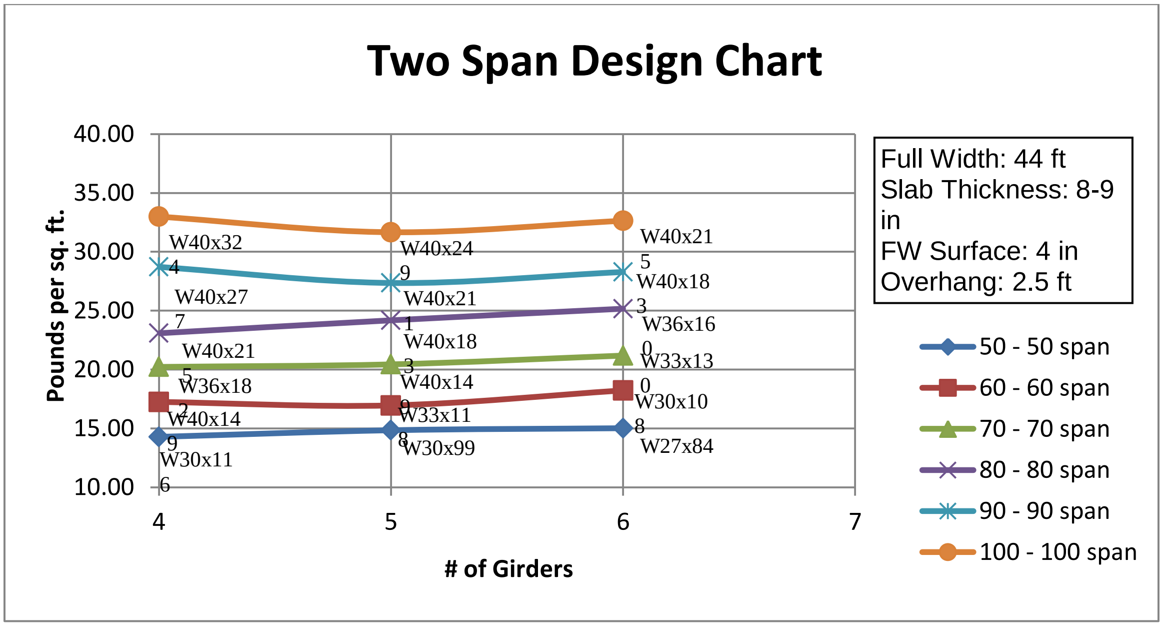


Figure 4.1 Example of a Two Span Design Chart.

The rolled beam sizes under each point represent the lowest size girder that is adequate to support the imposed loads, using the assumptions listed below.

Analysis is also conducted in this study to determine if the results in the design charts can be interpolated in any way. After examination, results are inconclusive. In some cases, weight per square foot can be interpolated between span lengths. In other cases, the minimum girder size between two points is very close to being the same as one of the bounds. Consider the case of a 95 ft. – 95 ft. two span bridge with the same properties as the design chart in Figure 17. Results for the weight per square foot using four and six girders are very close to being linear interpolations between the 90-ft. and 100-ft. two spans. But when using five girders, the minimum girder size is only 2 lbs./ft. less than the 100-ft. span, and therefore the weight per square foot is almost the same. The near intersection between the spans is shown in Figure 4.2.

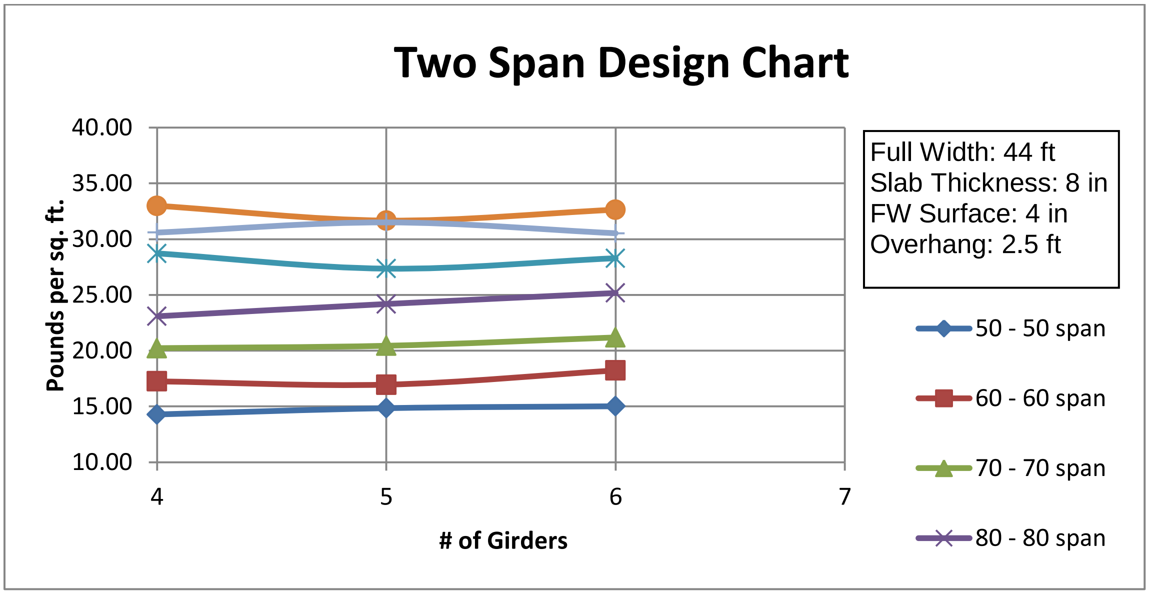


Figure 4.2 Linear Interpolation between a 90-ft. and 100-ft. two span bridge.

The same analsyis is performed to see if interpolation can be done between full widths and the results are similar to what is mentioned above. In some cases, linear interpolation between widths was very close, but in others the minimum girder size is either the same or very close to the same. Because the interpolation does not hold true for all cases, it is recommended that interpolation not be used for design, but could be used to bound a bid, if needed.

4.2.1 Assumptions

- 8 in. – 9 in. slab with 4.5 ksi concrete along with a 4 in. future wearing surface based on CDOT bridge design manual subsection 8.2 [CDOT, 2002]
- Two 2.5 ft. overhang, where possible based on CDOT subsection 8.2 policy of an overhang less than the centerline to centerline girder spacing divided by 3 (S/3)
- Two 486 lbs./ft. barriers with 1.5 ft. width
- C15 x 33.9 diaphragms
- 18-ft. interior and 12-ft. exterior diaphragm spacing
- Five in. x 7/8 in. shear studs with three studs in a row using minimum spacing throughout the length (6*dia. = 5.25 in.). In the field, spacing will vary depending on the shear force range.

- Two design lanes when out to out width is 44 ft. or less, three design lanes for widths greater than 44 ft.
- Exterior girder controls design for future bridge widening if necessary
- Diaphragm and diaphragm erection costs and weights gathered from NSBA (National Steel Bridge Alliance) (Schrage 2007)
- Beam weight greater than 124 lbs./ft. and less than 331 lbs./ft. for cost per square foot estimations
- Girder cost per pound varies by weight (Roscoe Steel and Culvert Quote Billings, MT) Ranum 2007)
- Cost of erection $.065 per pound (Structures Inc. Quote Denver, CO) (Jackson 2008) with $.03 per pound contingency

It was determined during a meeting with members of the CDOT bridge research study panel that an in depth analysis of the shear stud spacing would not be necessary. A shear stud spacing plan would be done in a more detailed design. Because of this, it is conservatively estimated that shear studs will be spaced at the minimum of six times the diameter of the stud. In the analysis of a two 90 ft. span composite I beam steel bridge by HDR Engineering and AISC, (HDR Engr AISC 1997) shear studs are designed with an average spacing of 8.4 in. Using the same dimensions as the example, four girders with a 37 ft. out to out width, it is determined that the structural steel weight is 28.97 lbs./ft.^{2} using a minimum stud spacing of 5.25 in. When this value is compared to that when using an average spacing of 8.4" from the example, 28.73 lbs/ft^2, one can see that using minimum shear stud spacing compared to average spacing is only nominally different.

Two design lanes are specified in the charts because two lanes carry a higher moment distribution factor than three design lanes. This is true because of specifications that the exterior girder controls the design and the special analysis of C.4.6.2.2.2d for each of the cases examined is the controlling moment distribution factor. Using the two lane moment distribution factor allows for a slightly more conservative estimation of the girders required, but in some cases do not make a difference because the moment capacity of the girder is greater than the maximum factored moment created by the loading for both lane sizes. For more information on the special analysis procedure see Section 2.5.1.

For the design charts and tables, a variable slab depth is used depending on the spacing of the girders. According to the CDOT bridge design manual subsection 8.2, the minimum thickness of the deck is 8 inches (CDOT 2002). This is due to thicker slabs showing higher performance and longevity compared to a thinner slab (CDOT 2002). CDOT also requires that the minimum thickness of the slab increases with girder spacing. An 8 in. deck can be used until the girder spacing reaches 9 ft. At this point, deck thickness changes by a ¼ in. until a 9 in. slab thickness is required with girders spacing greater than 11.5 ft. (CDOT 2002).

4.3 Design Tables

The design tables in this study are made using the same span ratios used in the design charts. The tables show the different span lengths, along with bridge width, number of girders, girder spacing, slab depth and overhang length. They then provide the five lightest shapes for the given span arrangement and their size and weight. A cost per square foot and the weight of the structural steel per square foot is also listed in the tables. The tables are organized by span arrangement and each contains four to eight girders similar to the design charts. Figure 4.3 depicts the design tables. All design tables can be seen in Appendix C.

Two Equal Span Design Table – 44 ft width

50 – 50 ft span

				Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	116	$13.30	14.28
Longest Span	L	50	ft	W33	X	118	$13.46	14.46
No. of girders	Nb	4		W30	X	124	$13.96	15.01
Girder spacing	S	13	ft	W27	X	129	$14.38	15.46
Overhang	de	2.5	ft	W33	X	130	$14.46	15.55

				Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	99	$14.27	14.84
Longest Span	L	50	ft	W27	X	102	$14.59	15.18
No. of girders	Nb	5		W24	X	104	$14.80	15.41
Girder spacing	S	9.75	ft	W30	X	108	$15.22	15.87
Overhang	de	2.5	ft	W27	X	114	$15.86	16.55

				Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W27	X	84	$14.80	15.02
Longest Span	L	50	ft	W30	X	90	$15.58	15.83
No. of girders	Nb	6		W27	X	94	$16.09	16.38
Girder spacing	S	7.8	ft	W24	X	94	$16.09	16.38
Overhang	de	2.5	ft	W30	X	99	$16.73	17.06

70 – 70 ft span

				Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W36	X	182	$18.61	20.22
Longest Span	L	70	ft	W40	X	183	$18.69	20.32
No. of girders	Nb	4		W36	X	194	$19.55	21.32
Girder spacing	S	13	ft	W40	X	199	$19.93	21.77
Overhang	de	2.5	ft	W33	X	201	$20.09	21.95

				Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$19.41	20.44
Longest Span	L	70	ft	W36	X	150	$19.51	20.55
No. of girders	Nb	5		W33	X	152	$19.71	20.78
Girder spacing	S	9.75	ft	W36	X	160	$20.52	21.69
Overhang	de	2.5	ft	W40	X	167	$21.22	22.49

				Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W33	X	130	$20.56	21.19
Longest Span	L	70	ft	W36	X	135	$21.18	21.87
No. of girders	Nb	6		W33	X	141	$21.92	22.69
Girder spacing	S	7.8	ft	W30	X	148	$22.77	23.64
Overhang	de	2.5	ft	W40	X	149	$22.90	23.78

Figure 4.3 Example of a Two Span Design Table.

4.4 Updating the Steel Costs

The price of steel fluctuates month to month, so it is important to determine a way to keep the cost per square foot provided in the summary report up to date. During this 2011 research, several steel fabrication companies close to the Colorado area were contacted for associated costs of fabrication and shipping different size girders to a potential project site. After this data was collected, it was evident that Roscoe Steel and Culvert in Billings, Montana, and Big R Manufacturing in Greeley, Colorado, had provided the most competitive quotes. To update the cost of the steel every month, it was discovered that Nucor Yamato posts a raw steel price monthly for several shapes and sizes of rolled beam sections (Nucor-Yamato Steel 2008). To account for this monthly change, a cell is added to the girder selection design spreadsheet (see Section 3) where the Nucor Yamato raw steel price is input. Because Nucor Yamato revises steel cost data for many different sizes and weights, the most accurate steel price for this research is the average cost of a W36 girder with weights per foot between 135 and 256. The fluctuating steel price is coupled with the cost of fabrication gathered from Roscoe Steel and Culvert to generate the cost of a beam per pound. Fabrication costs include Grade 50 weathering steel, bearings, holes, and other general fabrication requirements. Next, erection costs are collected from Structures Inc. of Denver, Colorado. Structures Inc is the contractor that assembled a simple for dead load continuous for live load rolled steel girder bridge near Watkins, Colorado, mentioned in Section 1. They indicated that it would cost about $0.065 per pound of steel to erect the structural steel (Jackson 2008). A three cent per pound contingency is added onto this cost to bring the total erection costs to $0.095/lb. Diaphragm costs for both material and assembly are taken from Calvin Scharge, regional director of the National Steel Bridge Alliance. Costs for several types of diaphragms are determined. Specifically, these are cross frames, either k or x, C15 x 33.9 channel diaphragms, and bent plates. Bent plates are only available in lengths less than 10 ft. (Schrage 2007). In general, channel diaphragms provide the best economy. The erection cost of a channel diaphragm is $60 per channel, while the material costs are dependent on the girder spacing (Schrage 2007). This data is used for the values seen in the design tables. The cost per square foot on the design tables is current as of April 2008 and is based on a Nucor Yamato average base steel price of $0.46. This equates to a fabricated girder price between $0.79-$0.88 for girder sizes between 331 lbs./ft. and 124 lbs./ft., respectively. The total erected cost of the beams, $0.095, is added onto the fabricated beam costs. These prices do not include diaphragm material or erection costs, which will vary between each design table.

4.5 Summary

In this study, several design charts and tables reflect the structural steel weight per square foot of deck for a rolled steel girder bridge designed as simple for dead load continuous for live load. These charts and tables show how the amount of steel required changes as a function of span length. Each chart and table also provides the minimum wide flange shape required to support the deck and traffic loads such that it meets the AASHTO LRFD Bridge Design Specifications. The price of steel fluctuates month to month, so a method was developed to update the steel price from Nucor Yamato steel price charts.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Report Summary

This research focuses on the cost effectiveness of a rolled steel girder bridge system, using an innovative design method. The girders are designed as simply supported for the self-weight and wet concrete. They are then made continuous at the piers using different methods to establish continuity, including a concrete diaphragm or welded connection plate to connect the two separate girders. After the girders are made continuous, they shared the superimposed dead loads (rails, future wearing surface, etc.) and the traffic live loads. Through an extensive literature review, this method has proved to be a cost effective solution for steel bridges because of the elimination of field splices. A software package developed for this study takes user-inputted data such as span lengths, out to out width, number of girders, and overhang along with various other inputs, and it outputs the lightest wide flange shape that will satisfy the loading. The girders are designed using appropriate provisions from the AASHTO LRFD Bridge Design Specifications 4th edition 2007. Bridge loadings use a standard lane load of 640 lbs/ft and HL-93 design truck(s) following AASHTO design provisions. These loads are input into a global stiffness analysis program from Colorado State University called the Continuous Beam Analysis (CSU-CBA). The global stiffness analysis program determines the maximum and minimum bending moments and shears, which are imported into an Excel spreadsheet. The results are factored using AASHTO LRFD Bridge Design Specifications and compared to flexural, stress, and shear resistance values for all AISC wide flange shapes. Shapes that support the applied loads are displayed with the lightest shapes first.

Design charts and design tables are also presented in this study for several one, two, and three span steel bridges. Each span arrangement for the design charts and tables is made using full widths of 39 ft., 44 ft., and 60 ft. Each chart and table depicts how the steel weight per square foot changes as the number of girders is increased, as well as providing the lightest wide flange shape required to support the deck and traffic loads. These charts and tables also illustrate how the required amount of structural steel changes when different spans are used. Finally, steel fabrication and erection cost are presented from regional steel fabricators and bridge contractors. This cost information led to an accurate measurement of the cost per square foot for the structural steel of a bridge to be built in the state of Colorado.

5.2 Conclusions

Many conclusions can be drawn from this report. First and foremost, it can be viewed as successful when results are compared to in-field examples. When bridge data from the Box Elder Creek Bridge (section 1.3.5) is entered into the girder selection design software, a W33 x 152 girder displayed as the third lightest girder that would support the loads. The two lighter shapes have a larger nominal depth and because of flood restrictions in the area the 33 in. section is selected. A comparison can also be made with the two span 97-ft. bridge in Nebraska (section 1.3.1) using four girders, W40 x 249. Using the assumption that it is designed with a 4 in. future wearing surface, the girder selection design software outputs the lightest shape as a W36 x 247, followed by a W40 x 249. Through these trials, it can be concluded that the software gives a very accurate representation of minimum girder sizes.

Because the software has been verified, a bridge designer can use it to get an excellent idea of what minimum rolled steel section should be used for a given bridge, given it is designed as simple made continuous. The designer can either pull up the appropriate design chart and size the girders or quickly run the Excel software for a more complete analysis of a bridge system. In fewer than 10 minutes, an experienced user can input the data for a given bridge and have it output the minimum girder sizes with supporting calculations. Next, it serves as a great tool to compare a rolled steel girder bridge to a precast concrete bridge, especially with the competitive market in Colorado. The design charts will aid the bridge type selection process by giving designers an accurate measurement of minimum steel requirements for numerous one, two, and three span steel bridges. Overall, this research has provided CDOT and others who will use the software or design charts with a tool that will facilitate the construction of innovative steel girder bridges.

5.3 Recommendations for Future Research

There are numerous topics in the simple made continuous design field where research can be expanded. First, the same type of software could be created for a plate girder bridge system. Plate girders allow a designer to optimize a steel section, rather than choosing a standard rolled section size. Plate girders can also utilize much deeper web and flange sizes, therefore allowing for longer spans or fewer girder lines. Other research could focus on a way to make field splices less expensive. If field splicing were economical, longer spans could be called for and designed as continuous throughout, leading to smaller sections. Finally, research could be developed to incorporate skewed pier sections, elevation changes between abutments, and curved sections into the simple made continuous design method. In the future, if these different types of steel girders bridge systems are researched for cost effectiveness, it will make steel girder bridges a very attractive alternative in bridge design.

5.4 Recommendations for Engineers

After using the software and selecting an appropriate girder size, there are several considerations an engineer should account for to provide a complete design. The following is a list of factors that should be considered for design.

- Before the girders are made continuous, the unbraced length should be short enough to satisfy lateral torsional buckling effects. If the limiting unbraced length is exceeded, the beam moment capacity is reduced. A girder erection analysis should be performed for a selected non-composite I-beam with a given lateral-torsional bracing configuration.
- Construction loads should be monitored to not exceed what was designed for a dead load one. This could include crane weight, screed weight and other construction loads. A deck pour analysis shall be performed to check whether or not a selected non-composite I-beam is adequate before concrete cures for unshored construction.
- It is assumed that all logical shapes to be used are compact sections. If the shape is a W40x149, W36x135, or W33x108, the designer should recheck the shear design because these shapes are non-compact.
- A complete slab design should be completed. This includes rebar sizes and placements. Special attention should be paid at the centerline of the pier. Because the top flanges of the two connected girders are not touching, material needs to be provided to handle the tension of the negative moment. This could include a top cover plate between the girders or sufficient reinforcement in the deck.
- The design of the connection at the pier should provide full continuity. The designer should consider the compressive force in the bottom flange and if a concrete diaphragm is to be used, that the concrete is not crushed.
- If holes are to be cut in the web, the shear capacity should be checked with the net area of steel. If holes are to be placed in the flanges, they should be at points with low bending moments.

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APPENDIX A:
SAMPLE CALCULATIONS

Design of a simple for dead load continuous for live load steel girder bridge

Three Spans: 80 ft – 100 ft – 80 ft
Out to Out Width: 44 ft
Number of Girders: 5
Slab Thickness: 8.25 in
Future Wearing Surface Thickness: 4 in
Girder Spacing: 9 ft 6 in
Overhang: 3 ft
Haunch Thickness: 0.75 in
Beam Yield Strength: 50 ksi
Concrete Yield Strength: 4.5 ksi

Selected Girder: W40 x 215

Interior Effective Flange Width

$\frac{L}{4} = \frac{100ft*12\frac{in}{ft}}{4} = 300\ in$

$12t_s + \frac{BF}{2} = 12 * 8.25in + \frac{15.8in}{2} = 106.9\ in$ Controls

$S = 9.5\ ft * 12\frac{in}{ft} = 114\ in$

Exterior Effective Flange Width

$\frac{b_{int}}{2} + \frac{L}{8} = \frac{106.9in}{2} + \frac{100ft*12\frac{in}{ft}}{8} = 203.5\ in$

$\frac{b_{int}}{2} + 6t_s + \frac{BF}{4} = \frac{106.9in}{2} + 6 * 8.25in + \frac{15.8in}{4} = 156.4\ in$

$\frac{b_{int}}{2} + d_e = \frac{106.9in}{2} + 3ft * 12\frac{in}{ft} = 89.5\ in$ Controls

Modular Ratio

$n = \frac{E_s}{E_c} = \frac{290000ksi}{3824ksi} = 7.58$

Unfactored Loads

Dead Load One: Wet Concrete + Beam Weight + Haunch + Shear Studs
Dead Load Two: Barriers + Future Wearing Surface
Live Load: Lane Load (640 lbs/ft) + Design Truck (HL-93)
DL1 = .216 + 1.217 + .005 = 1.437 kips/ft
DL2 = .193 + .456 = .649 kips/ft
LL = .640 kips/ft + Design Truck

Moment and Shear Distribution Factors – Exterior Girder Control
Two Design Lanes

$$e = 0.77 + \frac{d_e}{9.1} = 0.77 + \frac{1.5ft}{9.1} = 0.935$$

$$g_{\text{interior}} = 0.075 + \left(\frac{S}{9.5ft}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12Lt_s^{\ 3}}\right)^{0.1} = .0670$$

$$g = eg_{interior} = .935 * .670 = .626$$

Special Analysis

$R = \frac{N_L}{N_b} + \frac{X_{ext}\sum e}{\sum x^2} = \frac{2}{5} + \frac{19ft*19ft}{2*451.25\ ft^2} = 0.80$ Controls for both moment and shear

Calculated Maximum Moments and Shears using Strength I and Service II Factors

	Unfactored Moment	IM	Service II	Strength I	Moment Distribution Factor
Positive Moment	kip ft				
Truck Live Load	945.07	1.33	1.3	1.75	0.800
Live Lane Load	281.15	1	1.3	1.75	0.800
Dead Load II	85.23	1	1	1.25	
Future Wearing Surface	200.32	1	1	1.5	
Dead Load I	1796.83	1	1	1.25	
Shear					
Truck Live Load	74.01	1.33	1.3	1.75	0.800
Live Lane Load	32.00	1	1.3	1.75	0.800
Dead Load II	9.72	1	1	1.25	
Future Wearing Surface	22.80	1	1	1.5	
Dead Load I	71.87	1	1	1.25	
Negative Moment					
Truck Live Load	-1101.01	1.33	1.3	1.75	0.800
Live Lane Load	-525.91	1	1.3	1.75	0.800
Dead Load II	-159.42	1	1	1.25	
Future Wearing Surface	-374.71	1	1	1.5	
Dead Load I	0.00	1	1	1.25	

Flexure Calculations

Positive Plastic Moment and Neutral Axis

$P_s = .85f'_c b_s t_s = .85 * 4.5ksi * 89.5in * 8.25in = 2822.8\ kips$

$$P_c = P_t = f_y b_c t_c = 50ksi * 15.8in * 1.22in = 963.8\ kips$$

$$P_w = f_y b_w t_w = 50ksi * 36.56in * .65in = 1188.2\ kips$$

Longitudinal Reinforcement in positive flexure was conservatively neglected

Case 2: Neutral Axis in Top Flange

$$P_t + P_w + P_c \geq P_s = 3115.8kips \geq 2822.8kips$$

$\bar{Y} = \left(\frac{t_c}{2}\right)\left[\frac{P_w+P_t-P_s}{P_c} + 1\right] = \left(\frac{1.22in}{2}\right)\left[\frac{1188.2k+963.8k-2822.8k}{963.8k} + 1\right] = 0.19\ in$

Measured From Top of Top Flange

Distances to the plastic neutral axis

d_s = 5.06 in

d_w = 18.70 in

d_c = 0.42 in

d_t = 38.20 in

D_p = 9.19 in

D_t = 48.0 in

$$M_p = \frac{P_c}{2t_c}[\bar{Y}^2 + (t_c - \bar{Y})^2] + [P_s d_s + P_w d_w + P_t d_t]$$

$M_p = \frac{963.8k}{2*1.22in}[0.19in^2 + (1.22in - 0.19in)^2] + [2822.8k * 5.06in + 1188.2k * 18.7in + 963.8k * 38.2in]$

$$M_p = 73767\ kip\ in = 6147.2\ kip\ ft$$

If

$$D_p \leq 0.1D_t = 9.19in \leq 4.8in$$
$$M_n = M_p$$
Otherwise
$$M_n = M_p\left(1.07 - 0.7\frac{D_p}{D_t}\right) = 6147.2k\ ft\left(1.07 - 0.7\frac{9.19in}{48.0in}\right) = 5754.1kip\ ft$$
$\Phi M_n = 5754.1\ kip\ ft$
Yield Moment (See Elastic Properties for S values)
$$M_y = \left[F_y - \frac{M_{DC1}}{S_{NC}} - \frac{M_{DC2}}{S_{LT}}\right]S_{ST} + M_{DC1} + M_{DC2}$$
$$M_y = \left[50ksi - \frac{21562\ k\ in}{859\ in^3} - \frac{3426.6\ k\ in}{1067.9in^3}\right]1169.3in^3 + 21562\ k\ in + 3426.6\ k\ in$$
$M_y = 4195.9\ kip\ ft$
$M_n \geq 1.3M_y = 5454.7\ kip\ ft$

Factored Moments at Strength I from Table 1
$$M_u = 1.25M_{DC1} + 1.25_{DC2} + 1.5M_{DW} + 1.75M_{LL+IM}$$
M_{LL+IM} = 2153.3 kip ft
M_{DC1} = 2246 kip ft
M_{DC2+DW} = 407 kip ft
M_u = 4806.4 kip ft

$$M_u \leq \Phi M_n$$
$4806.4\ kip\ ft\ \leq 5454.7\ kip\ ft \leq 5754.1\ kip\ ft$ OK

Negative Plastic Moment and Neutral Axis
$P_s = .85f'_c b_s t_s = .85 * 4.5ksi * 89.5in * 8.25in = 2822.8\ kips$
$$P_c = P_t = f_y b_c t_c = 50ksi * 15.8in * 1.22in = 963.8\ kips$$
$$P_w = f_y b_w t_w = 50ksi * 36.56in * .65in = 1188.2\ kips$$
$P_{rt} = F_{yrt}A_{rt} = 60ksi * 3.5in^2 = 210\ kips$
$P_{rb} = F_{yrb}A_{rb} = 60ksi * 4.0in^2 = 240\ kips$

Case 1: Neutral Axis in Web
$P_c + P_w \geq P_t + P_{rb} + P_{rt} = 2152kips \geq 1413.8kips$
$\bar{Y} = \left(\frac{D}{2}\right)\left[\frac{P_c - P_t - P_{rt} - P_{rb}}{P_w} + 1\right] = \left(\frac{36.56in}{2}\right)\left[\frac{963.8k - 963.8k - 210k - 240k}{1188.2k} + 1\right] = 11.36\ in$
Measured From Bottom of Top Flange
Distances to the plastic neutral axis
d_s = 17.45 in
d_c = 25.81 in
d_w = 6.92 in
d_t = 11.97 in
d_{rt} = 14.58 in
d_{rb} = 19.08 in
D_p = 21.58 in
D_t = 48.0 in

$M_p = \frac{P_w}{2D}[\bar{Y}^2 + (D - \bar{Y})^2] + [d_{rt}P_{rt} + d_{rb}P_{rb} + d_t P_t + d_c P_c]$
$M_p = \frac{1188.2k}{2*36.56in}[11.36^2 in^2 + (36.56in - 11.36in)^2] + [210k * 14.58in + 240k * 19.08in + 963.8k * 11.97in + 963.8k * 25.8in]$

$M_p = \phi M_n = 56334.8 kip\ in = 4694.6\ kip\ ft$

Factored Moments at Strength I from Table 1
Live Load Reduced 10% due to Article 3.6.1.3

$$M_u = 1.25 M_{DC1} + 1.25_{DC2} + 1.5 M_{DW} + 1.75 M_{LL+IM}$$

M_{LL+IM} = -2584.4 kip ft
M_{DC1} = 0 kip ft
M_{DC2+DW} = -761.3 kip ft
M_u = 3342.7 kip ft

$$M_u \leq \Phi M_n$$

$3342.7\ kip\ ft\ \leq 4694.6\ kip\ ft$ OK

Shear Calculations

Factored Moments at Strength I from Table 1
V_{LL+IM} = 182.6 kips
V_{DC1} = 89.8 kips
V_{DC2+DW} = 46.3 kips
V_u = 318.7 kips

Nominal Shear Strength of An Unstiffened Web
$V_n = .58 F_{yw} D t_w C_v = .58 * 50 ksi * 36.56 in * 0.65 in * 1.0 = 689.2 kips$

$$V_u \leq \Phi V_n$$

$318.7\ kips \leq 689.2\ kips$ OK

If $V_u \leq .75 \Phi V_n$ Bearing Stiffeners Not Required

$318.7\ kips \leq 516.9\ kips$
Bearing Stiffeners Not Required

Web Properties
$\frac{D}{t_w} \leq 150 = \frac{36.56 in}{0.65\ in} = 56.25 \leq 150$ OK
$\frac{2D_c}{t_w} \leq 6.8 \sqrt{\frac{E}{F_y}} = \frac{2*14.0 in}{0.65 in} \leq 6.8 \sqrt{\frac{29000 ksi}{50 ksi}}$
$43.1 \leq 163.8$ OK
$D_{cp} \leq .75 D$
N.A in Flange OK
Compression Flange Properties
$\frac{b_{fc}}{2 t_{fc}} \leq .38 \frac{E}{F_y} = \frac{15.8\text{in}}{2*1.22\text{in}} \leq .38 \sqrt{\frac{29000\text{ksi}}{50\text{ksi}}}$
$6.48 \leq 9.15$ OK

Permanent Deformations

Elastic Section Properties

Positive Section
Long Term Composite 3n = 22.8

Component	$A(in^2)$	d(in)	$Ad(in^3)$	$Ad^2(in^4)$	$I_o(in^4)$	$I(in^4)$
Steel Sect	63.4					16700
Conc. Sect	32.4	24.375	790.6	19270.2	184.0	19454.1
	95.8					36154.1
					I_{NA}=	29632.38 in^4
d_{3n}=	8.2 in					
d_{Top_II} =	11.3 in				S_{Top_II} =	2633.85 in^3
d_{Bot_II} =	27.7 in				S_{Bot_II} =	1067.857 in^3

$$A_c = \frac{b_{eff} t_s}{3n} = \frac{89.5in*8.25in}{22.8} = 32.4\ in^2$$

$$S_{Top\_II} = S_{LT} = \frac{I_{NA}}{d_{LT}} = \frac{29632.4\ in^4}{11.2\ in} = 2633.85\ in^3$$

Short Term Composite n = 7.6

Component	$A(in^2)$	d(in)	$Ad(in^3)$	$Ad^2(in^4)$	$I_o(in^4)$	$I(in^4)$
Steel Sect	63.4					16700
Conc. Sect	97.30	24.375	2371.7	57810.5	551.9	58362.4
	160.7					75062
					I_{NA}=	40059.36 in^4
d_{3n}=	14.8 in		2371.7124			
d_{Top_II} =	4.7 in				S_{Top_II} =	8448.739 in^3
d_{Bot_II} =	34.3 in				S_{Bot_II} =	1169.325 in^3

Negative Section

	$A(in^2)$	d(in)	$Ad(in^3)$	$Ad^2(in^4)$	$I_o(in^4)$	$I(in^4)$
Steel Section	63.4					16700
Top Reinforcement	3.5	2.6	91.0	2366.0		2366.0
Bottom Reinforcement	4.0	21.5	86	1849.0		1849.0
	70.9		177.0			20915.0
				I_{NA}=		20473.12 in^4
d_{3n}= 2.5 in						
d_{Top_II} = 17.0 in				S_{Top_II} =		1204.052 in^3
d_{Bot_II} = 22.0 in				S_{Bot_II} =		930.7457 in^3

Flange Stresses from Service II Loads

Positive Section
Bottom Flange

$$f_{DC1} = \frac{M_{DC1}}{S_x} = \frac{21562\ kip\ in}{859in^3} = 25.1ksi$$

$f_{DC2+DW} = \frac{M_{DC2+DW}}{S_{Bot\_II}} = \frac{3426.6\ kip\ in}{1067.8in^3} = 3.2ksi$
$f_{LL+IM} = \frac{M_{LL+IM}}{S_{Bot\_II}} = \frac{19195.5\ kip\ in}{1169.3in^3} = 16.4ksi$
$f_{bot\_flange} = 25.1ksi + 3.2ksi + 16.4ksi = 44.73ksi$
$.95f_y > f_{DC1} + f_{DC2+DW} + 1.3f_{LL+IM}$

$47.5ksi > 44.73ksi$ OK

Top Flange
$f_{DC1} = 25.1ksi$
$f_{DC2+DW} = 1.3ksi$
$f_{LL+IM} = 2.3ksi$
$f_{top\_flange} = 28.7ksi$
$47.5ksi > 28.7ksi$ OK

Negative Section
Bottom Flange
$f_{DC1} = 0\ ksi$
$f_{DC2+DW} = 6.9ksi$
$f_{LL+IM} = 26.7ksi$
$f_{bot\_flange} = 33.6\ ksi$
$47.5ksi > 33.6\ ksi$ OK

Top Flange
$f_{DC1} = 0\ ksi$
$f_{DC2+DW} = 5.3ksi$
$f_{LL+IM} = 20.6\ ksi$
$f_{top\_flange} = 26.0\ ksi$
$47.5ksi > 26.0ksi$ OK

Dead Load One Deflection

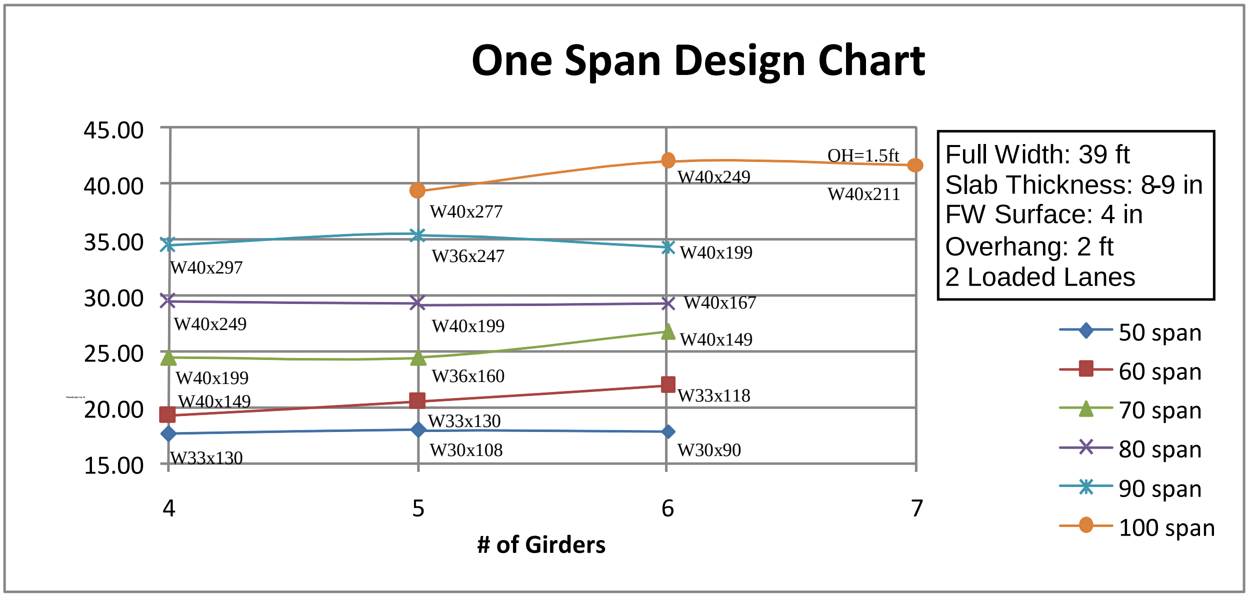
For simply supported beam after concrete has been poured

$$\Delta_{\max} = \frac{5\omega L^4}{384EI} = \frac{5*1.44\frac{k}{ft}*\frac{1ft}{12in}*\left(100ft*12\frac{in}{ft}\right)^4}{384*29000ksi*16700in^4} = 6.68\ in$$

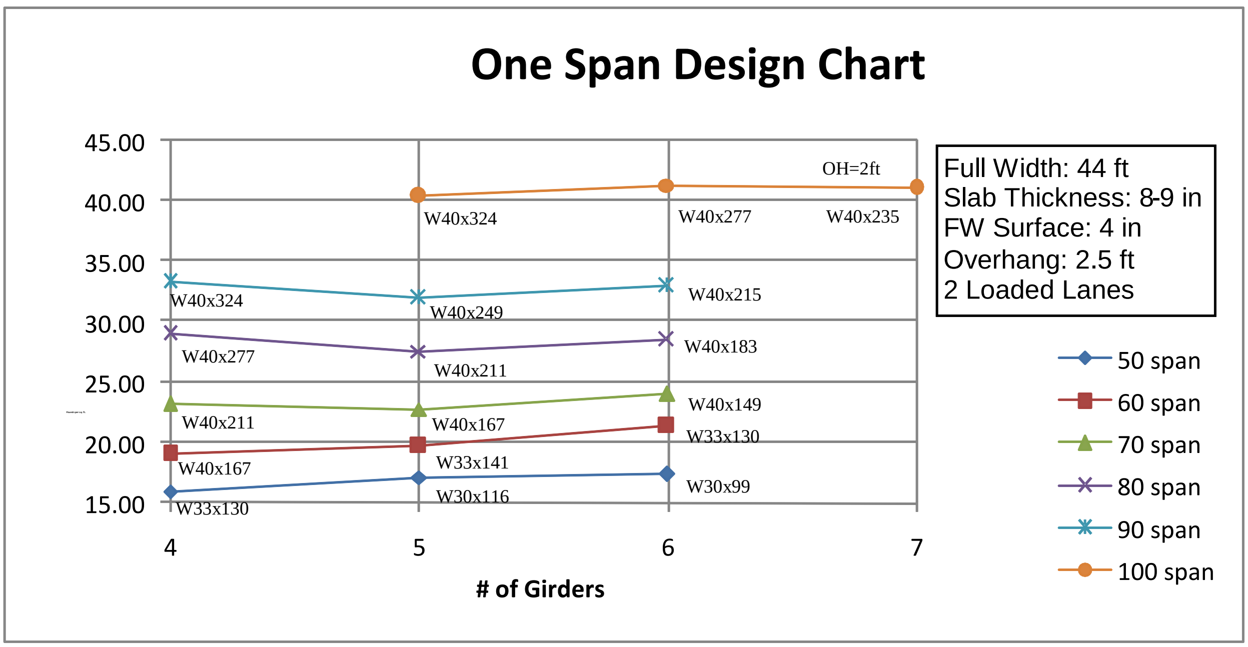
APPENDIX B:
DESIGN CHARTS

Design Chart Assumptions

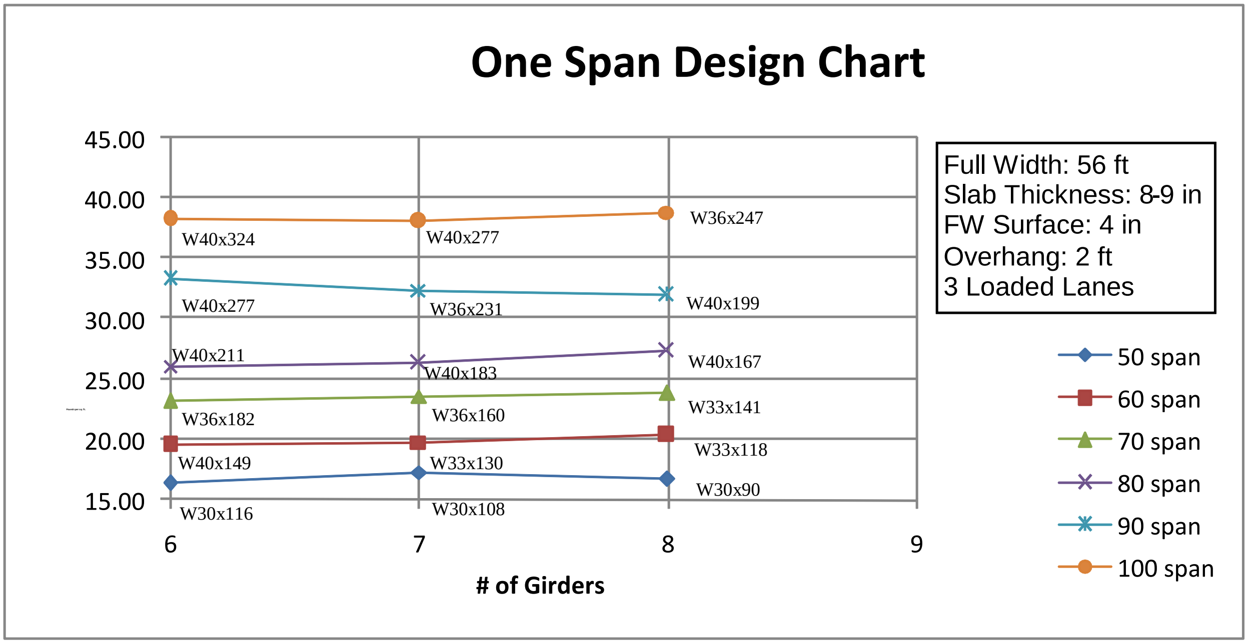
- 8 – 9 in. slab depending on girder spacing 4.5 ksi concrete w/ 4 in. future wearing surface
- Two 2.5 ft. overhang
- C15 x 33.9 diaphragms
- 18 ft. interior and 12 ft. exterior diaphragm spacing
- Three rows of 5 in. x 7/8 in. shear studs spaced at 5.25 in. ir 6*dia throughout length for conservative estimate
- Two 486 lbs./ft. barriers with 1.5 ft. width
- Two design lanes when out to out width was 44 ft. or less, three design lanes for widths greater than 44 ft.
- Weight estimate per square foot includes lightest wide flange beam weight, shear studs, and diaphragm weight
- All design charts are designed using a HL-93 Design Truck

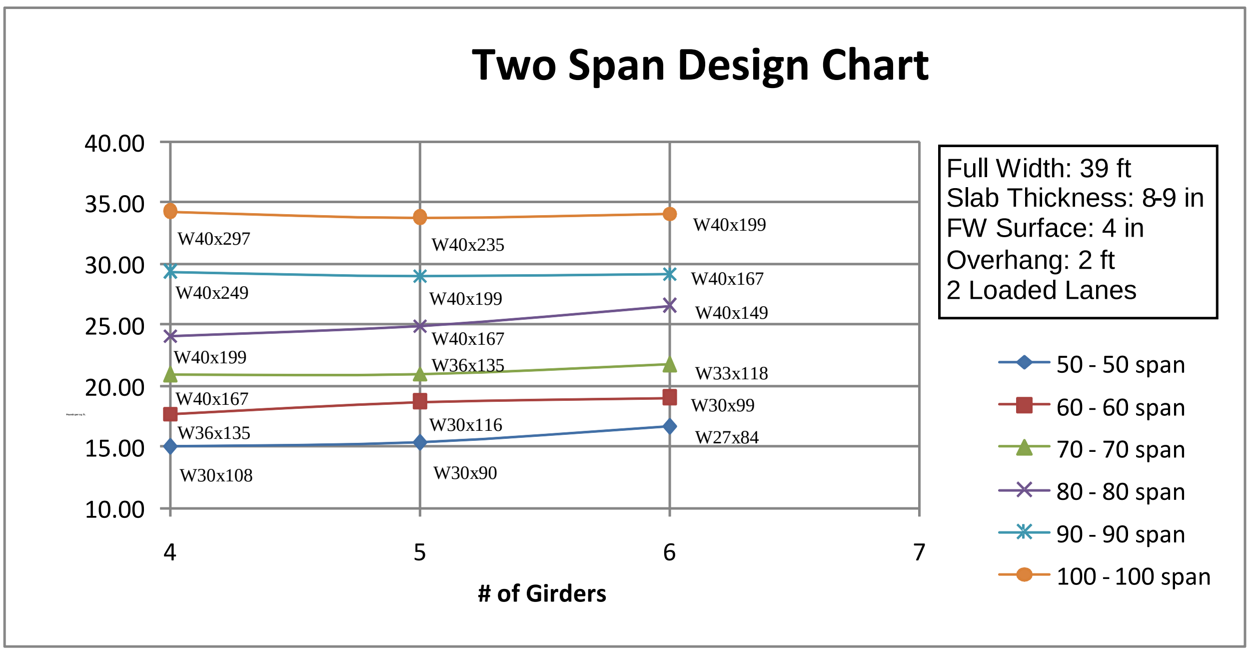


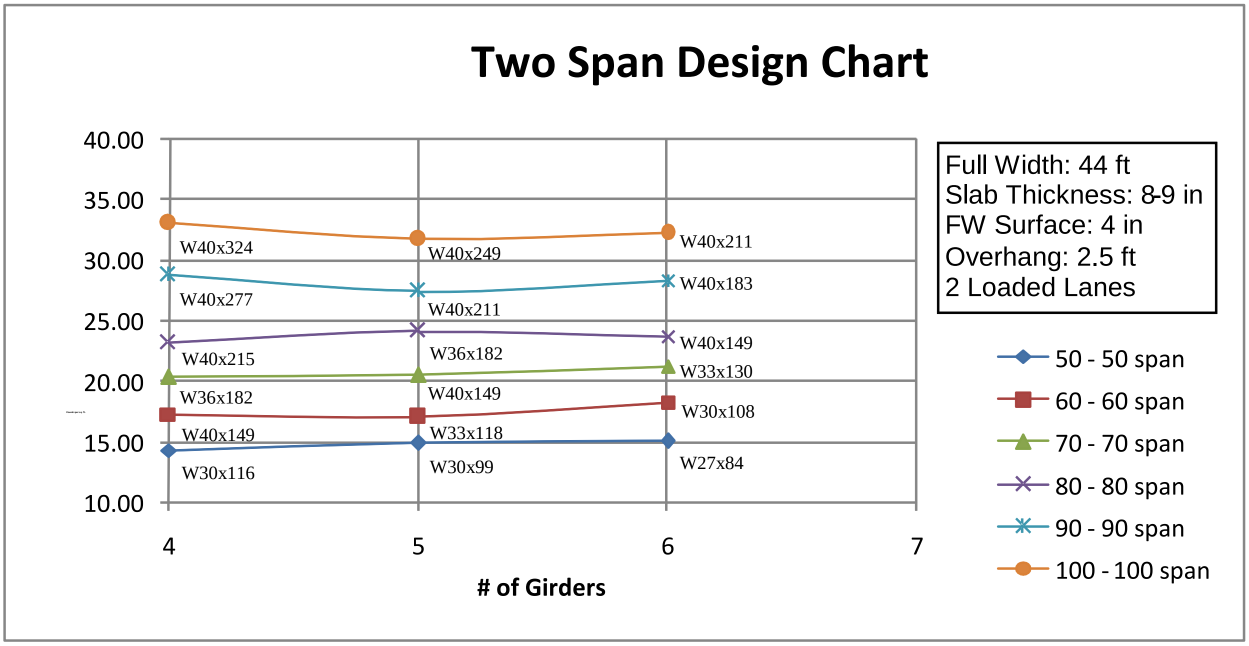
One Span Design Chart
45.00
40.00
35.00
30.00
25.00
20.00
15.00
4
5
6
7
# of Girders
OH=1.5ft
W40x249
W40x211
W40x277
W40x297
W36x247
W40x199
W40x249
W40x199
W40x167
W40x149
W40x199
W36x160
W40x149
W33x118
W33x130
W30x108
W30x90
W33x130
Full Width: 39 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2 ft
2 Loaded Lanes
50 span
60 span
70 span
80 span
90 span
100 span



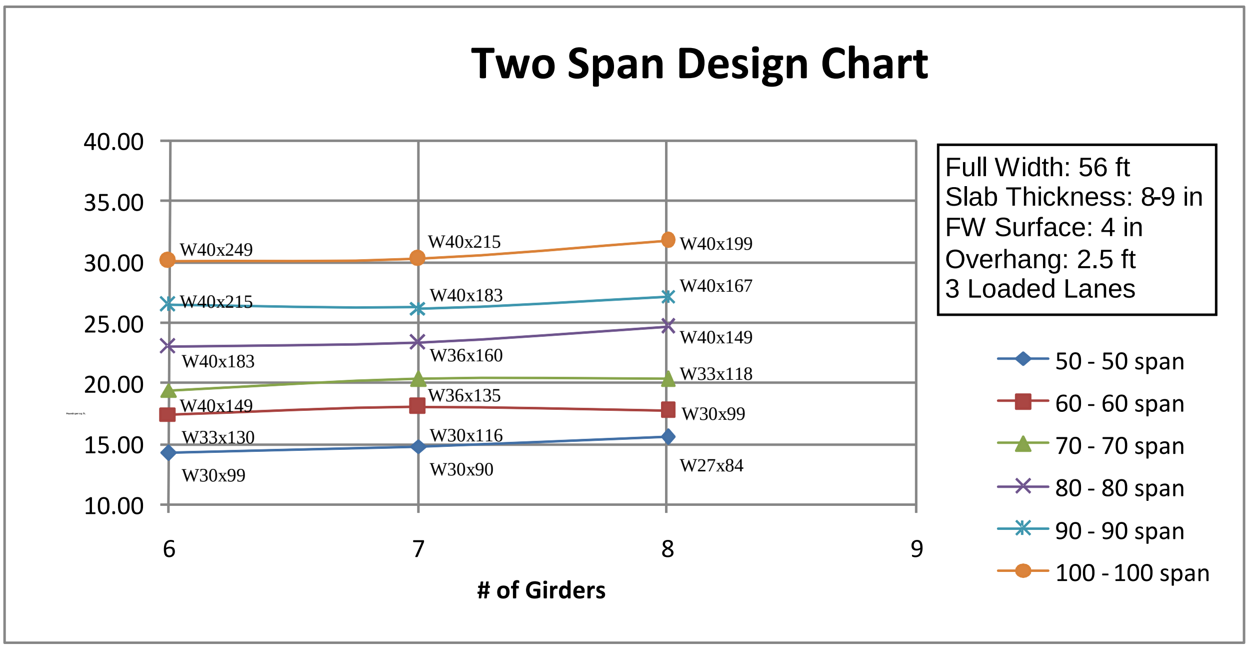
One Span Design Chart
45.00
40.00
35.00
30.00
25.00
20.00
15.00
4
5
6
7
# of Girders
OH=2ft
W40x324
W40x277
W40x235
W40x324
W40x249
W40x215
W40x277
W40x211
W40x183
W40x149
W40x211
W40x167
W33x130
W40x167
W33x141
W30x116
W30x99
W33x130
Full Width: 44 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2.5 ft
2 Loaded Lanes
50 span
60 span
70 span
80 span
90 span
100 span


One Span Design Chart
Full Width: 56 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2 ft
3 Loaded Lanes
45.00
40.00
35.00
30.00
25.00
20.00
15.00
6
7
8
9
# of Girders
W40x324
W40x277
W36x247
W40x277
W36x231
W40x199
W40x211
W40x183
W40x167
W36x182
W36x160
W33x141
W40x149
W33x130
W33x118
W30x116
W30x108
W30x90
50 span
60 span
70 span
80 span
90 span
100 span

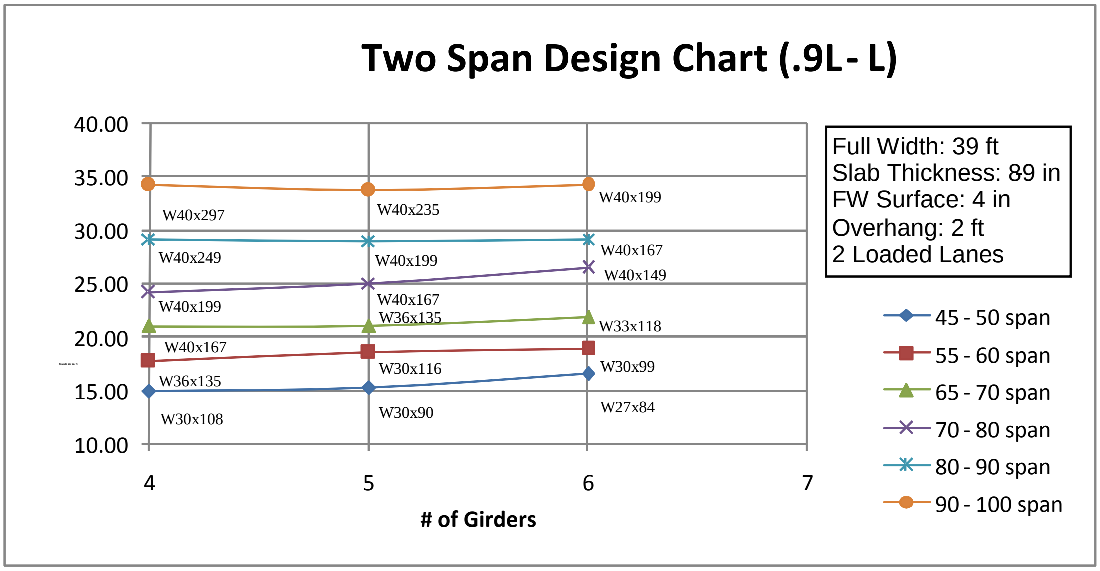

Two Span Design Chart
Full Width: 39 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2 ft
2 Loaded Lanes
40.00
35.00
30.00
25.00
20.00
15.00
10.00
4
5
6
7
# of Girders
W40x297
W40x235
W40x199
W40x249
W40x199
W40x167
W40x149
W40x199
W40x167
W36x135
W33x118
W40x167
W30x99
W36x135
W30x116
W27x84
W30x108
W30x90
50 - 50 span
60 - 60 span
70 - 70 span
80 - 80 span
90 - 90 span
100 - 100 span

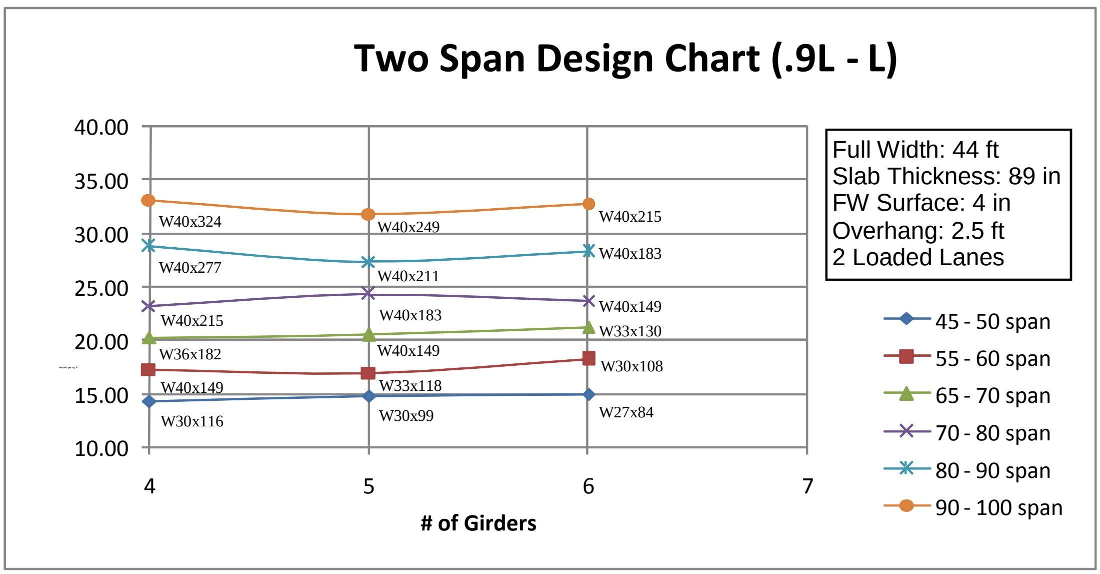


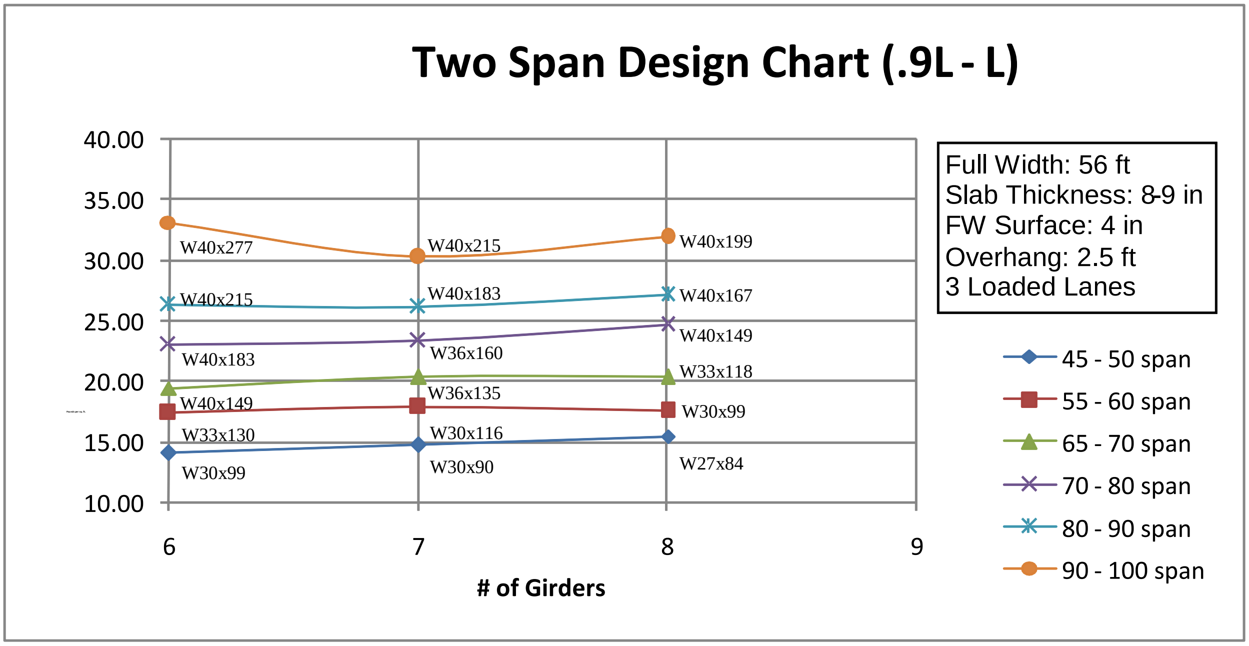
Two Span Design Chart
40.00
35.00
30.00
25.00
20.00
15.00
10.00
4
5
6
7
# of Girders
W40x324
W40x249
W40x211
W40x277
W40x211
W40x183
W40x215
W36x182
W40x149
W36x182
W40x149
W33x130
W40x149
W33x118
W30x108
W30x116
W30x99
W27x84
Full Width: 44 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2.5 ft
2 Loaded Lanes
50 - 50 span
60 - 60 span
70 - 70 span
80 - 80 span
90 - 90 span
100 - 100 span

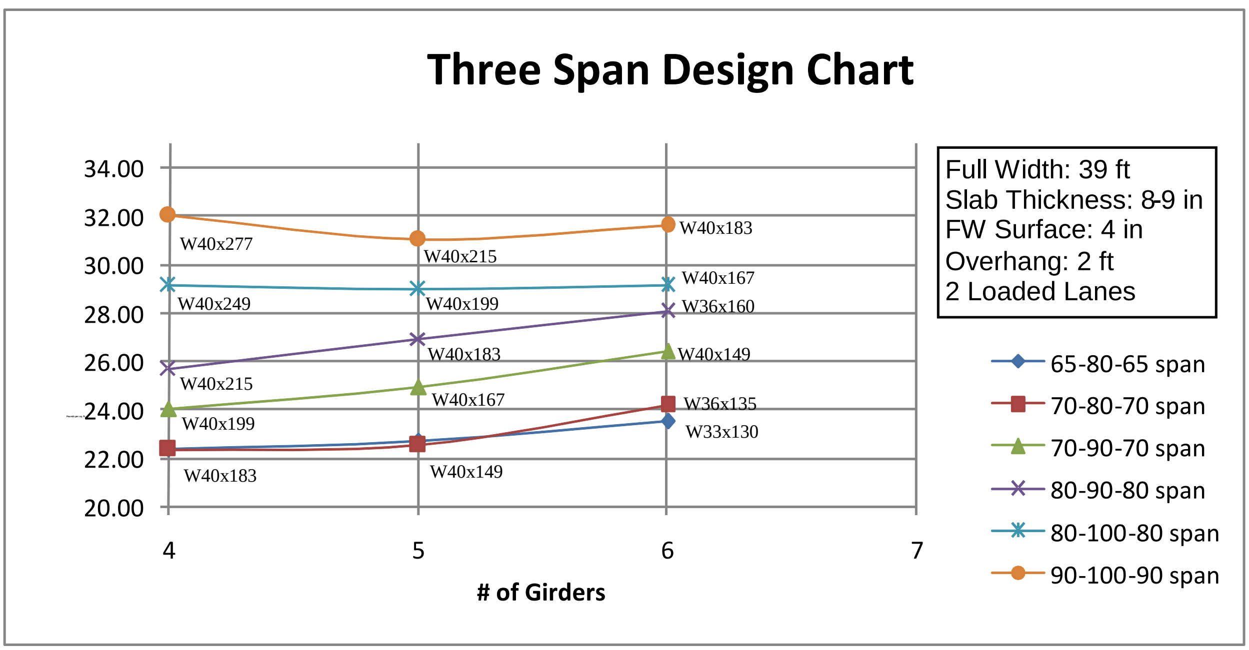


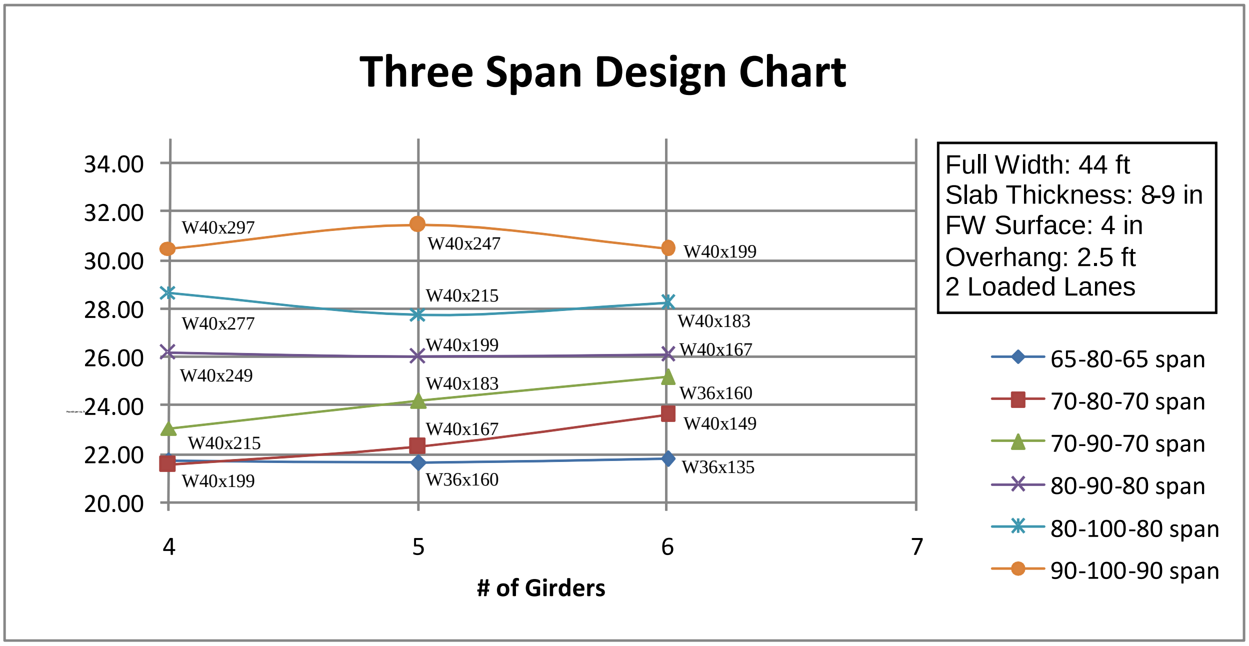
Two Span Design Chart
40.00
35.00
30.00
25.00
20.00
15.00
10.00
6
7
8
9
# of Girders
W40x249
W40x215
W40x199
W40x215
W40x183
W40x167
W40x183
W36x160
W40x149
W40x149
W36x135
W33x118
W33x130
W30x116
W30x99
W30x99
W30x90
W27x84
Full Width: 56 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2.5 ft
3 Loaded Lanes
50 - 50 span
60 - 60 span
70 - 70 span
80 - 80 span
90 - 90 span
100 - 100 span

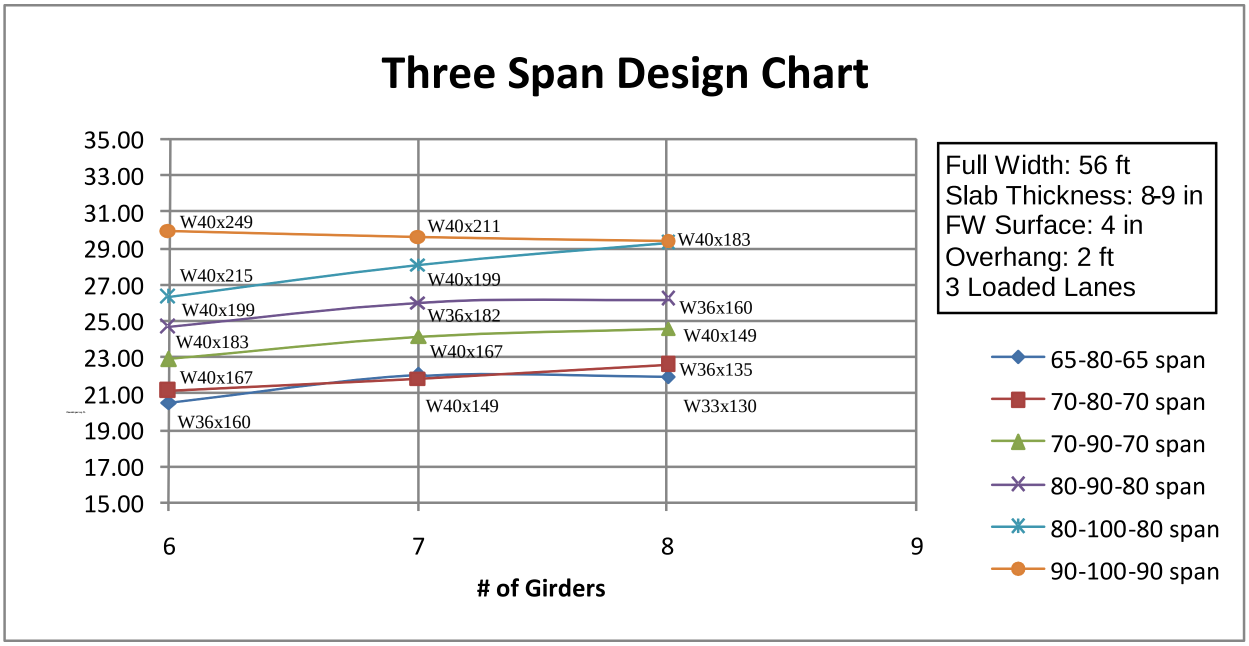

Two Span Design Chart (.9L - L)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
4
5
6
7
# of Girders
W40x297
W40x235
W40x199
W40x249
W40x199
W40x167
W40x149
W40x199
W40x167
W36x135
W33x118
W40x167
W30x116
W30x99
W36x135
W30x108
W30x90
W27x84
Full Width: 39 ft
Slab Thickness: 89 in
FW Surface: 4 in
Overhang: 2 ft
2 Loaded Lanes
45 - 50 span
55 - 60 span
65 - 70 span
70 - 80 span
80 - 90 span
90 - 100 span

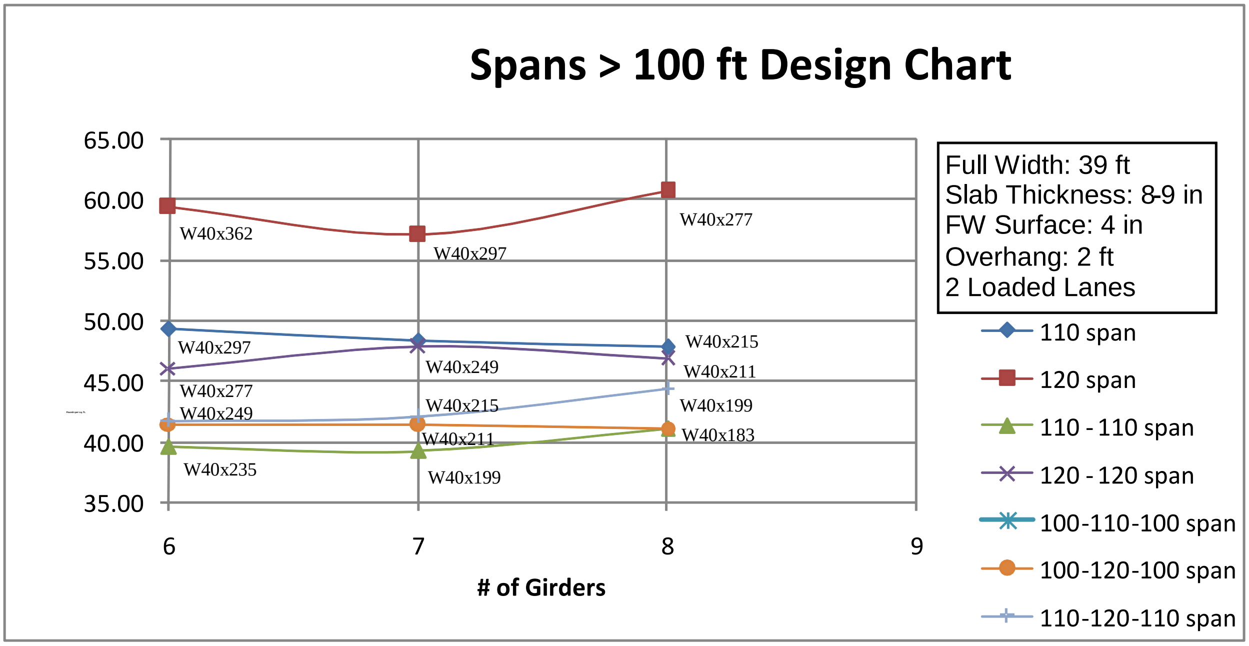

Two Span Design Chart (.9L - L)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
4
5
6
7
# of Girders
W40x324
W40x249
W40x215
W40x277
W40x211
W40x183
W40x215
W40x183
W40x149
W33x130
W36x182
W40x149
W30x108
W40x149
W33x118
W30x116
W30x99
W27x84
Full Width: 44 ft
Slab Thickness: 89 in
FW Surface: 4 in
Overhang: 2.5 ft
2 Loaded Lanes
45 - 50 span
55 - 60 span
65 - 70 span
70 - 80 span
80 - 90 span
90 - 100 span


Two Span Design Chart (.9L - L)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
6
7
8
9
# of Girders
W40x277
W40x215
W40x199
W40x215
W40x183
W40x167
W40x183
W36x160
W40x149
W40x149
W36x135
W33x118
W33x130
W30x116
W30x99
W30x99
W30x90
W27x84
Full Width: 56 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2.5 ft
3 Loaded Lanes
45 - 50 span
55 - 60 span
65 - 70 span
70 - 80 span
80 - 90 span
90 - 100 span

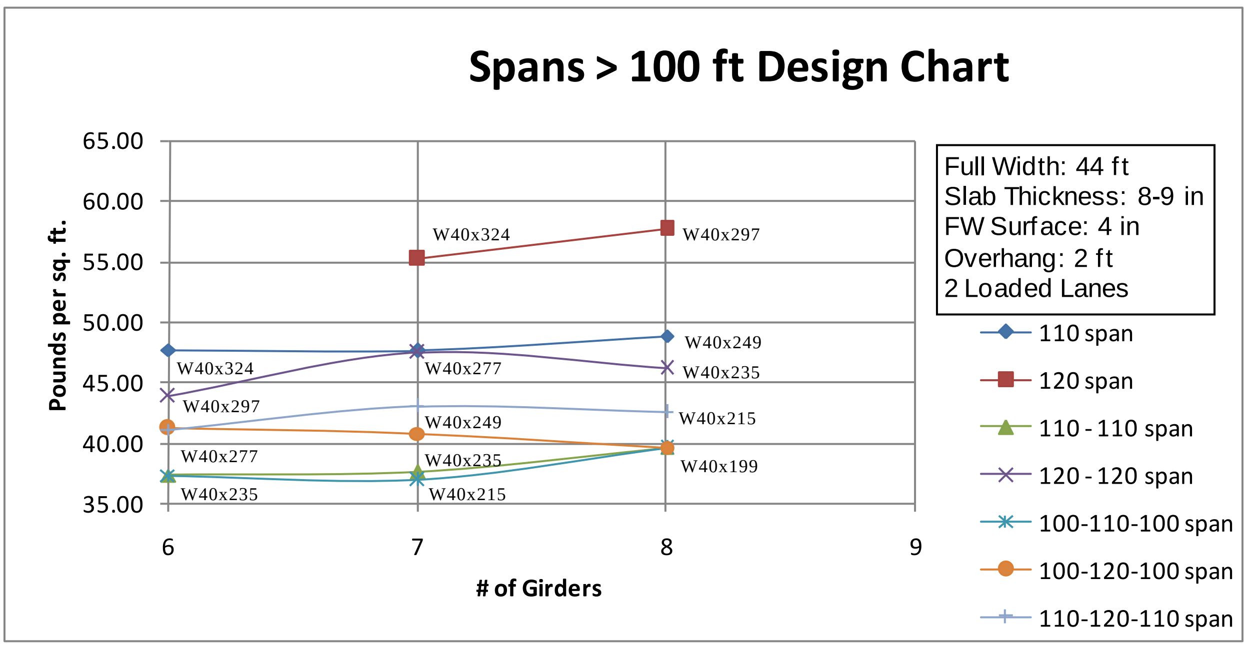

Three Span Design Chart
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
4
5
6
7
# of Girders
W40x277
W40x215
W40x183
W40x249
W40x199
W40x167
W36x160
W40x183
W40x149
W40x215
W40x167
W36x135
W40x199
W33x130
W40x183
W40x149
Full Width: 39 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2 ft
2 Loaded Lanes
65-80-65 span
70-80-70 span
70-90-70 span
80-90-80 span
80-100-80 span
90-100-90 span


Three Span Design Chart
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
4
5
6
7
# of Girders
W40x297
W40x247
W40x199
W40x215
W40x277
W40x183
W40x199
W40x167
W40x249
W40x183
W36x160
W40x167
W40x149
W40x215
W36x135
W40x199
W36x160
Full Width: 44 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2.5 ft
2 Loaded Lanes
65-80-65 span
70-80-70 span
70-90-70 span
80-90-80 span
80-100-80 span
90-100-90 span

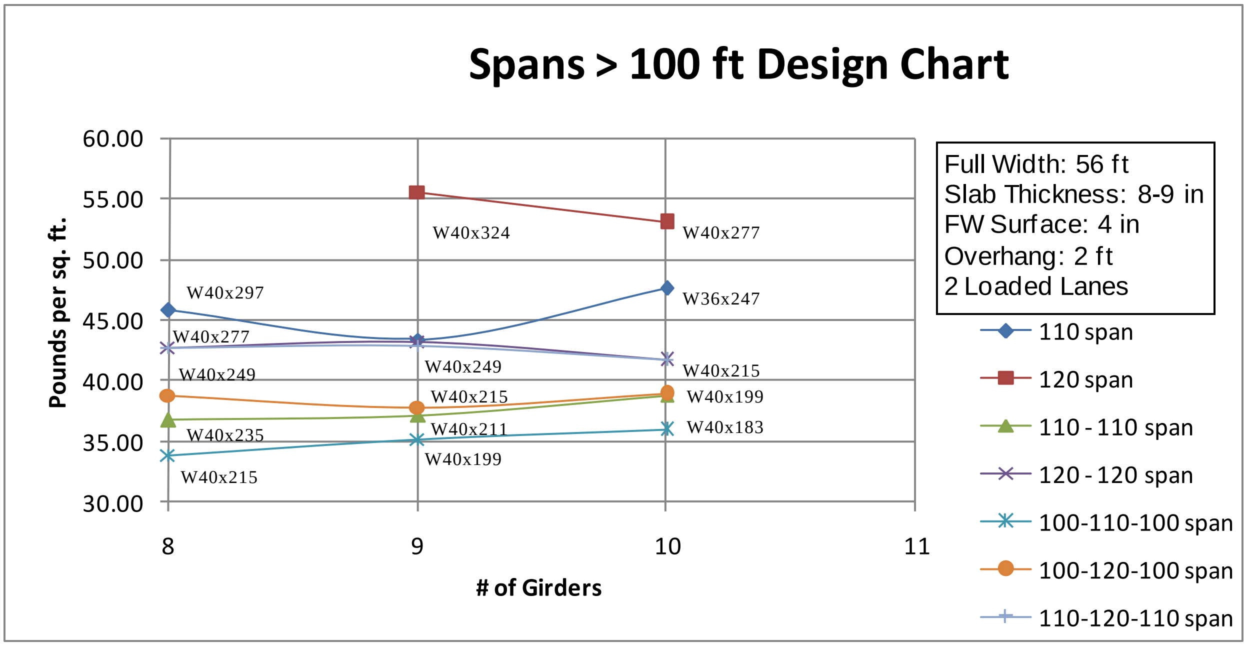

Three Span Design Chart
35.00
33.00
31.00
29.00
27.00
25.00
23.00
21.00
19.00
17.00
15.00
6
7
8
9
# of Girders
W40x249
W40x211
W40x183
W40x215
W40x199
W40x199
W36x160
W36x182
W40x183
W40x149
W40x167
W40x167
W36x135
W40x149
W33x130
W36x160
Full Width: 56 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2 ft
3 Loaded Lanes
65-80-65 span
70-80-70 span
70-90-70 span
80-90-80 span
80-100-80 span
90-100-90 span



Spans > 100 ft Design Chart
65.00
60.00
55.00
50.00
45.00
40.00
35.00
6
7
8
9
# of Girders
W40x362
W40x297
W40x277
W40x297
W40x249
W40x215
W40x277
W40x249
W40x215
W40x211
W40x199
W40x211
W40x183
W40x235
W40x199
Full Width: 39 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2 ft
2 Loaded Lanes
110 span
120 span
110 - 110 span
120 - 120 span
100-110-100 span
100-120-100 span
110-120-110 span



Spans > 100 ft Design Chart
Pounds per sq. ft.
65.00
60.00
55.00
50.00
45.00
40.00
35.00
6
7
8
9
# of Girders
W40x324
W40x297
W40x249
W40x324
W40x277
W40x235
W40x297
W40x249
W40x215
W40x277
W40x235
W40x199
W40x235
W40x215
Full Width: 44 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2 ft
2 Loaded Lanes
110 span
120 span
110 - 110 span
120 - 120 span
100-110-100 span
100-120-100 span
110-120-110 span



Spans > 100 ft Design Chart
Full Width: 56 ft
Slab Thickness: 8-9 in
FW Surface: 4 in
Overhang: 2 ft
2 Loaded Lanes
60.00
55.00
50.00
45.00
40.00
35.00
30.00
Pounds per sq. ft.
8
9
10
11
# of Girders
W40x324
W40x277
W40x297
W36x247
W40x277
W40x249
W40x249
W40x215
W40x215
W40x199
W40x235
W40x211
W40x183
W40x199
W40x215
110 span
120 span
110 - 110 span
120 - 120 span
100-110-100 span
100-120-100 span
110-120-110 span

APPENDIX C: DESIGN TABLES

One Span Design Table – 39 ft. width

50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W33	X	130	$15.96	17.58
Slab Thickness	Ts	9	in	W30	X	132	$16.15	17.79
No. of girders	Nb	4		W36	X	135	$16.43	18.10
Girder spacing	S	11.67	ft	W33	X	141	$16.98	18.71
Overhang		2	ft	W27	X	146	$17.44	19.22

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	108	$16.72	17.94
Slab Thickness	Ts	8	in	W27	X	114	$17.44	18.71
No. of girders	Nb	5		W30	X	116	$17.68	18.97
Girder spacing	S	8.75	ft	W24	X	117	$17.79	19.10
Overhang		2	ft	W33	X	118	$17.91	19.22

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	90	$17.03	17.91
Slab Thickness	Ts	8	in	W27	X	94	$17.61	18.52
No. of girders	Nb	6		W30	X	99	$18.33	19.29
Girder spacing	S	7	ft	W27	X	102	$18.77	19.76
Overhang		2	ft	W24	X	103	$18.91	19.91

70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$22.07	24.49
Slab Thickness	Ts	9	in	W36	X	210	$23.03	25.61
No. of girders	Nb	4		W40	X	211	$23.11	25.72
Girder spacing	S	11.67	ft	W40	X	215	$23.46	26.13
Overhang		2	ft	W33	X	221	$23.97	26.74

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	160	$22.64	24.41
Slab Thickness	Ts	8	in	W40	X	167	$23.43	25.31
No. of girders	Nb	5		W33	X	169	$23.65	25.57
Girder spacing	S	8.75	ft	W36	X	170	$23.76	25.70
Overhang		2	ft	W36	X	182	$25.10	27.23

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	149	$25.23	26.78
Slab Thickness	Ts	8	in	W36	X	150	$25.36	26.93
No. of girders	Nb	6		W33	X	152	$25.64	27.24
Girder spacing	S	7	ft	W36	X	160	$26.73	28.47
Overhang		2	ft	W40	X	167	$27.68	29.55

60-ft. span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	149	$17.54	19.26
Slab Thickness	Ts	9	in	W36	X	160	$18.54	20.39
No. of girders	Nb	4		W40	X	167	$19.18	21.11
Girder spacing	S	11.67	ft	W33	X	169	$19.36	21.31
Overhang		2	ft	W36	X	170	$19.45	21.42

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W33	X	130	$19.11	20.46
Slab Thickness	Ts	8	in	W36	X	135	$19.69	21.10
No. of girders	Nb	5		W33	X	141	$20.38	21.87
Girder spacing	S	8.75	ft	W27	X	146	$20.96	22.51
Overhang		2	ft	W30	X	148	$21.19	22.77

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W33	X	118	$20.81	21.89
Slab Thickness	Ts	8	in	W30	X	124	$21.65	22.82
No. of girders	Nb	6		W27	X	129	$22.36	23.59
Girder spacing	S	7	ft	W33	X	130	$22.50	23.74
Overhang		2	ft	W30	X	132	$22.78	24.05

80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	249	$26.19	29.43
Slab Thickness	Ts	9	in	W36	X	262	$27.26	30.77
No. of girders	Nb	4		W33	X	263	$27.34	30.87
Girder spacing	S	11.67	ft	W40	X	264	$27.42	30.97
Overhang		2	ft	W40	X	277	$28.47	32.31

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$26.82	29.21
Slab Thickness	Ts	8	in	W36	X	210	$28.02	30.62
No. of girders	Nb	5		W40	X	211	$28.12	30.75
Girder spacing	S	8.75	ft	W40	X	215	$28.55	31.26
Overhang		2	ft	W33	X	221	$29.19	32.03

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	$27.51	29.33
Slab Thickness	Ts	8	in	W36	X	182	$29.52	31.64
No. of girders	Nb	6		W40	X	183	$29.66	31.79
Girder spacing	S	7	ft	W30	X	191	$30.71	33.02
Overhang		2	ft	W36	X	194	$31.11	33.48

One Span Design Table – 39 ft. width

90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	297	$30.10	34.44
Slab Thickness	Ts	9	in	W40	X	324	$32.18	37.21
No. of girders	Nb	4		W40	X	327	$32.40	37.52
Girder spacing	S	11.67	ft	W36	X	330	$32.63	37.83
Overhang		2	ft	W40	X	331	$32.70	37.93

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	247	$31.99	35.46
Slab Thickness	Ts	8	in	W40	X	249	$32.19	35.71
No. of girders	Nb	5		W36	X	256	$32.91	36.61
Girder spacing	S	8.75	ft	W36	X	262	$33.52	37.38
Overhang		2	ft	W33	X	263	$33.62	37.51

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	31.84	34.35
Slab Thickness	Ts	8	in	W40	X	211	33.40	36.20
No. of girders	Nb	6		W40	X	215	33.92	36.82
Girder spacing	S	7	ft	W33	X	221	34.68	37.74
Overhang		2	ft	W36	X	231	35.95	39.28

100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	277	$34.98	39.23
Slab Thickness	Ts	8	in	W40	X	294	$36.66	41.41
No. of girders	Nb	5		W40	X	297	$36.95	41.79
Girder spacing	S	8.75	ft	W36	X	302	$37.44	42.43
Overhang		2	ft	W40	X	324	$39.55	45.25

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	249	$38.17	42.01
Slab Thickness	Ts	8	in	W36	X	262	$39.77	44.01
No. of girders	Nb	6		W40	X	264	$40.01	44.31
Girder spacing	S	7	ft	W40	X	277	$41.58	46.31
Overhang		2	ft	W40	X	278	$41.70	46.47

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	211	$38.67	41.69
Slab Thickness	Ts	8	in	W40	X	215	$39.27	42.40
No. of girders	Nb	7		W36	X	231	$41.65	45.28
Girder spacing	S	6.00	ft	W36	X	232	$41.79	45.45
Overhang		1.5	ft	W40	X	235	$42.23	45.99

One Span Design Table – 44 ft. width

50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W33	X	130	$14.33	15.96
Slab Thickness	Ts	9	in	W36	X	135	$14.74	16.41
No. of girders	Nb	4		W33	X	141	$15.24	16.96
Girder spacing	S	13	ft	W27	X	146	$15.65	17.41
Overhang		2.5	ft	W30	X	148	$15.81	17.59

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	116	$15.84	17.15
Slab Thickness	Ts	8.25	in	W33	X	118	$16.05	17.38
No. of girders	Nb	5		W30	X	124	$16.67	18.06
Girder spacing	S	9.75	ft	W27	X	129	$17.19	18.63
Overhang		2.5	ft	W33	X	130	$17.30	18.74

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	99	$16.41	17.42
Slab Thickness	Ts	8	in	W27	X	102	$16.80	17.83
No. of girders	Nb	6		W30	X	108	$17.56	18.65
Girder spacing	S	7.8	ft	W27	X	114	$18.32	19.47
Overhang		2.5	ft	W30	X	116	$18.57	19.74

70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	211	$20.66	23.15
Slab Thickness	Ts	9	in	W40	X	215	$20.97	23.51
No. of girders	Nb	4		W36	X	231	$22.17	24.97
Girder spacing	S	13	ft	W36	X	232	$22.25	25.06
Overhang		2.5	ft	W40	X	235	$22.47	25.33

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	167	$20.92	22.75
Slab Thickness	Ts	8.25	in	W36	X	182	$22.41	24.46
No. of girders	Nb	5		W40	X	183	$22.51	24.57
Girder spacing	S	9.75	ft	W36	X	194	$23.58	25.82
Overhang		2.5	ft	W40	X	199	$24.07	26.39

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$22.51	24.03
Slab Thickness	Ts	8	in	W36	X	150	$22.63	24.17
No. of girders	Nb	6		W36	X	160	$23.84	25.53
Girder spacing	S	7.8	ft	W40	X	167	$24.68	26.49
Overhang		2.5	ft	W33	X	169	$24.92	26.76

60-ft. span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	167	$17.17	19.05
Slab Thickness	Ts	9	in	W36	X	170	$17.41	19.32
No. of girders	Nb	4		W36	X	182	$18.36	20.42
Girder spacing	S	13	ft	W40	X	183	$18.43	20.51
Overhang		2.5	ft	W30	X	191	$19.06	21.23

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W33	X	141	$18.22	19.69
Slab Thickness	Ts	8.25	in	W40	X	149	$19.04	20.60
No. of girders	Nb	5		W36	X	150	$19.14	20.71
Girder spacing	S	9.75	ft	W33	X	152	$19.34	20.94
Overhang		2.5	ft	W36	X	160	$20.15	21.85

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W33	X	130	$20.09	21.33
Slab Thickness	Ts	8	in	W30	X	132	$20.33	21.60
No. of girders	Nb	6		W36	X	135	$20.71	22.01
Girder spacing	S	7.8	ft	W33	X	141	$21.45	22.83
Overhang		2.5	ft	W27	X	146	$22.06	23.51

80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	$25.40	28.97
Slab Thickness	Ts	9	in	W40	X	278	$25.47	29.06
No. of girders	Nb	4		W36	X	282	$25.75	29.42
Girder spacing	S	13	ft	W33	X	291	$26.38	30.24
Overhang		2.5	ft	W40	X	294	$26.59	30.51

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	211	$25.08	27.55
Slab Thickness	Ts	8.25	in	W40	X	215	$25.46	28.01
No. of girders	Nb	5		W36	X	231	$26.96	29.83
Girder spacing	S	9.75	ft	W36	X	232	$27.05	29.94
Overhang		2.5	ft	W40	X	235	$27.33	30.28

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	183	$26.43	28.46
Slab Thickness	Ts	8	in	W36	X	194	$27.71	29.96
No. of girders	Nb	6		W40	X	199	$28.29	30.64
Girder spacing	S	7.8	ft	W33	X	201	$28.53	30.91
Overhang		2.5	ft	W36	X	210	$29.56	32.14

One Span Design Table – 44 ft. width

90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	324	$28.69	33.32
Slab Thickness	Ts	9	in	W36	X	361	$31.12	36.69
No. of girders	Nb	4		W40	X	362	$31.18	36.78
Girder spacing	S	13	ft	W40	X	372	$31.81	37.69
Overhang		2.5	ft	W33	X	387	$32.75	39.05

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	249	$28.69	31.96
Slab Thickness	Ts	8.25	in	W40	X	264	$30.05	33.67
No. of girders	Nb	5		W40	X	277	$31.21	35.15
Girder spacing	S	9.75	ft	W40	X	278	$31.30	35.26
Overhang		2.5	ft	W36	X	282	$31.65	35.71

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	215	30.21	32.92
Slab Thickness	Ts	8	in	W36	X	231	32.01	35.10
No. of girders	Nb	6		W36	X	232	32.12	35.24
Girder spacing	S	7.8	ft	W40	X	235	32.46	35.65
Overhang		2.5	ft	W33	X	241	33.12	36.47

100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	324	$35.20	40.41
Slab Thickness	Ts	8.25	in	W40	X	327	$35.45	40.75
No. of girders	Nb	5		W36	X	330	$35.70	41.09
Girder spacing	S	9.75	ft	W40	X	331	$35.79	41.21
Overhang		2.5	ft	W33	X	354	$37.67	43.82

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	$37.00	41.33
Slab Thickness	Ts	8	in	W40	X	278	$37.10	41.47
No. of girders	Nb	6		W36	X	282	$37.53	42.02
Girder spacing	S	7.8	ft	W40	X	294	$38.79	43.65
Overhang		2.5	ft	W40	X	297	$39.10	44.06

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	235	$37.57	41.04
Slab Thickness	Ts	8	in	W36	X	247	$39.12	42.95
No. of girders	Nb	7		W40	X	249	$39.38	43.27
Girder spacing	S	6.67	ft	W36	X	256	$40.27	44.38
Overhang		2	ft	W36	X	262	$41.03	45.33

One Span Design Table – 56 ft. width

50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	116	$15.00	16.33
Slab Thickness	Ts	8.5	in	W33	X	118	$15.20	16.54
No. of girders	Nb	6		W30	X	124	$15.79	17.19
Girder spacing	S	10.4	ft	W27	X	129	$16.28	17.72
Overhang		2	ft	W33	X	130	$16.38	17.83

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	108	$16.20	17.32
Slab Thickness	Ts	8	in	W27	X	114	$16.90	18.07
No. of girders	Nb	7		W30	X	116	$17.13	18.32
Girder spacing	S	8.5	ft	W24	X	117	$17.24	18.44
Overhang		2.5	ft	W33	X	118	$17.36	18.57

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	90	$15.86	16.75
Slab Thickness	Ts	8	in	W27	X	94	$16.40	17.32
No. of girders	Nb	8		W30	X	99	$17.07	18.04
Girder spacing	S	7.43	ft	W27	X	102	$17.47	18.46
Overhang		2	ft	W24	X	103	$17.61	18.61

70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	182	$21.18	23.18
Slab Thickness	Ts	8.5	in	W40	X	183	$21.27	23.29
No. of girders	Nb	6		W36	X	194	$22.28	24.47
Girder spacing	S	10.4	ft	W40	X	199	$22.74	25.01
Overhang		2	ft	W33	X	201	$22.92	25.22

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	160	$21.94	23.60
Slab Thickness	Ts	8	in	W40	X	167	$22.71	24.47
No. of girders	Nb	7		W33	X	169	$22.93	24.72
Girder spacing	S	8.5	ft	W36	X	170	$23.04	24.85
Overhang		2.5	ft	W30	X	173	$23.37	25.22

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W33	X	141	$22.42	23.80
Slab Thickness	Ts	8	in	W40	X	149	$23.44	24.95
No. of girders	Nb	8		W36	X	150	$23.57	25.09
Girder spacing	S	7.43	ft	W33	X	152	$23.83	25.38
Overhang		2	ft	W36	X	160	$24.84	26.52

60-ft. span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	149	$17.99	19.53
Slab Thickness	Ts	8.5	in	W36	X	150	$18.08	19.64
No. of girders	Nb	6		W33	X	152	$18.27	19.85
Girder spacing	S	10.4	ft	W36	X	160	$19.04	20.71
Overhang		2	ft	W27	X	161	$19.13	20.81

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W33	X	130	$18.51	19.78
Slab Thickness	Ts	8	in	W30	X	132	$18.74	20.03
No. of girders	Nb	7		W36	X	135	$19.08	20.40
Girder spacing	S	8.667	ft	W33	X	141	$19.76	21.15
Overhang		2	ft	W27	X	146	$20.32	21.78

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W33	X	118	$19.33	20.39
Slab Thickness	Ts	8	in	W30	X	124	$20.11	21.25
No. of girders	Nb	8		W27	X	129	$20.77	21.96
Girder spacing	S	7.43	ft	W33	X	130	$20.90	22.10
Overhang		2	ft	W30	X	132	$21.16	22.39

80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	211	$23.67	26.07
Slab Thickness	Ts	8.5	in	W40	X	215	$24.03	26.50
No. of girders	Nb	6		W36	X	231	$25.45	28.21
Girder spacing	S	10.4	ft	W36	X	232	$25.54	28.32
Overhang		2	ft	W40	X	235	$25.80	28.64

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	183	$24.31	26.29
Slab Thickness	Ts	8	in	W36	X	194	$25.50	27.67
No. of girders	Nb	7		W40	X	199	$26.03	28.29
Girder spacing	S	8.667	ft	W33	X	201	$26.24	28.54
Overhang		2	ft	W36	X	210	$27.19	29.67

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	167	$25.54	27.28
Slab Thickness	Ts	8	in	W36	X	170	$25.92	27.71
No. of girders	Nb	8		W36	X	182	$27.41	29.42
Girder spacing	S	7.43	ft	W40	X	183	$27.53	29.56
Overhang		2	ft	W30	X	191	$28.51	30.71

One Span Design Table – 56 ft. width

90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	277	$29.46	33.24
Slab Thickness	Ts	8.5	in	W40	X	278	$29.55	33.35
No. of girders	Nb	6		W36	X	282	$29.88	33.78
Girder spacing	S	10.4	ft	W33	X	291	$30.62	34.74
Overhang		2	ft	W40	X	294	$30.87	35.06

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	231	$29.42	32.35
Slab Thickness	Ts	8	in	W40	X	235	$29.83	32.85
No. of girders	Nb	7		W36	X	247	$31.04	34.35
Girder spacing	S	8.5	ft	W40	X	249	$31.25	34.60
Overhang		2.5	ft	W40	X	256	$31.95	35.48

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	199	29.57	31.96
Slab Thickness	Ts	8	in	W40	X	211	31.02	33.68
No. of girders	Nb	8		W40	X	215	31.50	34.25
Girder spacing	S	7.43	ft	W33	X	221	32.21	35.10
Overhang		2	ft	W36	X	231	33.39	36.53

100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	324	$33.25	38.24
Slab Thickness	Ts	8.5	in	W36	X	330	$33.72	38.88
No. of girders	Nb	6		W40	X	331	$33.80	38.99
Girder spacing	S	10.4	ft	W36	X	361	$36.11	42.20
Overhang		2	ft	W40	X	362	$36.18	42.31

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	277	$34.03	38.14
Slab Thickness	Ts	8	in	W40	X	278	$34.13	38.26
No. of girders	Nb	7		W36	X	282	$34.52	38.76
Girder spacing	S	8.667	ft	W40	X	294	$35.67	40.26
Overhang		2	ft	W40	X	297	$35.96	40.64

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	247	$35.25	38.82
Slab Thickness	Ts	8	in	W40	X	249	$35.48	39.10
No. of girders	Nb	8		W36	X	256	$36.28	40.10
Girder spacing	S	7.43	ft	W36	X	262	$36.96	40.96
Overhang		2	ft	W40	X	264	$37.19	41.25

Two Equal Spans Design Table – 39 ft. width

50 – 50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	108	$13.61	14.92
Slab Thickness	Ts	9	in	W27	X	114	$14.18	15.54
No. of girders	Nb	4		W30	X	116	$14.37	15.74
Girder spacing	S	11.67	ft	W33	X	118	$14.56	15.95
Overhang		2	ft	W30	X	124	$15.13	16.56

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	90	$14.29	15.25
Slab Thickness	Ts	8	in	W27	X	94	$14.77	15.77
No. of girders	Nb	5		W30	X	99	$15.37	16.41
Girder spacing	S	8.75	ft	W27	X	102	$15.73	16.79
Overhang		2	ft	W24	X	103	$15.85	16.92

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W27	X	84	$15.87	16.62
Slab Thickness	Ts	8	in	W24	X	84	$15.87	16.62
No. of girders	Nb	6		W30	X	90	$16.75	17.54
Girder spacing	S	7	ft	W21	X	93	$17.19	18.01
Overhang		2	ft	W27	X	94	$17.33	18.16

70 – 70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	$19.05	20.91
Slab Thickness	Ts	9	in	W36	X	170	$19.32	21.22
No. of girders	Nb	4		W36	X	182	$20.39	22.45
Girder spacing	S	11.67	ft	W40	X	183	$20.48	22.56
Overhang		2	ft	W30	X	191	$21.18	23.38

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	135	$19.57	20.94
Slab Thickness	Ts	8	in	W33	X	141	$20.27	21.71
No. of girders	Nb	5		W30	X	148	$21.07	22.60
Girder spacing	S	8.75	ft	W40	X	149	$21.19	22.73
Overhang		2	ft	W36	X	150	$21.30	22.86

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W33	X	118	$20.69	21.75
Slab Thickness	Ts	8	in	W33	X	130	$22.39	23.59
No. of girders	Nb	6		W30	X	132	$22.67	23.90
Girder spacing	S	7	ft	W36	X	135	$23.09	24.36
Overhang		2	ft	W33	X	141	$23.92	25.29

60 – 60-ft.span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	135	$16.14	17.66
Slab Thickness	Ts	9	in	W33	X	141	$16.69	18.27
No. of girders	Nb	4		W30	X	148	$17.34	18.99
Girder spacing	S	11.67	ft	W40	X	149	$17.43	19.09
Overhang		2	ft	W36	X	150	$17.52	19.20

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	116	$17.37	18.54
Slab Thickness	Ts	8	in	W33	X	118	$17.60	18.79
No. of girders	Nb	5		W30	X	124	$18.31	19.56
Girder spacing	S	8.75	ft	W27	X	129	$18.90	20.20
Overhang		2	ft	W33	X	130	$19.02	20.33

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	99	$18.01	18.87
Slab Thickness	Ts	8	in	W30	X	108	$19.30	20.25
No. of girders	Nb	6		W27	X	114	$20.16	21.18
Girder spacing	S	7	ft	W30	X	116	$20.44	21.48
Overhang		2	ft	W24	X	117	$20.59	21.64

80 – 80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$21.79	24.05
Slab Thickness	Ts	9	in	W40	X	211	$22.83	25.28
No. of girders	Nb	4		W40	X	215	$23.17	25.69
Girder spacing	S	11.67	ft	W33	X	221	$23.68	26.31
Overhang		2	ft	W36	X	231	$24.53	27.33

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	$23.15	24.92
Slab Thickness	Ts	8	in	W36	X	170	$23.48	25.30
No. of girders	Nb	5		W36	X	182	$24.82	26.84
Girder spacing	S	8.75	ft	W40	X	183	$24.93	26.97
Overhang		2	ft	W30	X	191	$25.81	27.99

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	149	$24.94	26.41
Slab Thickness	Ts	8	in	W36	X	150	$25.08	26.56
No. of girders	Nb	6		W33	X	152	$25.35	26.87
Girder spacing	S	7	ft	W36	X	160	$26.45	28.10
Overhang		2	ft	W40	X	167	$27.40	29.18

Two Equal Spans Design Table – 39 ft. width

90 – 90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	249	$26.03	29.18
Slab Thickness	Ts	9	in	W36	X	262	$27.09	30.51
No. of girders	Nb	4		W40	X	264	$27.25	30.72
Girder spacing	S	11.67	ft	W40	X	277	$28.30	32.05
Overhang		2	ft	W40	X	278	$28.38	32.15

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$26.68	29.01
Slab Thickness	Ts	8	in	W36	X	210	$27.87	30.42
No. of girders	Nb	5		W40	X	211	$27.98	30.55
Girder spacing	S	8.75	ft	W40	X	215	$28.41	31.06
Overhang		2	ft	W33	X	221	$29.05	31.83

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	27.38	29.16
Slab Thickness	Ts	8	in	W36	X	182	29.39	31.47
No. of girders	Nb	6		W40	X	183	29.53	31.62
Girder spacing	S	7	ft	W30	X	191	30.59	32.85
Overhang		2	ft	W36	X	194	30.98	33.31

100 – 100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	297	$29.88	34.10
Slab Thickness	Ts	9	in	W40	X	324	$31.95	36.87
No. of girders	Nb	4		W40	X	327	$32.18	37.18
Girder spacing	S	11.67	ft	W36	X	330	$32.41	37.49
Overhang		2	ft	W40	X	331	$32.48	37.59

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	235	$30.52	33.62
Slab Thickness	Ts	8	in	W36	X	247	$31.77	35.15
No. of girders	Nb	5		W40	X	249	$31.97	35.41
Girder spacing	S	8.75	ft	W36	X	256	$32.69	36.31
Overhang		2	ft	W36	X	262	$33.31	37.08

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$31.62	34.07
Slab Thickness	Ts	8	in	W36	X	210	$33.05	35.76
No. of girders	Nb	6		W40	X	211	$33.18	35.92
Girder spacing	S	7.00	ft	W40	X	215	$33.70	36.53
Overhang		2	ft	W33	X	221	$34.47	37.45

Two Equal Spans Design Table – 44 ft. width

50 – 50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	116	$12.91	14.28
Slab Thickness	Ts	9	in	W33	X	118	$13.07	14.46
No. of girders	Nb	4		W30	X	124	$13.57	15.01
Girder spacing	S	13	ft	W27	X	129	$13.99	15.46
Overhang		2.5	ft	W33	X	130	$14.07	15.55

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	99	$13.78	14.84
Slab Thickness	Ts	8.25	in	W27	X	102	$14.10	15.18
No. of girders	Nb	5		W24	X	104	$14.31	15.41
Girder spacing	S	9.75	ft	W30	X	108	$14.73	15.87
Overhang		2.5	ft	W27	X	114	$15.37	16.55

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W27	X	84	$14.21	15.02
Slab Thickness	Ts	8	in	W30	X	90	$14.99	15.83
No. of girders	Nb	6		W27	X	94	$15.50	16.38
Girder spacing	S	7.8	ft	W24	X	94	$15.50	16.38
Overhang		2.5	ft	W30	X	99	$16.15	17.06

70 – 70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W36	X	182	$18.23	20.22
Slab Thickness	Ts	9	in	W40	X	183	$18.31	20.32
No. of girders	Nb	4		W36	X	194	$19.17	21.32
Girder spacing	S	13	ft	W40	X	199	$19.56	21.77
Overhang		2.5	ft	W33	X	201	$19.71	21.95

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$18.93	20.44
Slab Thickness	Ts	8.25	in	W36	X	150	$19.03	20.55
No. of girders	Nb	5		W33	X	152	$19.23	20.78
Girder spacing	S	9.75	ft	W36	X	160	$20.04	21.69
Overhang		2.5	ft	W40	X	167	$20.74	22.49

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W33	X	130	$19.98	21.19
Slab Thickness	Ts	8	in	W36	X	135	$20.60	21.87
No. of girders	Nb	6		W33	X	141	$21.34	22.69
Girder spacing	S	7.8	ft	W27	X	146	$21.95	23.37
Overhang		2.5	ft	W30	X	148	$22.20	23.64

60 – 60-ft. span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$15.61	17.25
Slab Thickness	Ts	9	in	W36	X	150	$15.69	17.34
No. of girders	Nb	4		W33	X	152	$15.85	17.52
Girder spacing	S	13	ft	W36	X	160	$16.50	18.25
Overhang		2.5	ft	W40	X	167	$17.06	18.88

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W33	X	118	$15.75	16.95
Slab Thickness	Ts	8.25	in	W33	X	130	$17.00	18.32
No. of girders	Nb	5		W30	X	132	$17.21	18.54
Girder spacing	S	9.75	ft	W36	X	135	$17.52	18.88
Overhang		2.5	ft	W33	X	141	$18.14	19.57

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	108	$17.25	18.23
Slab Thickness	Ts	8	in	W27	X	114	$18.01	19.05
No. of girders	Nb	6		W30	X	116	$18.26	19.32
Girder spacing	S	7.8	ft	W33	X	118	$18.51	19.59
Overhang		2.5	ft	W30	X	124	$19.26	20.41

80 – 80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	215	$20.69	23.08
Slab Thickness	Ts	9	in	W36	X	231	$21.89	24.54
No. of girders	Nb	4		W36	X	232	$21.97	24.63
Girder spacing	S	13	ft	W40	X	235	$22.19	24.90
Overhang		2.5	ft	W33	X	241	$22.64	25.45

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W36	X	182	$22.14	24.07
Slab Thickness	Ts	8.25	in	W40	X	183	$22.24	24.18
No. of girders	Nb	5		W36	X	194	$23.31	25.43
Girder spacing	S	9.75	ft	W40	X	199	$23.80	26.00
Overhang		2.5	ft	W33	X	201	$23.99	26.23

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$22.24	23.67
Slab Thickness	Ts	8	in	W36	X	160	$23.57	25.17
No. of girders	Nb	6		W40	X	167	$24.41	26.12
Girder spacing	S	7.8	ft	W33	X	169	$24.65	26.40
Overhang		2.5	ft	W36	X	170	$24.77	26.53

Two Equal Spans Design Table – 44 ft. width

90 – 90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	$25.24	28.72
Slab Thickness	Ts	9	in	W40	X	278	$25.31	28.81
No. of girders	Nb	4		W36	X	282	$25.59	29.17
Girder spacing	S	13	ft	W40	X	294	$26.43	30.26
Overhang		2.5	ft	W40	X	297	$26.64	30.54

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	211	$24.94	27.35
Slab Thickness	Ts	8.25	in	W40	X	215	$25.32	27.81
No. of girders	Nb	5		W36	X	231	$26.82	29.63
Girder spacing	S	9.75	ft	W36	X	232	$26.92	29.74
Overhang		2.5	ft	W40	X	235	$27.20	30.08

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	183	26.30	28.29
Slab Thickness	Ts	8	in	W36	X	194	27.59	29.79
No. of girders	Nb	6		W40	X	199	28.17	30.47
Girder spacing	S	7.8	ft	W33	X	201	28.40	30.74
Overhang		2.5	ft	W36	X	210	29.44	31.97

100 – 100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	324	$28.48	32.99
Slab Thickness	Ts	9	in	W36	X	361	$30.90	36.35
No. of girders	Nb	4		W40	X	362	$30.96	36.45
Girder spacing	S	13	ft	W40	X	372	$31.60	37.35
Overhang		2.5	ft	W33	X	387	$32.54	38.72

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	249	$28.48	31.66
Slab Thickness	Ts	8.25	in	W36	X	262	$29.66	33.14
No. of girders	Nb	5		W40	X	264	$29.84	33.37
Girder spacing	S	9.75	ft	W40	X	277	$31.00	34.85
Overhang		2.5	ft	W40	X	278	$31.09	34.96

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	211	$29.54	32.09
Slab Thickness	Ts	8	in	W40	X	215	$30.00	32.64
No. of girders	Nb	6		W36	X	231	$31.80	34.82
Girder spacing	S	7.80	ft	W36	X	232	$31.92	34.96
Overhang		2.5	ft	W40	X	235	$32.25	35.37

Two Equal Spans Design Table – 56 ft. width

50 – 50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	99	$13.05	14.13
Slab Thickness	Ts	8.5	in	W27	X	102	$13.35	14.45
No. of girders	Nb	6		W24	X	104	$13.55	14.67
Girder spacing	S	10.4	ft	W30	X	108	$13.95	15.09
Overhang		2	ft	W27	X	114	$14.55	15.74

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	90	$13.85	14.76
Slab Thickness	Ts	8	in	W27	X	94	$14.33	15.26
No. of girders	Nb	7		W24	X	94	$14.33	15.26
Girder spacing	S	8.667	ft	W30	X	99	$14.92	15.89
Overhang		2	ft	W21	X	101	$15.15	16.14

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W27	X	84	$14.77	15.53
Slab Thickness	Ts	8	in	W24	X	84	$14.77	15.53
No. of girders	Nb	8		W30	X	90	$15.59	16.39
Girder spacing	S	7.43	ft	W21	X	93	$15.99	16.82
Overhang		2	ft	W27	X	94	$16.13	16.96

70 – 70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	149	$17.89	19.38
Slab Thickness	Ts	8.5	in	W36	X	150	$17.98	19.49
No. of girders	Nb	6		W36	X	160	$18.93	20.56
Girder spacing	S	10.4	ft	W40	X	167	$19.59	21.31
Overhang		2	ft	W33	X	169	$19.78	21.52

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	135	$18.98	20.27
Slab Thickness	Ts	8	in	W33	X	141	$19.66	21.02
No. of girders	Nb	7		W30	X	148	$20.45	21.89
Girder spacing	S	8.667	ft	W40	X	149	$20.56	22.02
Overhang		2	ft	W36	X	150	$20.67	22.14

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W33	X	118	$19.23	20.26
Slab Thickness	Ts	8	in	W33	X	130	$20.80	21.98
No. of girders	Nb	8		W30	X	132	$21.06	22.26
Girder spacing	S	7.43	ft	W36	X	135	$21.45	22.69
Overhang		2	ft	W33	X	141	$22.22	23.55

60 – 60-ft. span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W33	X	130	$16.08	17.39
Slab Thickness	Ts	8.5	in	W30	X	132	$16.27	17.60
No. of girders	Nb	6		W36	X	135	$16.57	17.92
Girder spacing	S	10.4	ft	W33	X	141	$17.15	18.57
Overhang		2	ft	W27	X	146	$17.63	19.10

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	116	$16.85	17.94
Slab Thickness	Ts	8	in	W33	X	118	$17.08	18.19
No. of girders	Nb	7		W30	X	124	$17.77	18.94
Girder spacing	S	8.667	ft	W27	X	129	$18.34	19.57
Overhang		2	ft	W33	X	130	$18.45	19.69

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	99	$16.74	17.60
Slab Thickness	Ts	8	in	W27	X	102	$17.15	18.03
No. of girders	Nb	8		W30	X	108	$17.95	18.89
Girder spacing	S	7.43	ft	W27	X	114	$18.74	19.74
Overhang		2	ft	W30	X	116	$19.01	20.03

80 – 80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	183	$21.01	22.91
Slab Thickness	Ts	8.5	in	W36	X	194	$22.02	24.09
No. of girders	Nb	6		W40	X	199	$22.48	24.62
Girder spacing	S	10.4	ft	W33	X	201	$22.66	24.84
Overhang		2	ft	W36	X	210	$23.47	25.80

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	160	$21.71	23.29
Slab Thickness	Ts	8	in	W40	X	167	$22.48	24.16
No. of girders	Nb	7		W33	X	169	$22.70	24.41
Girder spacing	S	8.667	ft	W36	X	170	$22.81	24.54
Overhang		2	ft	W30	X	173	$23.14	24.91

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	149	$23.18	24.59
Slab Thickness	Ts	8	in	W36	X	150	$23.31	24.74
No. of girders	Nb	8		W33	X	152	$23.56	25.02
Girder spacing	S	7.43	ft	W36	X	160	$24.58	26.17
Overhang		2	ft	W40	X	167	$25.46	27.17

Two Equal Spans Design Table – 56 ft. width

90 – 90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$23.91	26.32
Slab Thickness	Ts	8.5	in	W36	X	231	$25.33	28.03
No. of girders	Nb	6		W36	X	232	$25.42	28.14
Girder spacing	S	10.4	ft	W40	X	235	$25.68	28.46
Overhang		2	ft	W33	X	241	$26.20	29.11

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	183	$24.21	26.14
Slab Thickness	Ts	8	in	W36	X	194	$25.39	27.52
No. of girders	Nb	7		W40	X	199	$25.92	28.14
Girder spacing	S	8.667	ft	W33	X	201	$26.13	28.39
Overhang		2	ft	W36	X	210	$27.08	29.52

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	167	25.44	27.14
Slab Thickness	Ts	8	in	W36	X	170	25.81	27.57
No. of girders	Nb	8		W36	X	182	27.31	29.28
Girder spacing	S	7.43	ft	W40	X	183	27.43	29.43
Overhang		2	ft	W30	X	191	28.41	30.57

100 – 100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	249	$26.89	29.95
Slab Thickness	Ts	8.5	in	W40	X	277	$29.26	32.95
No. of girders	Nb	6		W40	X	278	$29.35	33.06
Girder spacing	S	10.4	ft	W36	X	282	$29.68	33.48
Overhang		2	ft	W33	X	291	$30.42	34.45

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$27.59	30.12
Slab Thickness	Ts	8	in	W36	X	231	$29.24	32.12
No. of girders	Nb	7		W40	X	235	$29.65	32.62
Girder spacing	S	8.667	ft	W36	X	247	$30.87	34.12
Overhang		2	ft	W40	X	249	$31.07	34.37

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	199	$29.37	31.69
Slab Thickness	Ts	8	in	W36	X	210	$30.70	33.26
No. of girders	Nb	8		W40	X	211	$30.82	33.41
Girder spacing	S	7.43	ft	W40	X	215	$31.30	33.98
Overhang		2	ft	W33	X	221	$32.01	34.83

Two Span .9L - L Design Table – 39 ft. width

45 – 50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	108	$13.58	14.88
Slab Thickness	Ts	9	in	W27	X	114	$14.16	15.49
No. of girders	Nb	4		W30	X	116	$14.35	15.70
Girder spacing	S	11.67	ft	W33	X	118	$14.53	15.90
Overhang		2	ft	W30	X	124	$15.10	16.52

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	90	$14.23	15.17
Slab Thickness	Ts	8	in	W27	X	94	$14.71	15.68
No. of girders	Nb	5		W30	X	99	$15.31	16.32
Girder spacing	S	8.75	ft	W27	X	102	$15.67	16.71
Overhang		2	ft	W24	X	103	$15.79	16.84

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W27	X	84	$15.79	16.51
Slab Thickness	Ts	8	in	W24	X	84	$15.79	16.51
No. of girders	Nb	6		W30	X	90	$16.67	17.44
Girder spacing	S	7	ft	W21	X	93	$17.10	17.90
Overhang		2	ft	W27	X	94	$17.25	18.05

55 – 60-ft. span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	135	$16.11	17.62
Slab Thickness	Ts	9	in	W33	X	141	$16.67	18.24
No. of girders	Nb	4		W30	X	148	$17.31	18.95
Girder spacing	S	11.67	ft	W40	X	149	$17.40	19.06
Overhang		2	ft	W36	X	150	$17.50	19.16

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	116	$17.32	18.47
Slab Thickness	Ts	8	in	W33	X	118	$17.55	18.72
No. of girders	Nb	5		W30	X	124	$18.26	19.49
Girder spacing	S	8.75	ft	W27	X	129	$18.85	20.13
Overhang		2	ft	W33	X	130	$18.96	20.26

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W30	X	99	$17.94	18.78
Slab Thickness	Ts	8	in	W30	X	108	$19.23	20.16
No. of girders	Nb	6		W27	X	114	$20.09	21.08
Girder spacing	S	7	ft	W30	X	116	$20.37	21.39
Overhang		2	ft	W24	X	117	$20.52	21.54

65 – 70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	$19.03	20.88
Slab Thickness	Ts	9	in	W36	X	170	$19.30	21.19
No. of girders	Nb	4		W36	X	182	$20.37	22.42
Girder spacing	S	11.67	ft	W40	X	183	$20.46	22.52
Overhang		2	ft	W30	X	191	$21.16	23.34

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	135	$19.57	20.93
Slab Thickness	Ts	8	in	W33	X	141	$20.26	21.70
No. of girders	Nb	5		W30	X	148	$21.07	22.60
Girder spacing	S	8.75	ft	W40	X	149	$21.18	22.73
Overhang		2	ft	W36	X	150	$21.30	22.85

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W33	X	118	$20.70	21.76
Slab Thickness	Ts	8	in	W33	X	130	$22.39	23.60
No. of girders	Nb	6		W30	X	132	$22.67	23.91
Girder spacing	S	7	ft	W36	X	135	$23.09	24.37
Overhang		2	ft	W33	X	141	$23.93	25.30

70 – 80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$21.83	24.12
Slab Thickness	Ts	9	in	W40	X	211	$22.87	25.35
No. of girders	Nb	4		W40	X	215	$23.21	25.76
Girder spacing	S	11.67	ft	W33	X	221	$23.73	26.38
Overhang		2	ft	W36	X	231	$24.57	27.40

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	$23.17	24.95
Slab Thickness	Ts	8	in	W36	X	170	$23.51	25.33
No. of girders	Nb	5		W36	X	182	$24.84	26.87
Girder spacing	S	8.75	ft	W40	X	183	$24.95	27.00
Overhang		2	ft	W30	X	191	$25.84	28.03

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	149	$24.95	26.42
Slab Thickness	Ts	8	in	W36	X	150	$25.09	26.57
No. of girders	Nb	6		W33	X	152	$25.36	26.88
Girder spacing	S	7	ft	W36	X	160	$26.46	28.11
Overhang		2	ft	W40	X	167	$27.40	29.19

Two Span .9L - L Design Table – 39 ft. width

80 – 90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	249	$25.99	29.12
Slab Thickness	Ts	9	in	W36	X	262	$27.05	30.45
No. of girders	Nb	4		W40	X	264	$27.21	30.66
Girder spacing	S	11.67	ft	W40	X	277	$28.26	31.99
Overhang		2	ft	W40	X	278	$28.34	32.10

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$26.64	28.95
Slab Thickness	Ts	8	in	W36	X	210	$27.83	30.36
No. of girders	Nb	5		W40	X	211	$27.94	30.49
Girder spacing	S	8.75	ft	W40	X	215	$28.36	31.00
Overhang		2	ft	W33	X	221	$29.00	31.77

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	27.33	29.10
Slab Thickness	Ts	8	in	W36	X	182	29.35	31.40
No. of girders	Nb	6		W40	X	183	29.48	31.56
Girder spacing	S	7	ft	W36	X	194	30.93	33.25
Overhang		2	ft	W40	X	199	31.59	34.02

90 – 100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	297	$29.92	34.16
Slab Thickness	Ts	9	in	W40	X	324	$31.99	36.93
No. of girders	Nb	4		W40	X	327	$32.22	37.23
Girder spacing	S	11.67	ft	W36	X	330	$32.44	37.54
Overhang		2	ft	W40	X	331	$32.52	37.64

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	235	$30.57	33.68
Slab Thickness	Ts	8	in	W36	X	247	$31.81	35.22
No. of girders	Nb	5		W40	X	249	$32.02	35.47
Girder spacing	S	8.75	ft	W36	X	256	$32.74	36.37
Overhang		2	ft	W36	X	262	$33.35	37.14

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$31.68	34.14
Slab Thickness	Ts	8	in	W40	X	211	$33.24	35.99
No. of girders	Nb	6		W40	X	215	$33.75	36.60
Girder spacing	S	7.00	ft	W33	X	221	$34.52	37.53
Overhang		2	ft	W36	X	231	$35.79	39.06

Two Span .9L - L Design Table – 44 ft. width

45 – 50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	116	$12.88	14.24
Slab Thickness	Ts	9	in	W33	X	118	$13.05	14.42
No. of girders	Nb	4		W30	X	124	$13.55	14.97
Girder spacing	S	13	ft	W27	X	129	$13.96	15.42
Overhang		2.5	ft	W33	X	130	$14.05	15.51

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	99	$13.72	14.76
Slab Thickness	Ts	8.25	in	W27	X	102	$14.04	15.10
No. of girders	Nb	5		W24	X	104	$14.25	15.33
Girder spacing	S	9.75	ft	W30	X	108	$14.68	15.78
Overhang		2.5	ft	W27	X	114	$15.31	16.47

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W27	X	84	$14.13	14.91
Slab Thickness	Ts	8	in	W30	X	90	$14.91	15.73
No. of girders	Nb	6		W27	X	94	$15.42	16.27
Girder spacing	S	7.8	ft	W24	X	94	$15.42	16.27
Overhang		2.5	ft	W30	X	99	$16.07	16.95

55- 60-ft. span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$15.59	17.21
Slab Thickness	Ts	9	in	W36	X	150	$15.67	17.30
No. of girders	Nb	4		W33	X	152	$15.83	17.49
Girder spacing	S	13	ft	W36	X	160	$16.48	18.21
Overhang		2.5	ft	W40	X	167	$17.04	18.85

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W33	X	118	$15.70	16.88
Slab Thickness	Ts	8.25	in	W33	X	130	$16.95	18.25
No. of girders	Nb	5		W30	X	132	$17.16	18.47
Girder spacing	S	9.75	ft	W36	X	135	$17.47	18.81
Overhang		2.5	ft	W33	X	141	$18.09	19.50

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W30	X	108	$17.18	18.14
Slab Thickness	Ts	8	in	W27	X	114	$17.94	18.96
No. of girders	Nb	6		W30	X	116	$18.19	19.23
Girder spacing	S	7.8	ft	W33	X	118	$18.44	19.50
Overhang		2.5	ft	W30	X	124	$19.20	20.32

65 – 70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W36	X	182	$18.21	20.19
Slab Thickness	Ts	9	in	W40	X	183	$18.29	20.28
No. of girders	Nb	4		W36	X	194	$19.15	21.28
Girder spacing	S	13	ft	W40	X	199	$19.54	21.74
Overhang		2.5	ft	W33	X	201	$19.69	21.92

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$18.92	20.43
Slab Thickness	Ts	8.25	in	W36	X	150	$19.02	20.55
No. of girders	Nb	5		W33	X	152	$19.23	20.77
Girder spacing	S	9.75	ft	W36	X	160	$20.03	21.68
Overhang		2.5	ft	W40	X	167	$20.73	22.48

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W33	X	130	$19.99	21.20
Slab Thickness	Ts	8	in	W36	X	135	$20.61	21.88
No. of girders	Nb	6		W33	X	141	$21.35	22.70
Girder spacing	S	7.8	ft	W27	X	146	$21.96	23.38
Overhang		2.5	ft	W30	X	148	$22.20	23.65

70 – 80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	215	$20.73	23.15
Slab Thickness	Ts	9	in	W36	X	231	$21.94	24.60
No. of girders	Nb	4		W36	X	232	$22.01	24.69
Girder spacing	S	13	ft	W40	X	235	$22.23	24.97
Overhang		2.5	ft	W33	X	241	$22.68	25.51

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	183	$22.26	24.21
Slab Thickness	Ts	8.25	in	W36	X	194	$23.33	25.46
No. of girders	Nb	5		W40	X	199	$23.82	26.03
Girder spacing	S	9.75	ft	W33	X	201	$24.01	26.26
Overhang		2.5	ft	W36	X	210	$24.87	27.28

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$22.25	23.68
Slab Thickness	Ts	8	in	W36	X	160	$23.58	25.18
No. of girders	Nb	6		W40	X	167	$24.42	26.13
Girder spacing	S	7.8	ft	W33	X	169	$24.66	26.41
Overhang		2.5	ft	W36	X	170	$24.78	26.54

Two Span .9L - L Design Table – 44 ft. width

80 – 90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	$25.20	28.66
Slab Thickness	Ts	9	in	W40	X	278	$25.27	28.75
No. of girders	Nb	4		W36	X	282	$25.55	29.11
Girder spacing	S	13	ft	W40	X	294	$26.39	30.20
Overhang		2.5	ft	W40	X	297	$26.60	30.48

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	211	$24.90	27.29
Slab Thickness	Ts	8.25	in	W40	X	215	$25.28	27.75
No. of girders	Nb	5		W36	X	231	$26.78	29.57
Girder spacing	S	9.75	ft	W36	X	232	$26.88	29.68
Overhang		2.5	ft	W40	X	235	$27.15	30.02

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	183	26.26	28.23
Slab Thickness	Ts	8	in	W36	X	194	27.54	29.73
No. of girders	Nb	6		W40	X	199	28.12	30.41
Girder spacing	S	7.8	ft	W33	X	201	28.36	30.68
Overhang		2.5	ft	W36	X	210	29.39	31.91

90 – 100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	324	$28.51	33.04
Slab Thickness	Ts	9	in	W36	X	361	$30.93	36.41
No. of girders	Nb	4		W40	X	362	$31.00	36.50
Girder spacing	S	13	ft	W40	X	372	$31.63	37.41
Overhang		2.5	ft	W33	X	387	$32.57	38.77

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	249	$28.52	31.73
Slab Thickness	Ts	8.25	in	W40	X	264	$29.88	33.43
No. of girders	Nb	5		W40	X	277	$31.04	34.91
Girder spacing	S	9.75	ft	W40	X	278	$31.13	35.02
Overhang		2.5	ft	W36	X	282	$31.48	35.48

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	215	$30.05	32.71
Slab Thickness	Ts	8	in	W36	X	231	$31.86	34.89
No. of girders	Nb	6		W36	X	232	$31.97	35.03
Girder spacing	S	7.80	ft	W40	X	235	$32.30	35.44
Overhang		2.5	ft	W33	X	241	$32.97	36.25

Two Span .9L - L Design Table - 56 ft. width

45 – 50-ft. span

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	99	$12.97	14.02
Slab Thickness	Ts	8.5	in	W27	X	102	$13.27	14.34
No. of girders	Nb	6		W30	X	108	$13.87	14.98
Girder spacing	S	10.4	ft	W27	X	114	$14.47	15.62
Overhang		2	ft	W30	X	116	$14.67	15.84

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	90	$13.76	14.63
Slab Thickness	Ts	8	in	W27	X	94	$14.23	15.13
No. of girders	Nb	7		W24	X	94	$14.23	15.13
Girder spacing	S	8.667	ft	W30	X	99	$14.82	15.76
Overhang		2	ft	W21	X	101	$15.06	16.01

Longest Span	L	50	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W27	X	84	$14.67	15.39
Slab Thickness	Ts	8	in	W24	X	84	$14.67	15.39
No. of girders	Nb	8		W30	X	90	$15.48	16.25
Girder spacing	S	7.43	ft	W21	X	93	$15.89	16.68
Overhang		2	ft	W27	X	94	$16.02	16.82

65 – 70-ft. span

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	149	$17.89	19.39
Slab Thickness	Ts	8.5	in	W36	X	150	$17.99	19.50
No. of girders	Nb	6		W36	X	160	$18.94	20.57
Girder spacing	S	10.4	ft	W40	X	167	$19.60	21.32
Overhang		2	ft	W33	X	169	$19.79	21.53

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	135	$19.00	20.29
Slab Thickness	Ts	8	in	W33	X	141	$19.68	21.04
No. of girders	Nb	7		W30	X	148	$20.46	21.91
Girder spacing	S	8.667	ft	W40	X	149	$20.57	22.04
Overhang		2	ft	W36	X	150	$20.69	22.16

Longest Span	L	70	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W33	X	118	$19.25	20.29
Slab Thickness	Ts	8	in	W33	X	130	$20.82	22.00
No. of girders	Nb	8		W30	X	132	$21.08	22.29
Girder spacing	S	7.43	ft	W36	X	135	$21.47	22.72
Overhang		2	ft	W33	X	141	$22.25	23.58

55 – 60-ft. span

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W33	X	130	$16.01	17.29
Slab Thickness	Ts	8.5	in	W30	X	132	$16.21	17.51
No. of girders	Nb	6		W36	X	135	$16.50	17.83
Girder spacing	S	10.4	ft	W33	X	141	$17.08	18.47
Overhang		2	ft	W27	X	146	$17.56	19.01

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	116	$16.77	17.83
Slab Thickness	Ts	8	in	W33	X	118	$17.00	18.08
No. of girders	Nb	7		W30	X	124	$17.69	18.83
Girder spacing	S	8.667	ft	W27	X	129	$18.26	19.46
Overhang		2	ft	W33	X	130	$18.37	19.58

Longest Span	L	60	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W30	X	99	$16.65	17.48
Slab Thickness	Ts	8	in	W30	X	108	$17.86	18.77
No. of girders	Nb	8		W27	X	114	$18.65	19.62
Girder spacing	S	7.43	ft	W30	X	116	$18.92	19.91
Overhang		2	ft	W24	X	117	$19.05	20.05

70 – 80-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	183	$21.02	22.92
Slab Thickness	Ts	8.5	in	W36	X	194	$22.03	24.10
No. of girders	Nb	6		W40	X	199	$22.49	24.63
Girder spacing	S	10.4	ft	W33	X	201	$22.67	24.85
Overhang		2	ft	W36	X	210	$23.48	25.81

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	160	$21.70	23.28
Slab Thickness	Ts	8	in	W40	X	167	$22.48	24.16
No. of girders	Nb	7		W33	X	169	$22.70	24.41
Girder spacing	S	8.667	ft	W36	X	170	$22.80	24.53
Overhang		2	ft	W36	X	182	$24.11	26.03

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	149	$23.17	24.58
Slab Thickness	Ts	8	in	W36	X	150	$23.29	24.72
No. of girders	Nb	8		W33	X	152	$23.55	25.01
Girder spacing	S	7.43	ft	W36	X	160	$24.56	26.15
Overhang		2	ft	W40	X	167	$25.45	27.15

Two Span .9L - L Design Table - 56 ft. width

80 – 90-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$23.87	26.25
Slab Thickness	Ts	8.5	in	W36	X	231	$25.28	27.97
No. of girders	Nb	6		W36	X	232	$25.37	28.08
Girder spacing	S	10.4	ft	W40	X	235	$25.64	28.40
Overhang		2	ft	W33	X	241	$26.16	29.04

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	183	$24.16	26.07
Slab Thickness	Ts	8	in	W40	X	199	$25.87	28.07
No. of girders	Nb	7		W33	X	201	$26.08	28.32
Girder spacing	S	8.667	ft	W36	X	210	$27.03	29.45
Overhang		2	ft	W40	X	211	$27.14	29.57

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	167	25.39	27.07
Slab Thickness	Ts	8	in	W36	X	182	27.25	29.22
No. of girders	Nb	8		W40	X	183	27.38	29.36
Girder spacing	S	7.43	ft	W30	X	191	28.36	30.50
Overhang		2	ft	W36	X	194	28.73	30.93

90 – 100-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	277	$29.31	33.02
Slab Thickness	Ts	8.5	in	W40	X	278	$29.39	33.13
No. of girders	Nb	6		W36	X	282	$29.73	33.56
Girder spacing	S	10.4	ft	W33	X	291	$30.47	34.52
Overhang		2	ft	W40	X	294	$30.72	34.84

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$27.64	30.20
Slab Thickness	Ts	8	in	W36	X	231	$29.30	32.20
No. of girders	Nb	7		W40	X	235	$29.71	32.70
Girder spacing	S	8.667	ft	W36	X	247	$30.93	34.20
Overhang		2	ft	W40	X	249	$31.13	34.45

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	199	$29.43	31.77
Slab Thickness	Ts	8	in	W40	X	211	$30.88	33.49
No. of girders	Nb	8		W40	X	215	$31.36	34.06
Girder spacing	S	7.43	ft	W33	X	221	$32.07	34.92
Overhang		2	ft	W36	X	231	$33.25	36.34

Three Spans Design Table - 39 ft. width

65 – 80 – 65-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	182	$20.32	22.36
Slab Thickness	Ts	9	in	W40	X	183	$20.41	22.46
No. of girders	Nb	4		W36	X	194	$21.38	23.59
Girder spacing	S	11.67	ft	W40	X	199	$21.82	24.10
Overhang		2	ft	W33	X	201	$21.99	24.31

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	149	$21.12	22.64
Slab Thickness	Ts	8	in	W36	X	150	$21.24	22.77
No. of girders	Nb	5		W33	X	152	$21.47	23.03
Girder spacing	S	8.75	ft	W36	X	160	$22.38	24.05
Overhang		2	ft	W40	X	167	$23.17	24.95

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W33	X	130	$22.32	23.51
Slab Thickness	Ts	8	in	W36	X	135	$23.02	24.28
No. of girders	Nb	6		W33	X	141	$23.85	25.20
Girder spacing	S	7	ft	W27	X	146	$24.55	25.97
Overhang		2	ft	W30	X	148	$24.82	26.28

70 – 90 – 70-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$21.76	24.01
Slab Thickness	Ts	9	in	W40	X	211	$22.80	25.24
No. of girders	Nb	4		W40	X	215	$23.14	25.65
Girder spacing	S	11.67	ft	W36	X	231	$24.50	27.29
Overhang		2	ft	W36	X	232	$24.58	27.39

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	$23.11	24.87
Slab Thickness	Ts	8	in	W36	X	170	$23.45	25.26
No. of girders	Nb	5		W36	X	182	$24.79	26.79
Girder spacing	S	8.75	ft	W40	X	183	$24.90	26.92
Overhang		2	ft	W30	X	191	$25.78	27.95

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	149	$24.91	26.36
Slab Thickness	Ts	8	in	W36	X	150	$25.04	26.52
No. of girders	Nb	6		W33	X	152	$25.32	26.82
Girder spacing	S	7	ft	W36	X	160	$26.41	28.05
Overhang		2	ft	W40	X	167	$27.36	29.13

70 - 80 – 70-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	183	$20.32	22.32
Slab Thickness	Ts	9	in	W36	X	194	$21.29	23.45
No. of girders	Nb	4		W40	X	199	$21.73	23.96
Girder spacing	S	11.67	ft	W33	X	201	$21.90	24.17
Overhang		2	ft	W36	X	210	$22.68	25.09

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	149	$21.03	22.51
Slab Thickness	Ts	8	in	W36	X	150	$21.15	22.64
No. of girders	Nb	5		W36	X	160	$22.29	23.92
Girder spacing	S	8.75	ft	W40	X	167	$23.08	24.82
Overhang		2	ft	W33	X	169	$23.30	25.08

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	135	$22.93	24.16
Slab Thickness	Ts	8	in	W33	X	141	$23.76	25.08
No. of girders	Nb	6		W30	X	148	$24.73	26.16
Girder spacing	S	7	ft	W40	X	149	$24.87	26.31
Overhang		2	ft	W36	X	150	$25.01	26.47

80 – 90 – 80-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	215	$23.14	25.65
Slab Thickness	Ts	9	in	W36	X	231	$24.50	27.29
No. of girders	Nb	4		W40	X	235	$24.84	27.70
Girder spacing	S	11.67	ft	W36	X	247	$25.83	28.93
Overhang		2	ft	W40	X	249	$26.00	29.14

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	183	$24.90	26.92
Slab Thickness	Ts	8	in	W36	X	194	$26.11	28.33
No. of girders	Nb	5		W40	X	199	$26.65	28.97
Girder spacing	S	8.75	ft	W33	X	201	$26.87	29.23
Overhang		2	ft	W36	X	210	$27.84	30.38

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	160	$26.41	28.05
Slab Thickness	Ts	8	in	W40	X	167	$27.35	29.12
No. of girders	Nb	6		W33	X	169	$27.62	29.43
Girder spacing	S	7	ft	W36	X	170	$27.76	29.58
Overhang		2	ft	W36	X	182	$29.36	31.43

Three Spans Design Table - 39 ft. width

80 – 100 – 80-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	249	$25.97	29.10
Slab Thickness	Ts	9	in	W36	X	262	$27.04	30.44
No. of girders	Nb	4		W40	X	264	$27.20	30.64
Girder spacing	S	11.67	ft	W40	X	277	$28.25	31.97
Overhang		2	ft	W40	X	278	$28.33	32.08

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$26.62	28.92
Slab Thickness	Ts	8	in	W36	X	210	$27.81	30.33
No. of girders	Nb	5		W40	X	211	$27.92	30.46
Girder spacing	S	8.75	ft	W40	X	215	$28.35	30.98
Overhang		2	ft	W33	X	221	$28.99	31.74

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	167	27.32	29.07
Slab Thickness	Ts	8	in	W36	X	182	29.33	31.38
No. of girders	Nb	6		W40	X	183	29.46	31.53
Girder spacing	S	7	ft	W36	X	194	30.91	33.23
Overhang		2	ft	W40	X	199	31.57	34.00

90 – 100 – 90-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	277	$28.25	31.98
Slab Thickness	Ts	9	in	W40	X	294	$29.60	33.72
No. of girders	Nb	4		W40	X	297	$29.83	34.03
Girder spacing	S	11.67	ft	W36	X	302	$30.22	34.54
Overhang		2	ft	W33	X	318	$31.45	36.18

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	215	$28.37	31.00
Slab Thickness	Ts	8	in	W36	X	231	$30.07	33.05
No. of girders	Nb	5		W36	X	232	$30.17	33.18
Girder spacing	S	8.75	ft	W40	X	235	$30.49	33.57
Overhang		2	ft	W33	X	241	$31.11	34.34

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	183	$29.49	31.57
Slab Thickness	Ts	8	in	W36	X	194	$30.94	33.27
No. of girders	Nb	6		W40	X	199	$31.60	34.04
Girder spacing	S	7.00	ft	W33	X	201	$31.86	34.34
Overhang		2	ft	W36	X	210	$33.03	35.73

Three Spans Design Table - 44 ft. width

65 – 80 – 65-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	199	$19.50	21.67
Slab Thickness	Ts	9	in	W36	X	210	$20.34	22.67
No. of girders	Nb	4		W40	X	211	$20.42	22.77
Girder spacing	S	13	ft	W40	X	215	$20.72	23.13
Overhang		2.5	ft	W33	X	221	$21.17	23.67

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W36	X	160	$19.98	21.60
Slab Thickness	Ts	8.25	in	W40	X	167	$20.68	22.40
No. of girders	Nb	5		W33	X	169	$20.88	22.62
Girder spacing	S	9.75	ft	W36	X	170	$20.98	22.74
Overhang		2.5	ft	W30	X	173	$21.27	23.08

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W36	X	135	$20.54	21.78
Slab Thickness	Ts	8	in	W33	X	141	$21.28	22.60
No. of girders	Nb	6		W30	X	148	$22.13	23.55
Girder spacing	S	7.8	ft	W40	X	149	$22.26	23.69
Overhang		2.5	ft	W36	X	150	$22.38	23.83

70 – 90 – 70-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	215	$20.66	23.04
Slab Thickness	Ts	9	in	W36	X	231	$21.87	24.49
No. of girders	Nb	4		W40	X	235	$22.16	24.86
Girder spacing	S	13	ft	W36	X	247	$23.05	25.95
Overhang		2.5	ft	W40	X	249	$23.20	26.13

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	183	$22.21	24.14
Slab Thickness	Ts	8.25	in	W40	X	194	$23.28	25.39
No. of girders	Nb	5		W40	X	199	$23.76	25.96
Girder spacing	S	9.75	ft	W33	X	201	$23.96	26.18
Overhang		2.5	ft	W36	X	210	$24.82	27.21

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W36	X	160	$23.54	25.12
Slab Thickness	Ts	8	in	W40	X	167	$24.38	26.08
No. of girders	Nb	6		W33	X	169	$24.62	26.35
Girder spacing	S	7.8	ft	W36	X	170	$24.74	26.49
Overhang		2.5	ft	W30	X	173	$25.10	26.90

70 – 80 – 70-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	199	$19.41	21.54
Slab Thickness	Ts	9	in	W40	X	211	$20.33	22.63
No. of girders	Nb	4		W40	X	215	$20.63	22.99
Girder spacing	S	13	ft	W33	X	221	$21.09	23.54
Overhang		2.5	ft	W36	X	231	$21.84	24.45

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	167	$20.59	22.27
Slab Thickness	Ts	8.25	in	W36	X	170	$20.89	22.61
No. of girders	Nb	5		W36	X	182	$22.08	23.98
Girder spacing	S	9.75	ft	W40	X	183	$22.17	24.09
Overhang		2.5	ft	W30	X	191	$22.96	25.00

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	149	$22.17	23.57
Slab Thickness	Ts	8	in	W36	X	150	$22.29	23.71
No. of girders	Nb	6		W33	X	152	$22.53	23.98
Girder spacing	S	7.8	ft	W36	X	160	$23.50	25.07
Overhang		2.5	ft	W40	X	167	$24.34	26.03

80 – 90 – 80-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	249	$23.20	26.13
Slab Thickness	Ts	9	in	W36	X	262	$24.14	27.31
No. of girders	Nb	4		W40	X	264	$24.29	27.50
Girder spacing	S	13	ft	W40	X	277	$25.21	28.68
Overhang		2.5	ft	W40	X	278	$25.28	28.77

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	199	$23.76	25.95
Slab Thickness	Ts	8.25	in	W36	X	210	$24.82	27.20
No. of girders	Nb	5		W40	X	211	$24.91	27.32
Girder spacing	S	9.75	ft	W40	X	215	$25.29	27.77
Overhang		2.5	ft	W33	X	221	$25.86	28.45

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	167	$24.37	26.07
Slab Thickness	Ts	8	in	W36	X	182	$26.16	28.12
No. of girders	Nb	6		W40	X	183	$26.27	28.25
Girder spacing	S	7.8	ft	W30	X	191	$27.21	29.34
Overhang		2.5	ft	W36	X	194	$27.56	29.75

Three Spans Design Table - 44 ft. width

80 – 100 – 80-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	$25.19	28.64
Slab Thickness	Ts	9	in	W40	X	294	$26.38	30.19
No. of girders	Nb	4		W40	X	297	$26.59	30.46
Girder spacing	S	13	ft	W36	X	302	$26.93	30.91
Overhang		2.5	ft	W33	X	318	$28.02	32.37

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	215	$25.26	27.73
Slab Thickness	Ts	8.25	in	W36	X	231	$26.77	29.54
No. of girders	Nb	5		W36	X	232	$26.86	29.66
Girder spacing	S	9.75	ft	W40	X	235	$27.14	30.00
Overhang		2.5	ft	W33	X	241	$27.69	30.68

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	183	26.24	28.20
Slab Thickness	Ts	8	in	W36	X	194	27.53	29.70
No. of girders	Nb	6		W40	X	199	28.11	30.38
Girder spacing	S	7.8	ft	W33	X	201	28.34	30.66
Overhang		2.5	ft	W36	X	210	29.37	31.88

90 – 100 – 90-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	297	$26.59	30.46
Slab Thickness	Ts	9	in	W40	X	324	$28.43	32.92
No. of girders	Nb	4		W40	X	327	$28.63	33.19
Girder spacing	S	13	ft	W36	X	330	$28.83	33.46
Overhang		2.5	ft	W40	X	331	$28.90	33.56

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W36	X	247	$28.26	31.39
Slab Thickness	Ts	8.25	in	W40	X	249	$28.45	31.62
No. of girders	Nb	5		W36	X	256	$29.08	32.41
Girder spacing	S	9.75	ft	W36	X	262	$29.63	33.09
Overhang		2.5	ft	W33	X	263	$29.72	33.21

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	199	$28.14	30.42
Slab Thickness	Ts	8	in	W40	X	211	$29.52	32.06
No. of girders	Nb	6		W40	X	215	$29.97	32.61
Girder spacing	S	7.80	ft	W33	X	221	$30.65	33.42
Overhang		2.5	ft	W36	X	231	$31.78	34.79

Three Spans Design Table - 56 ft. width

65 – 80 – 65-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	160	$18.87	20.47
Slab Thickness	Ts	8.5	in	W40	X	167	$19.53	21.22
No. of girders	Nb	6		W33	X	169	$19.72	21.43
Girder spacing	S	10.4	ft	W36	X	170	$19.82	21.54
Overhang		2	ft	W36	X	182	$20.93	22.82

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	149	$20.50	21.93
Slab Thickness	Ts	8	in	W36	X	150	$20.61	22.05
No. of girders	Nb	7		W33	X	152	$20.83	22.30
Girder spacing	S	8.667	ft	W36	X	160	$21.72	23.30
Overhang		2	ft	W40	X	167	$22.49	24.18

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W33	X	130	$20.74	21.89
Slab Thickness	Ts	8	in	W36	X	135	$21.39	22.60
No. of girders	Nb	8		W33	X	141	$22.16	23.46
Girder spacing	S	7.43	ft	W27	X	146	$22.80	24.18
Overhang		2	ft	W30	X	148	$23.06	24.46

70 – 90 – 70-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	183	$20.98	22.86
Slab Thickness	Ts	8.5	in	W36	X	194	$21.99	24.04
No. of girders	Nb	6		W40	X	199	$22.45	24.58
Girder spacing	S	10.4	ft	W33	X	201	$22.63	24.79
Overhang		2	ft	W36	X	210	$23.44	25.75

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	167	$22.44	24.11
Slab Thickness	Ts	8	in	W40	X	170	$22.77	24.49
No. of girders	Nb	7		W36	X	182	$24.08	25.99
Girder spacing	S	8.667	ft	W40	X	183	$24.19	26.11
Overhang		2	ft	W30	X	191	$25.05	27.11

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	149	$23.14	24.55
Slab Thickness	Ts	8	in	W36	X	150	$23.27	24.69
No. of girders	Nb	8		W33	X	152	$23.52	24.97
Girder spacing	S	7.43	ft	W36	X	160	$24.54	26.12
Overhang		2	ft	W40	X	167	$25.42	27.12

70 – 80 – 70-ft. span

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	167	$19.45	21.09
Slab Thickness	Ts	8.5	in	W36	X	170	$19.73	21.42
No. of girders	Nb	6		W36	X	182	$20.85	22.70
Girder spacing	S	10.4	ft	W40	X	183	$20.94	22.81
Overhang		2	ft	W30	X	191	$21.68	23.67

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	149	$20.41	21.81
Slab Thickness	Ts	8	in	W36	X	150	$20.52	21.94
No. of girders	Nb	7		W33	X	152	$20.75	22.19
Girder spacing	S	8.667	ft	W36	X	160	$21.64	23.19
Overhang		2	ft	W40	X	167	$22.41	24.06

Longest Span	L	80	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	135	$21.30	22.49
Slab Thickness	Ts	8	in	W33	X	141	$22.08	23.35
No. of girders	Nb	8		W30	X	148	$22.97	24.35
Girder spacing	S	7.43	ft	W40	X	149	$23.10	24.49
Overhang		2	ft	W36	X	150	$23.23	24.63

80 – 90 – 80-ft. span

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	199	$22.44	24.57
Slab Thickness	Ts	8.5	in	W40	X	211	$23.53	25.85
No. of girders	Nb	6		W40	X	215	$23.88	26.28
Girder spacing	S	10.4	ft	W33	X	221	$24.42	26.92
Overhang		2	ft	W36	X	231	$25.30	28.00

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	182	$24.07	25.98
Slab Thickness	Ts	8	in	W40	X	183	$24.18	26.10
No. of girders	Nb	7		W36	X	194	$25.36	27.48
Girder spacing	S	8.667	ft	W40	X	199	$25.89	28.10
Overhang		2	ft	W33	X	201	$26.10	28.35

Longest Span	L	90	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	160	$24.53	26.10
Slab Thickness	Ts	8	in	W40	X	167	$25.41	27.10
No. of girders	Nb	8		W33	X	169	$25.66	27.39
Girder spacing	S	7.43	ft	W36	X	170	$25.79	27.53
Overhang		2	ft	W36	X	182	$27.28	29.25

Three Spans Design Table - 56 ft. width

80 – 100 – 80-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$23.85	26.23
Slab Thickness	Ts	8.5	in	W36	X	231	$25.27	27.94
No. of girders	Nb	6		W40	X	235	$25.62	28.37
Girder spacing	S	10.4	ft	W36	X	247	$26.66	29.66
Overhang		2	ft	W40	X	249	$26.83	29.87

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	199	$25.85	28.05
Slab Thickness	Ts	8	in	W36	X	210	$27.01	29.42
No. of girders	Nb	7		W40	X	211	$27.12	29.55
Girder spacing	S	8.667	ft	W40	X	215	$27.53	30.05
Overhang		2	ft	W33	X	221	$28.16	30.80

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	182	27.23	29.19
Slab Thickness	Ts	8	in	W40	X	183	27.36	29.33
No. of girders	Nb	8		W36	X	194	28.71	30.90
Girder spacing	S	7.43	ft	W40	X	199	29.31	31.62
Overhang		2	ft	W33	X	201	29.56	31.90

90 – 100 – 90-ft. span

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	249	$26.86	29.91
Slab Thickness	Ts	8.5	in	W36	X	262	$27.97	31.31
No. of girders	Nb	6		W40	X	264	$28.14	31.52
Girder spacing	S	10.4	ft	W40	X	277	$29.24	32.91
Overhang		2	ft	W40	X	278	$29.32	33.02

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	211	$27.15	29.60
Slab Thickness	Ts	8	in	W40	X	215	$27.57	30.10
No. of girders	Nb	7		W36	X	231	$29.23	32.10
Girder spacing	S	8.667	ft	W36	X	232	$29.33	32.22
Overhang		2	ft	W40	X	235	$29.64	32.60

Longest Span	L	100	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	183	$27.40	29.39
Slab Thickness	Ts	8	in	W40	X	199	$29.36	31.67
No. of girders	Nb	8		W33	X	201	$29.60	31.96
Girder spacing	S	7.43	ft	W36	X	210	$30.68	33.24
Overhang		2	ft	W40	X	211	$30.80	33.39

Spans > 100 ft Design Table - 39 ft. width

110-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	297	$43.84	49.25
Slab Thickness	Ts	8	in	W40	X	324	$46.95	53.40
No. of girders	Nb	6		W40	X	327	$47.29	53.86
Girder spacing	S	7	ft	W36	X	330	$47.63	54.32
Overhang		2	ft	W40	X	331	$47.74	54.48

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	249	$44.11	48.28
Slab Thickness	Ts	8	in	W40	X	264	$46.25	50.97
No. of girders	Nb	7		W40	X	277	$48.09	53.30
Girder spacing	S	5.833	ft	W40	X	278	$48.23	53.48
Overhang		2	ft	W36	X	282	$48.78	54.20

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	215	$44.46	47.75
Slab Thickness	Ts	8	in	W36	X	231	$47.17	51.03
No. of girders	Nb	8		W40	X	235	$47.84	51.85
Girder spacing	S	5	ft	W36	X	247	$49.84	54.32
Overhang		2	ft	W40	X	249	$50.17	54.73

110 – 110-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	235	$36.19	39.54
Slab Thickness	Ts	8	in	W36	X	247	$37.69	41.39
No. of girders	Nb	6		W40	X	249	$37.93	41.70
Girder spacing	S	7	ft	W36	X	256	$38.80	42.77
Overhang		2	ft	W36	X	262	$39.53	43.70

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$36.56	39.14
Slab Thickness	Ts	8	in	W40	X	211	$38.37	41.30
No. of girders	Nb	7		W40	X	215	$38.97	42.01
Girder spacing	S	5.833	ft	W36	X	231	$41.35	44.88
Overhang		2	ft	W36	X	232	$41.50	45.06

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	183	$38.74	41.03
Slab Thickness	Ts	8	in	W36	X	194	$40.68	43.29
No. of girders	Nb	8		W40	X	199	$41.55	44.31
Girder spacing	S	5	ft	W33	X	201	$41.90	44.72
Overhang		2	ft	W36	X	210	$43.46	46.57

120-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	362	$55.71	59.33
Slab Thickness	Ts	8	in	W40	X	372	$56.78	60.87
No. of girders	Nb	6		W40	X	392	$58.89	63.95
Girder spacing	S	7	ft	W36	X	395	$59.20	64.41
Overhang		2	ft	W40	X	397	$59.41	64.71

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	297	$56.16	56.98
Slab Thickness	Ts	8	in	W40	X	324	$59.78	61.82
No. of girders	Nb	7		W40	X	327	$60.18	62.36
Girder spacing	S	5.833	ft	W36	X	330	$60.58	62.90
Overhang		2	ft	W40	X	331	$60.71	63.08

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	277	$60.78	60.55
Slab Thickness	Ts	8	in	W40	X	278	$60.94	60.76
No. of girders	Nb	8		W36	X	282	$61.57	61.58
Girder spacing	S	5	ft	W40	X	294	$63.47	64.04
Overhang		2	ft	W40	X	297	$63.94	64.66

120 – 120-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	277	$43.58	46.00
Slab Thickness	Ts	8	in	W40	X	294	$45.60	48.61
No. of girders	Nb	6		W40	X	297	$45.95	49.08
Girder spacing	S	7	ft	W36	X	302	$46.54	49.85
Overhang		2	ft	W33	X	318	$48.38	52.31

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	247	$46.30	47.75
Slab Thickness	Ts	8	in	W40	X	249	$46.59	48.11
No. of girders	Nb	7		W36	X	256	$47.59	49.36
Girder spacing	S	5.833	ft	W36	X	262	$48.45	50.44
Overhang		2	ft	W33	X	263	$48.59	50.62

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	211	$46.61	46.76
Slab Thickness	Ts	8	in	W40	X	215	$47.30	47.58
No. of girders	Nb	8		W36	X	231	$50.02	50.87
Girder spacing	S	5	ft	W36	X	232	$50.18	51.07
Overhang		2	ft	W40	X	235	$50.69	51.69

Spans > 100 ft Design Table - 39 ft. width

100 – 110 – 100-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	215	$33.63	36.45
Slab Thickness	Ts	8	in	W36	X	231	$35.67	38.91
No. of girders	Nb	6		W40	X	235	$36.18	39.53
Girder spacing	S	7	ft	W36	X	247	$37.67	41.37
Overhang		2	ft	W40	X	249	$37.92	41.68

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$36.54	39.12
Slab Thickness	Ts	8	in	W36	X	210	$38.21	41.10
No. of girders	Nb	7		W40	X	211	$38.36	41.28
Girder spacing	S	5.833	ft	W40	X	215	$38.96	41.99
Overhang		2	ft	W33	X	221	$39.85	43.07

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	182	38.55	40.80
Slab Thickness	Ts	8	in	W40	X	183	38.73	41.01
No. of girders	Nb	8		W36	X	194	40.66	43.27
Girder spacing	S	5	ft	W40	X	199	41.54	44.29
Overhang		2	ft	W33	X	201	41.88	44.70

110 – 120 – 110-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	249	$39.50	41.68
Slab Thickness	Ts	8	in	W40	X	277	$42.91	45.98
No. of girders	Nb	6		W40	X	278	$43.03	46.14
Girder spacing	S	7	ft	W36	X	282	$43.51	46.75
Overhang		2	ft	W33	X	291	$44.58	48.14

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	215	$40.81	42.00
Slab Thickness	Ts	8	in	W36	X	231	$43.18	44.87
No. of girders	Nb	7		W40	X	235	$43.77	45.59
Girder spacing	S	5.833	ft	W36	X	247	$45.52	47.74
Overhang		2	ft	W40	X	249	$45.81	48.10

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	199	$43.65	44.30
Slab Thickness	Ts	8	in	W40	X	211	$45.73	46.76
No. of girders	Nb	8		W40	X	215	$46.41	47.58
Girder spacing	S	5	ft	W33	X	221	$47.44	48.81
Overhang		2	ft	W36	X	231	$49.13	50.86

100 – 120 – 100-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W36	X	247	$39.38	41.41
Slab Thickness	Ts	8	in	W40	X	249	$39.63	41.72
No. of girders	Nb	6		W36	X	262	$41.23	43.72
Girder spacing	S	7	ft	W33	X	263	$41.35	43.87
Overhang		2	ft	W40	X	264	$41.47	44.02

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	211	$40.35	41.31
Slab Thickness	Ts	8	in	W40	X	215	$40.95	42.03
No. of girders	Nb	7		W36	X	231	$43.33	44.90
Girder spacing	S	5.833	ft	W36	X	232	$43.48	45.08
Overhang		2	ft	W40	X	235	$43.92	45.62

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	39	ft	W40	X	183	$41.00	41.05
Slab Thickness	Ts	8	in	W40	X	199	$43.81	44.33
No. of girders	Nb	8		W33	X	201	$44.16	44.74
Girder spacing	S	5.00	ft	W36	X	210	$45.72	46.59
Overhang		2	ft	W40	X	211	$45.89	46.79

Spans > 100 ft Design Table - 44 ft. width

110-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	324	$41.79	47.67
Slab Thickness	Ts	8	in	W36	X	361	$45.42	52.71
No. of girders	Nb	6		W40	X	362	$45.51	52.85
Girder spacing	S	8	ft	W40	X	372	$46.47	54.21
Overhang		2	ft	W33	X	387	$47.87	56.26

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	$42.78	47.57
Slab Thickness	Ts	8	in	W40	X	294	$44.87	50.27
No. of girders	Nb	7		W40	X	297	$45.23	50.75
Girder spacing	S	6.667	ft	W36	X	302	$45.84	51.54
Overhang		2	ft	W33	X	318	$47.74	54.09

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	249	$44.63	48.82
Slab Thickness	Ts	8	in	W36	X	262	$46.51	51.18
No. of girders	Nb	8		W40	X	264	$46.80	51.54
Girder spacing	S	5.714	ft	W40	X	277	$48.66	53.91
Overhang		2	ft	W40	X	278	$48.80	54.09

110 – 110-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	249	$33.78	37.27
Slab Thickness	Ts	8	in	W40	X	264	$35.41	39.32
No. of girders	Nb	6		W40	X	277	$36.80	41.09
Girder spacing	S	8	ft	W40	X	278	$36.91	41.23
Overhang		2	ft	W36	X	282	$37.33	41.77

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	215	$34.70	37.54
Slab Thickness	Ts	8	in	W36	X	231	$36.80	40.08
No. of girders	Nb	7		W40	X	235	$37.32	40.72
Girder spacing	S	6.667	ft	W36	X	247	$38.87	42.63
Overhang		2	ft	W40	X	249	$39.13	42.95

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	199	$36.98	39.57
Slab Thickness	Ts	8	in	W40	X	211	$38.82	41.75
No. of girders	Nb	8		W40	X	215	$39.43	42.48
Girder spacing	S	5.714	ft	W33	X	221	$40.33	43.57
Overhang		2	ft	W36	X	231	$41.83	45.38

120-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	324	$53.16	55.13
Slab Thickness	Ts	8	in	W36	X	361	$57.40	61.02
No. of girders	Nb	7		W40	X	362	$57.51	61.17
Girder spacing	S	6.667	ft	W40	X	372	$58.62	62.77
Overhang		2	ft	W33	X	387	$60.26	65.15

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	297	$56.83	57.63
Slab Thickness	Ts	8	in	W40	X	324	$60.51	62.54
No. of girders	Nb	8		W40	X	327	$60.91	63.09
Girder spacing	S	5.714	ft	W36	X	330	$61.31	63.63
Overhang		2	ft	W40	X	331	$61.44	63.81

120 – 120-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	297	$40.89	43.81
Slab Thickness	Ts	8	in	W40	X	324	$43.65	47.50
No. of girders	Nb	6		W40	X	327	$43.95	47.90
Girder spacing	S	8	ft	W36	X	330	$44.25	48.31
Overhang		2	ft	W40	X	331	$44.35	48.45

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	$44.97	47.40
Slab Thickness	Ts	8	in	W40	X	278	$45.09	47.55
No. of girders	Nb	7		W36	X	282	$45.59	48.19
Girder spacing	S	6.667	ft	W33	X	291	$46.69	49.62
Overhang		2	ft	W40	X	294	$47.06	50.10

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	235	$45.07	46.10
Slab Thickness	Ts	8	in	W36	X	247	$46.84	48.28
No. of girders	Nb	8		W40	X	249	$47.14	48.65
Girder spacing	S	5.714	ft	W36	X	256	$48.16	49.92
Overhang		2	ft	W36	X	262	$49.02	51.01

Spans > 100 ft Design Table - 44 ft. width

100 – 110 – 100-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	249	$33.77	37.26
Slab Thickness	Ts	8	in	W36	X	262	$35.18	39.03
No. of girders	Nb	6		W40	X	264	$35.40	39.30
Girder spacing	S	8	ft	W40	X	277	$36.79	41.08
Overhang		2	ft	W40	X	278	$36.90	41.21

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	211	$34.15	36.88
Slab Thickness	Ts	8	in	W40	X	215	$34.68	37.52
No. of girders	Nb	7		W36	X	231	$36.79	40.07
Girder spacing	S	6.667	ft	W36	X	232	$36.92	40.23
Overhang		2	ft	W40	X	235	$37.31	40.70

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	199	$36.96	39.55
Slab Thickness	Ts	8	in	W36	X	210	$38.65	41.55
No. of girders	Nb	8		W40	X	211	$38.80	41.73
Girder spacing	S	5.714	ft	W40	X	215	$39.41	42.45
Overhang		2	ft	W33	X	221	$40.32	43.55

110 – 120 – 110-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	$38.19	41.07
Slab Thickness	Ts	8	in	W40	X	297	$40.29	43.80
No. of girders	Nb	6		W36	X	302	$40.81	44.48
Girder spacing	S	8.00	ft	W40	X	324	$43.05	47.48
Overhang		2	ft	W40	X	327	$43.35	47.89

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	249	$40.75	42.93
Slab Thickness	Ts	8	in	W36	X	262	$42.40	45.00
No. of girders	Nb	7		W40	X	264	$42.66	45.32
Girder spacing	S	6.667	ft	W40	X	277	$44.28	47.39
Overhang		2	ft	W40	X	278	$44.40	47.54

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	215	$41.28	42.46
Slab Thickness	Ts	8	in	W36	X	231	$43.69	45.37
No. of girders	Nb	8		W40	X	235	$44.29	46.10
Girder spacing	S	5.714	ft	W36	X	247	$46.06	48.28
Overhang		2	ft	W40	X	249	$46.35	48.64

100 – 120 – 100-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	277	38.31	41.11
Slab Thickness	Ts	8	in	W40	X	278	38.42	41.25
No. of girders	Nb	6		W36	X	282	38.84	41.79
Girder spacing	S	8	ft	W40	X	294	40.10	43.43
Overhang		2	ft	W40	X	297	40.41	43.84

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	235	$39.08	40.74
Slab Thickness	Ts	8	in	W36	X	247	$40.63	42.65
No. of girders	Nb	7		W40	X	249	$40.88	42.97
Girder spacing	S	6.667	ft	W36	X	256	$41.78	44.08
Overhang		2	ft	W36	X	262	$42.53	45.04

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	44	ft	W40	X	199	$38.98	39.58
Slab Thickness	Ts	8	in	W40	X	211	$40.82	41.77
No. of girders	Nb	8		W40	X	215	$41.43	42.49
Girder spacing	S	5.714	ft	W36	X	231	$43.84	45.40
Overhang		2	ft	W36	X	232	$43.99	45.58

Spans > 100 ft Design Table – 56 ft. width

110-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	297	$40.72	45.80
Slab Thickness	Ts	8	in	W36	X	302	$41.27	46.51
No. of girders	Nb	8		W40	X	324	$43.61	49.66
Girder spacing	S	7.429	ft	W40	X	327	$43.93	50.08
Overhang		2	ft	W36	X	330	$44.24	50.51

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	249	$39.58	43.43
Slab Thickness	Ts	8	in	W40	X	277	$43.14	47.93
No. of girders	Nb	9		W40	X	278	$43.26	48.09
Girder spacing	S	6.5	ft	W36	X	282	$43.76	48.73
Overhang		2	ft	W40	X	294	$45.25	50.66

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	247	$43.52	47.57
Slab Thickness	Ts	8	in	W40	X	249	$43.80	47.92
No. of girders	Nb	10		W36	X	256	$44.80	49.17
Girder spacing	S	5.778	ft	W36	X	262	$45.66	50.25
Overhang		2	ft	W40	X	264	$45.94	50.60

110 – 110-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	235	$33.61	36.78
Slab Thickness	Ts	8	in	W36	X	247	$35.00	38.49
No. of girders	Nb	8		W40	X	249	$35.23	38.78
Girder spacing	S	7.429	ft	W36	X	256	$36.03	39.78
Overhang		2	ft	W36	X	262	$36.72	40.63

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	211	$34.43	37.16
Slab Thickness	Ts	8	in	W40	X	215	$34.97	37.80
No. of girders	Nb	9		W36	X	231	$37.10	40.37
Girder spacing	S	6.5	ft	W36	X	232	$37.23	40.53
Overhang		2	ft	W40	X	235	$37.63	41.01

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	199	$36.29	38.84
Slab Thickness	Ts	8	in	W36	X	210	$37.95	40.80
No. of girders	Nb	10		W40	X	211	$38.10	40.98
Girder spacing	S	5.778	ft	W40	X	215	$38.70	41.69
Overhang		2	ft	W33	X	221	$39.59	42.77

120-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	324	$53.62	55.57
Slab Thickness	Ts	8	in	W40	X	327	$53.98	56.05
No. of girders	Nb	9		W36	X	330	$54.33	56.53
Girder spacing	S	6.5	ft	W40	X	331	$54.45	56.69
Overhang		2	ft	W33	X	354	$57.11	60.39

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	277	$53.04	53.01
Slab Thickness	Ts	8	in	W40	X	294	$55.39	56.05
No. of girders	Nb	10		W40	X	297	$55.79	56.59
Girder spacing	S	5.778	ft	W36	X	302	$56.47	57.48
Overhang		2	ft	W33	X	318	$58.61	60.34

120 – 120-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	277	$40.48	42.77
Slab Thickness	Ts	8	in	W40	X	294	$42.35	45.20
No. of girders	Nb	8		W40	X	297	$42.68	45.62
Girder spacing	S	7.429	ft	W36	X	302	$43.22	46.34
Overhang		2	ft	W33	X	318	$44.93	48.62

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	249	$41.78	43.25
Slab Thickness	Ts	8	in	W36	X	262	$43.45	45.34
No. of girders	Nb	9		W40	X	264	$43.71	45.66
Girder spacing	S	6.5	ft	W40	X	277	$45.35	47.75
Overhang		2	ft	W40	X	278	$45.47	47.91

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$41.29	41.68
Slab Thickness	Ts	8	in	W36	X	231	$43.65	44.54
No. of girders	Nb	10		W40	X	235	$44.24	45.25
Girder spacing	S	5.778	ft	W36	X	247	$45.98	47.40
Overhang		2	ft	W40	X	249	$46.27	47.75

Spans > 100 ft Design Table – 56 ft. width

100 – 110 – 100-ft. span

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$31.24	33.90
Slab Thickness	Ts	8	in	W36	X	231	$33.13	36.19
No. of girders	Nb	8		W40	X	235	$33.60	36.76
Girder spacing	S	7.429	ft	W36	X	247	$34.99	38.47
Overhang		2	ft	W40	X	249	$35.22	38.76

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	199	$32.79	35.21
Slab Thickness	Ts	8	in	W40	X	211	$34.42	37.14
No. of girders	Nb	9		W40	X	215	$34.95	37.78
Girder spacing	S	6.5	ft	W33	X	221	$35.76	38.74
Overhang		2	ft	W36	X	231	$37.08	40.35

Longest Span	L	110	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	183	$33.82	35.96
Slab Thickness	Ts	8	in	W36	X	194	$35.51	37.92
No. of girders	Nb	10		W40	X	199	$36.27	38.81
Girder spacing	S	5.778	ft	W33	X	201	$36.57	39.17
Overhang		2	ft	W36	X	210	$37.93	40.78

110 – 120 – 110-ft. span

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	277	$39.86	42.76
Slab Thickness	Ts	8	in	W40	X	278	$39.97	42.90
No. of girders	Nb	8		W36	X	282	$40.41	43.48
Girder spacing	S	7.429	ft	W33	X	291	$41.40	44.76
Overhang		2	ft	W40	X	294	$41.73	45.19

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W36	X	247	$40.83	42.93
Slab Thickness	Ts	8	in	W40	X	249	$41.09	43.25
No. of girders	Nb	9		W36	X	256	$41.99	44.37
Girder spacing	S	6.5	ft	W36	X	262	$42.76	45.34
Overhang		2	ft	W33	X	263	$42.89	45.50

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$40.52	41.68
Slab Thickness	Ts	8	in	W36	X	231	$42.89	44.54
No. of girders	Nb	10		W36	X	232	$43.03	44.72
Girder spacing	S	5.778	ft	W40	X	235	$43.47	45.25
Overhang		2	ft	W33	X	241	$44.34	46.32

100 – 120 – 100-ft. span

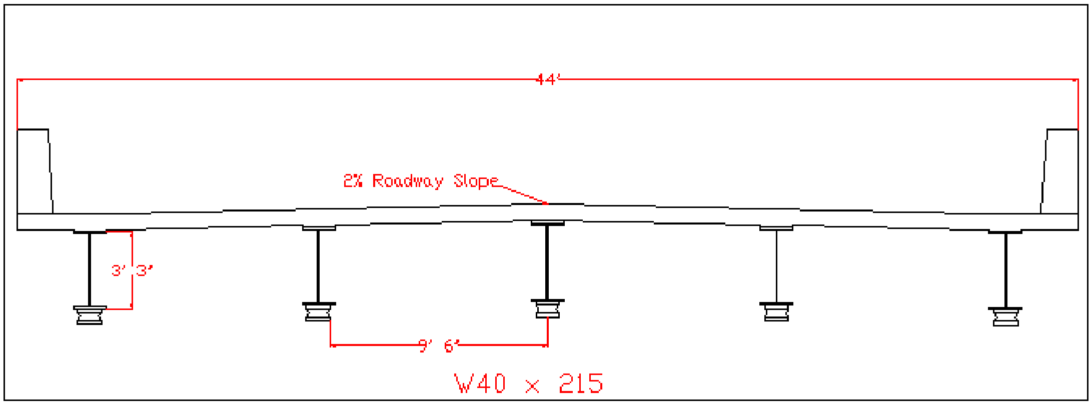
Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	249	$36.81	38.80
Slab Thickness	Ts	8	in	W36	X	262	$38.29	40.65
No. of girders	Nb	8		W40	X	264	$38.52	40.94
Girder spacing	S	7.429	ft	W40	X	277	$39.98	42.80
Overhang		2	ft	W40	X	278	$40.09	42.94

Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	215	$36.74	37.82
Slab Thickness	Ts	8	in	W36	X	231	$38.87	40.39
No. of girders	Nb	9		W40	X	235	$39.40	41.03
Girder spacing	S	6.5	ft	W33	X	241	$40.18	42.00
Overhang		2	ft	W36	X	247	$40.96	42.96

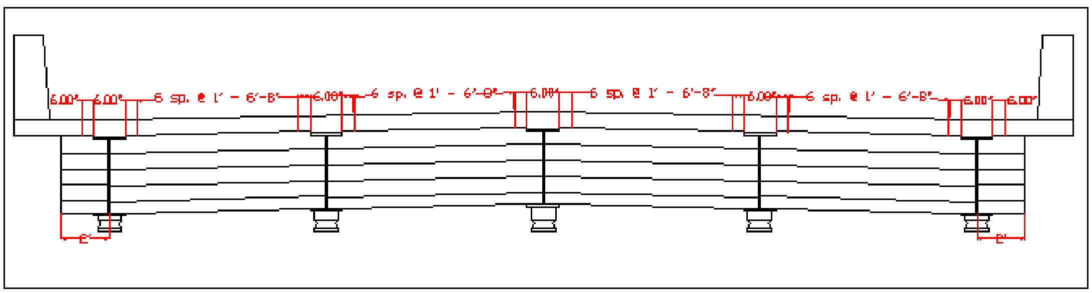
Longest Span	L	120	ft	Nominal Depth		Weight per linear foot	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
Full Width	w	56	ft	W40	X	199	$38.26	38.85
Slab Thickness	Ts	8	in	W40	X	211	$40.06	41.00
No. of girders	Nb	10		W40	X	215	$40.66	41.71
Girder spacing	S	5.778	ft	W33	X	221	$41.55	42.78
Overhang		2	ft	W36	X	231	$43.03	44.57

APPENDIX D: DESIGN DETAILS

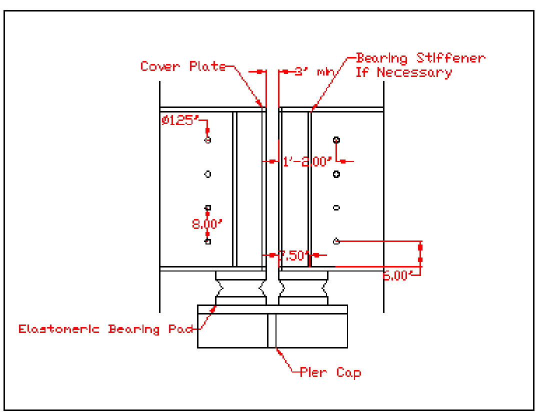
Three Span Steel Bridge Details (Same as example in Appendix A)
80 – 100 – 80-ft. spans
44-ft. out to out width



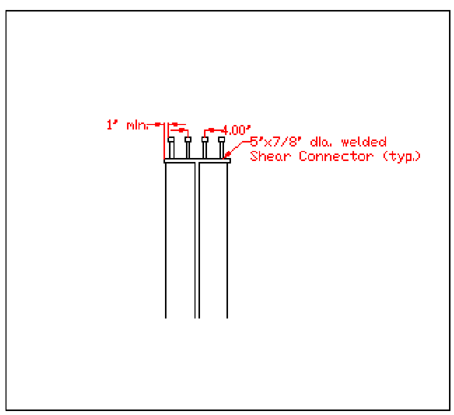
Roadway Cross Section



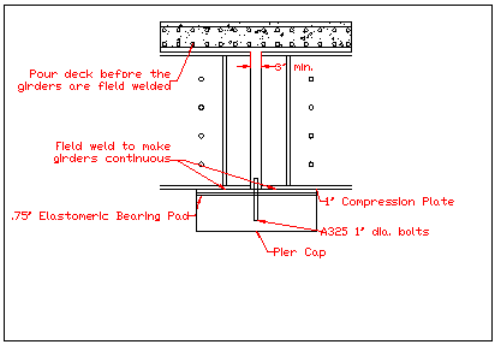
Concrete Diaphragm at Pier



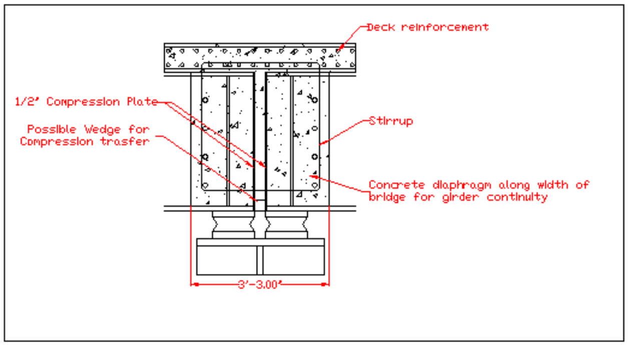
Stage 1



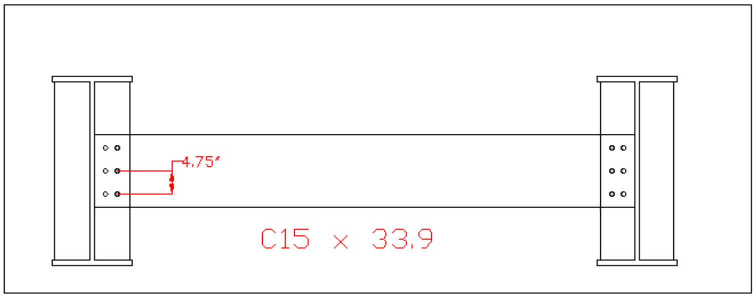
Stage 1



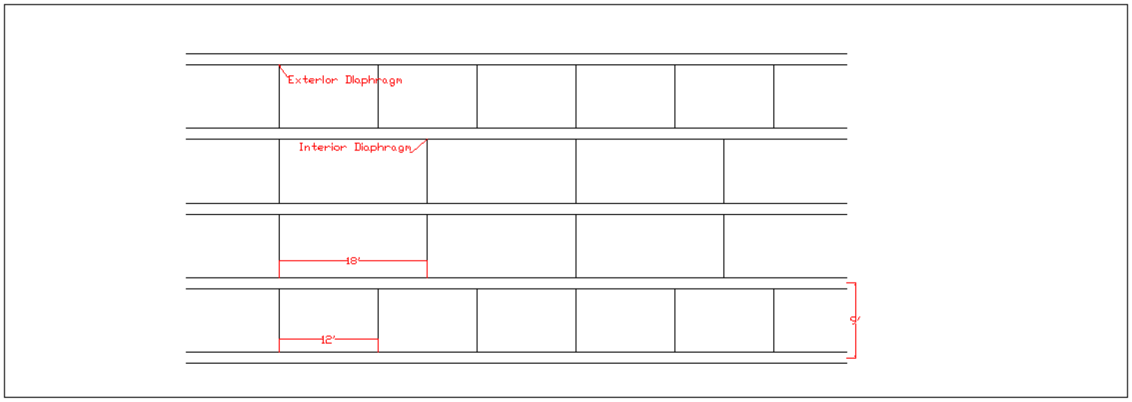
Stage 2
Field Weld



Stage 2
Concrete Diapragm



Diaphragm Cross Section



Framing Plan Spans 1 and 3

Framing Plan Span 2

APPENDIX E:
CSU-CBA USER'S MANUAL AND EXAMPLES

CSU-CBA

(Colorado State University-Continuous Beam Analysis)

Program Users Guide

Alex Stone
John W. van de Lindt
Thang N. Dao

Introduction

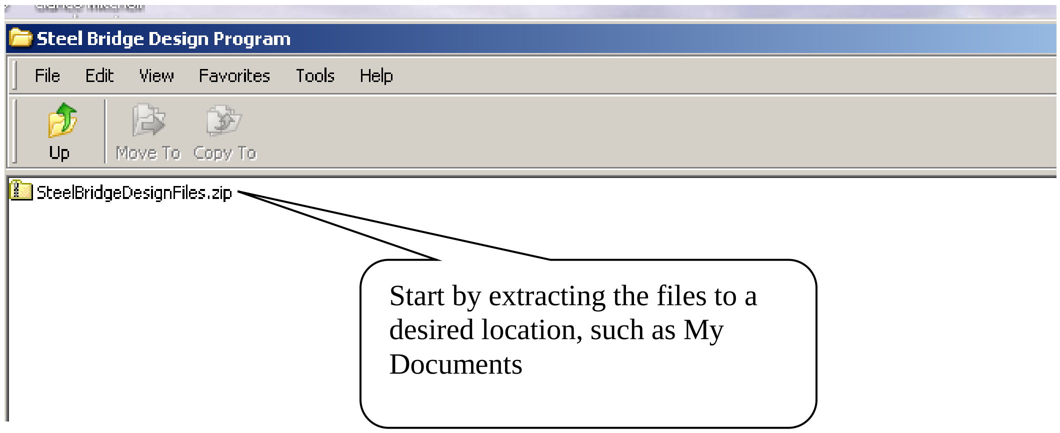
The purpose of this spreadsheet is to find the minimum rolled steel girder size required to support the deck and traffic loads. The girders are designed by a method called simple for dead load and continuous for live load. This implies the beams are designed as simply supported for dead load one (beam weight and concrete deck) and continuous for all other loads (wearing surface, traffic loads, rails, etc). The beams are made continuous at the piers after casting the deck by connecting two separate beams using various methods including using a concrete diaphragm or welding the beams to a connection plate.

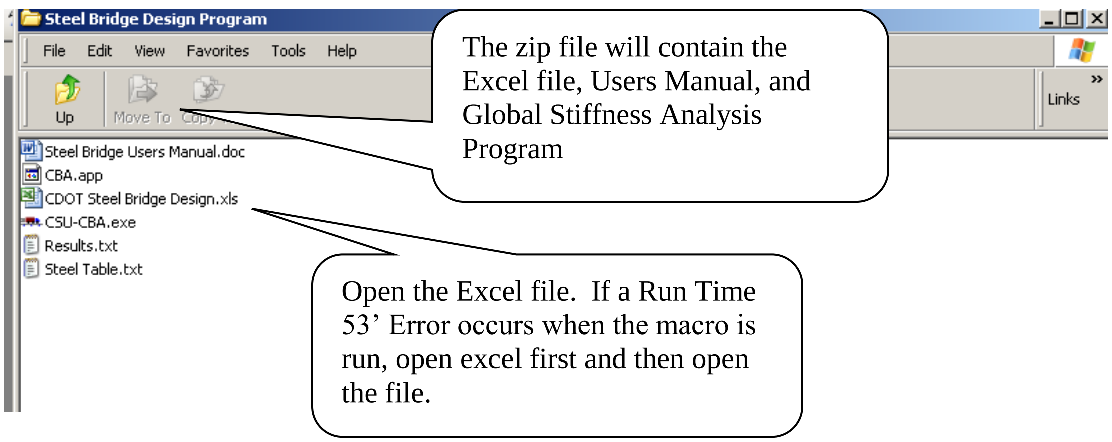
Using this method, the spreadsheet was designed to give the user control to select/input various bridge parameters in order to find the lightest wide flange beam to support the loads. Once the user has entered bridge data and run the spreadsheet to find the minimum beam size, the total structural weight of the beams is found and a cost analysis is preformed to give an erected steel price estimate.

The design program gives the user freedom to create a bridge with any number of spans and lengths. A global stiffness analysis program was created to compute bending moments and shears for any number of trucks, spans, and span lengths. Once the analysis is saved, results are imported into excel and minimum beam sizes are found using a macro that checks all AISC wide flange beams against the AASHTO LRFD Bridge Design Specifications.

AASHTO LRFD Bridge Design 3.6.1.3 requires the larger extreme force effect of one design truck with variable axle spacing specified by article 3.6.1.2.2 and the lane load or 90% of two design trucks spaced at least 50 ft apart and 90% of the lane load. To do this, two analyses may be required to find which loading combination causes the larger extreme force effect.

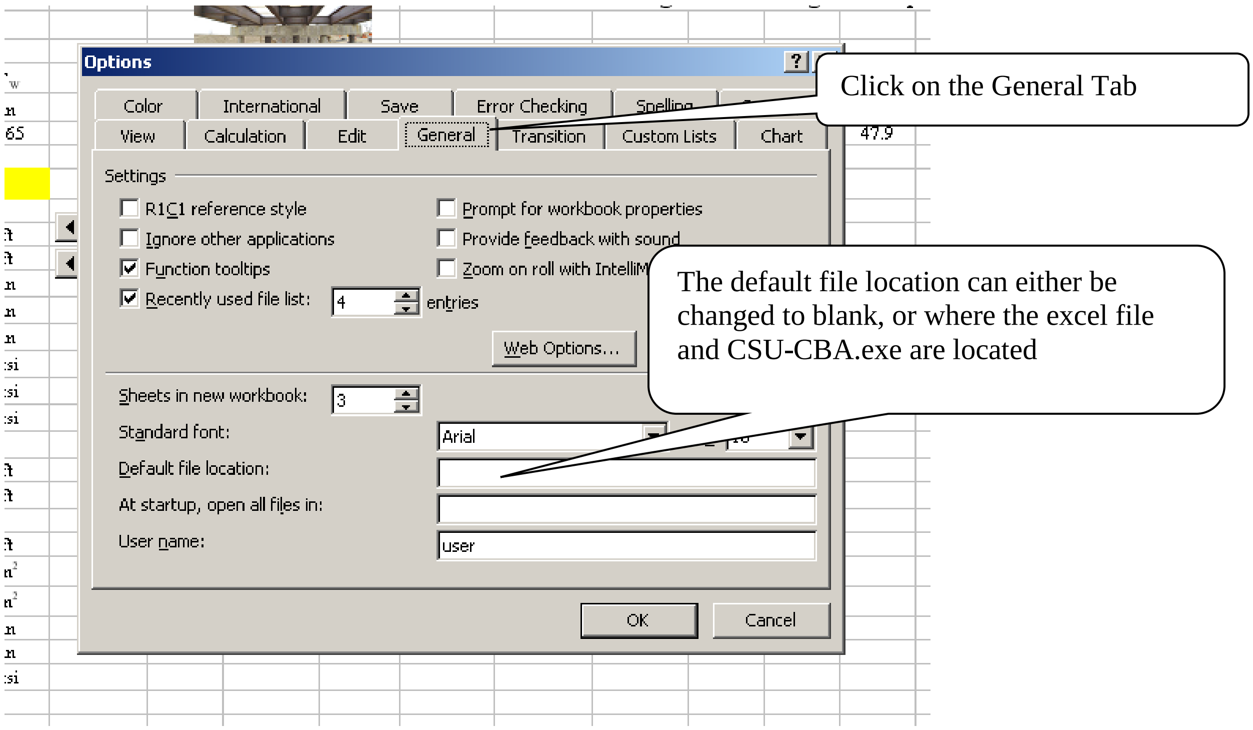
Initial Setup



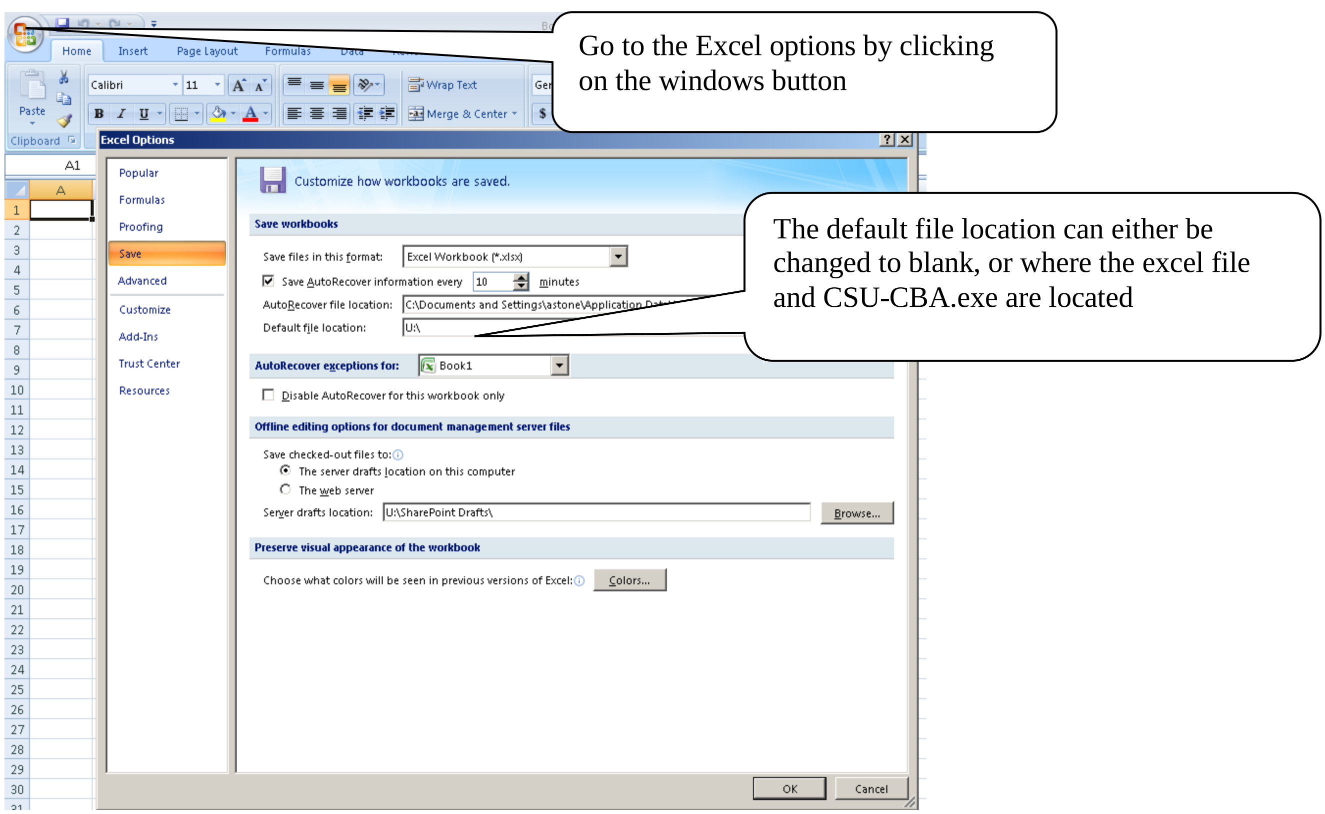


Note: In order for the program to run correctly, the CSU-CBA.exe file must be located where excel looks for and saves files. In many cases the default location is the "My Documents" directory. It is recommended that the default file location be changed to a blank value in the Excel options. If this is done, the .exe file must be located in the same directory as the excel file.

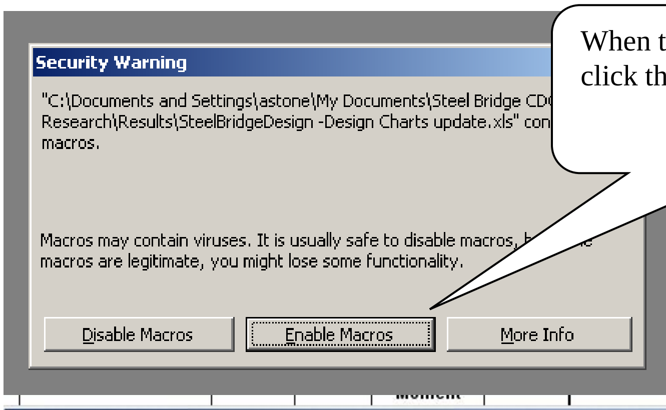
In Excel 2003, go the tools menu, then options to change the default file location.



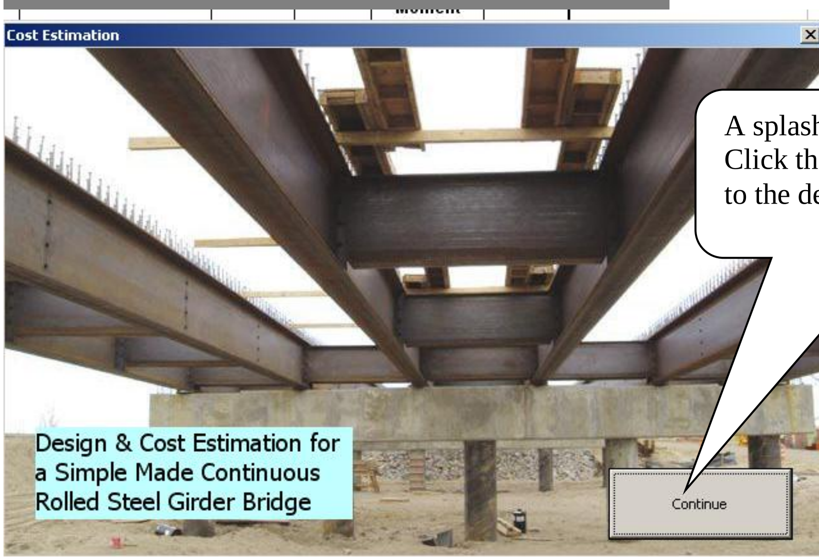
In Excel 2007, go to the Excel option, then the save button to change the default file location.



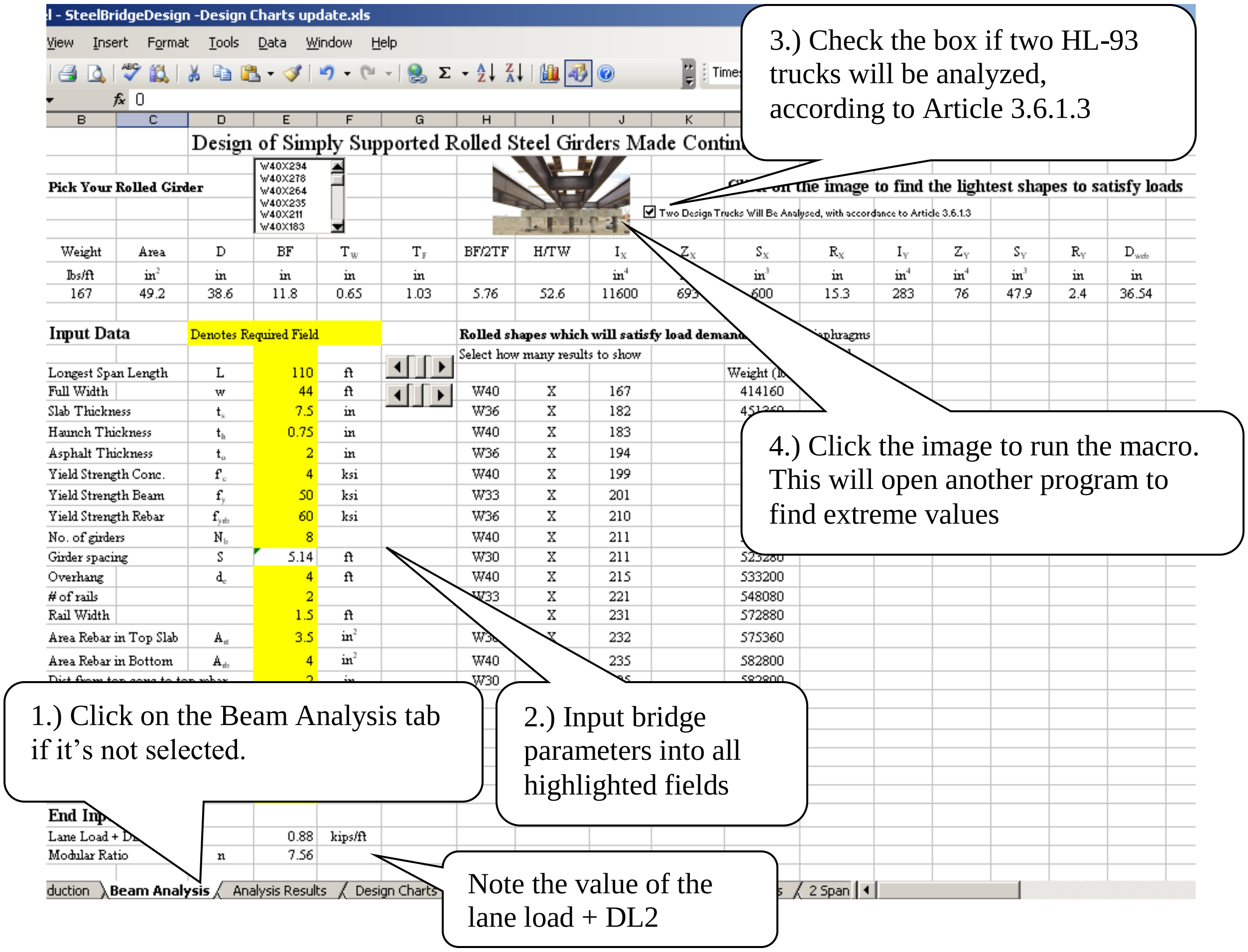
Operating the Steel Bridge Design Program



When the program is opened, click the Enable Macros button.

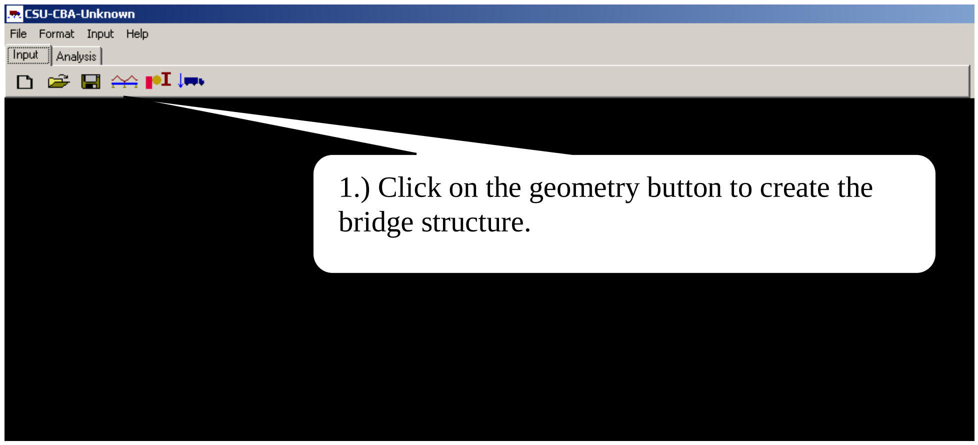


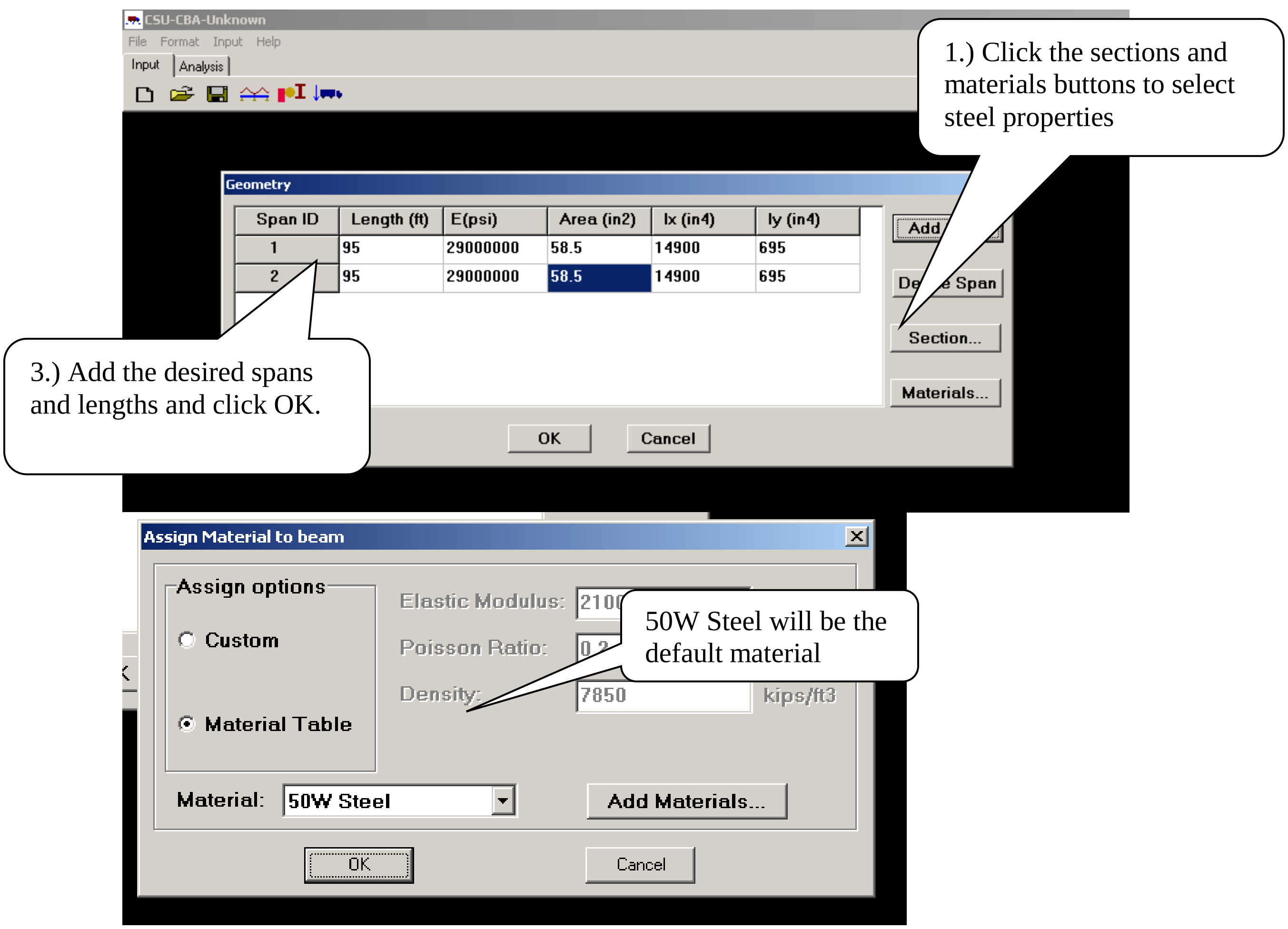
A splash screen will appear. Click the Continue button to get to the design program.

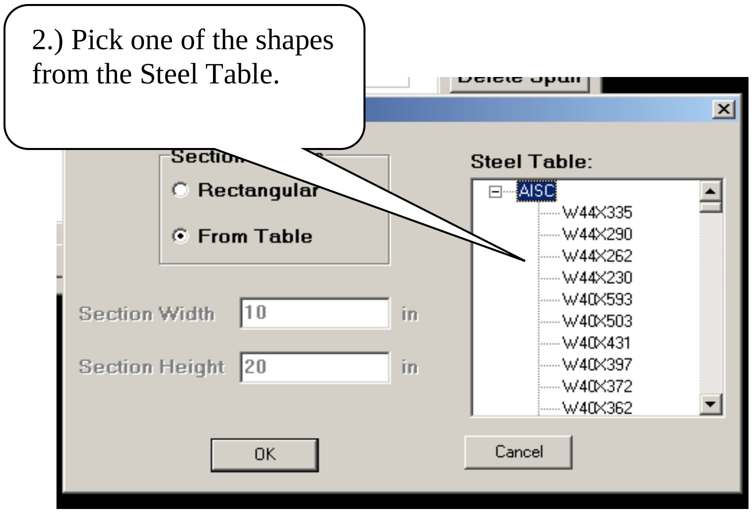


NOTE: In the global stiffness analysis, the distributed load represents the lane load plus the dead load two. The value shown above indicates the 640 lbs/ft lane load plus the load of the wearing surface, rails etc. If there will be an extra dead load that is not accounted for in the excel program, simply add the extra load when putting in the distributed load in the global stiffness analysis program.

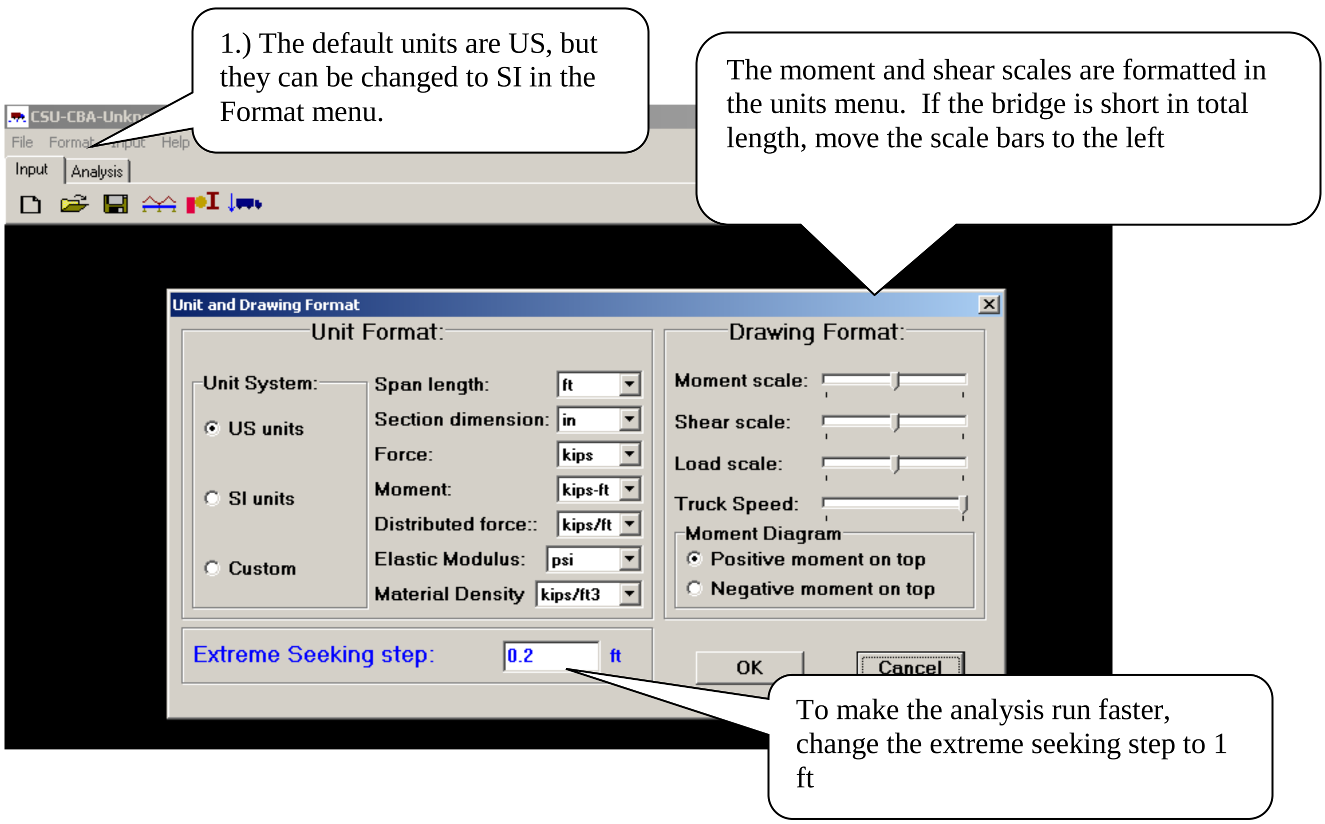
Running the global stiffness analysis program

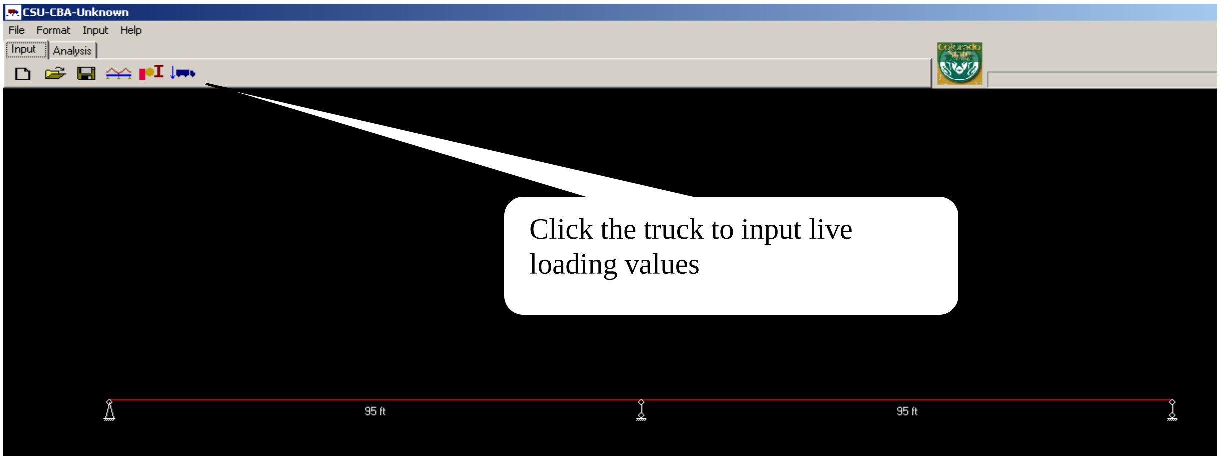


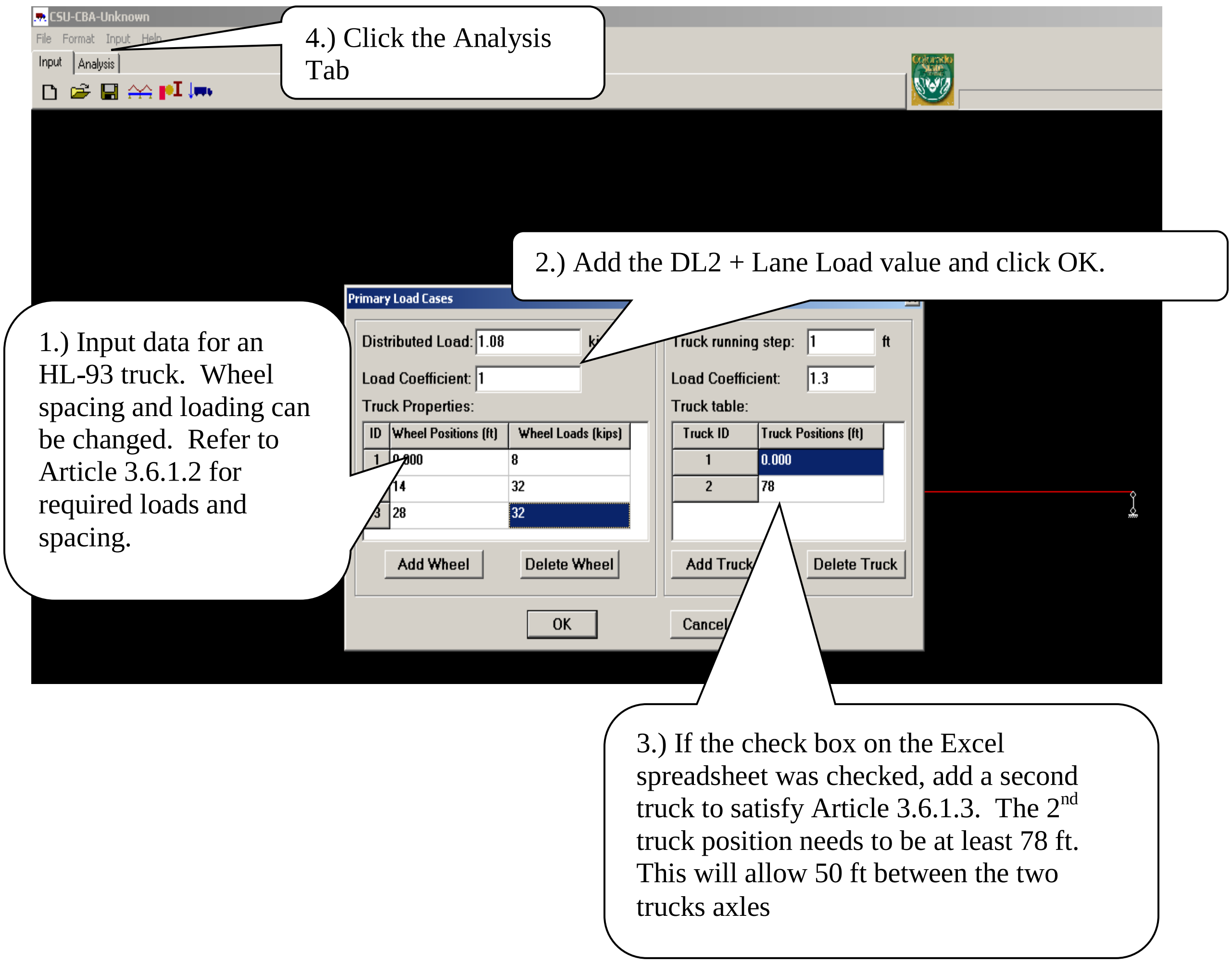




NOTE: Because this research was looking at prismatic cross sections of all the same material, it does not matter which material shape is chosen from the section selection because the EI value will drop out.

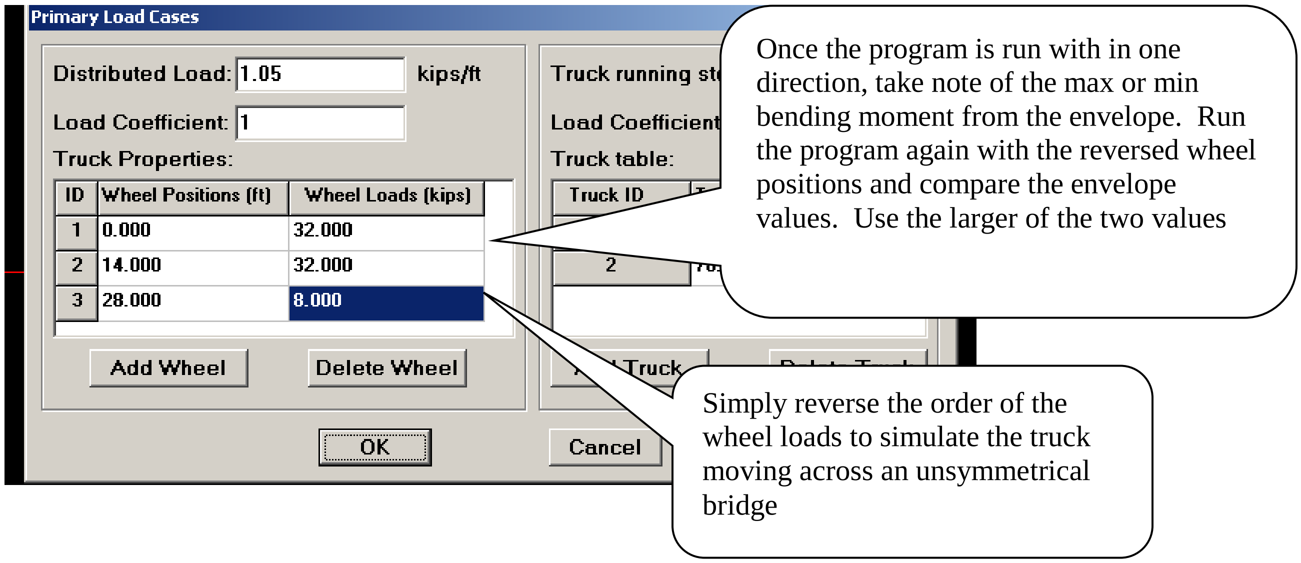



CSU-CBA-Unknown
File Format Input Help
Input Analysis
Click the truck to input live loading values
95 ft
95 ft


CSU-CBA-Unknown
File Format Input Help
Input Analysis
4.) Click the Analysis Tab
2.) Add the DL2 + Lane Load value and click OK.
Primary Load Cases
Distributed Load: 1.08
Load Coefficient: 1
Truck Properties:
ID Wheel Positions (ft) Wheel Loads (kips)
Truck running step: 1 ft
Load Coefficient: 1.3
Truck table:
Truck ID Truck Positions (ft)
1 0.000
2 78
Add Wheel
Delete Wheel
Add Truck
Delete Truck
OK
Cancel
1.) Input data for an HL-93 truck. Wheel spacing and loading can be changed. Refer to Article 3.6.1.2 for required loads and spacing.
3.) If the check box on the Excel spreadsheet was checked, add a second truck to satisfy Article 3.6.1.3. The 2nd truck position needs to be at least 78 ft. This will allow 50 ft between the two trucks axles

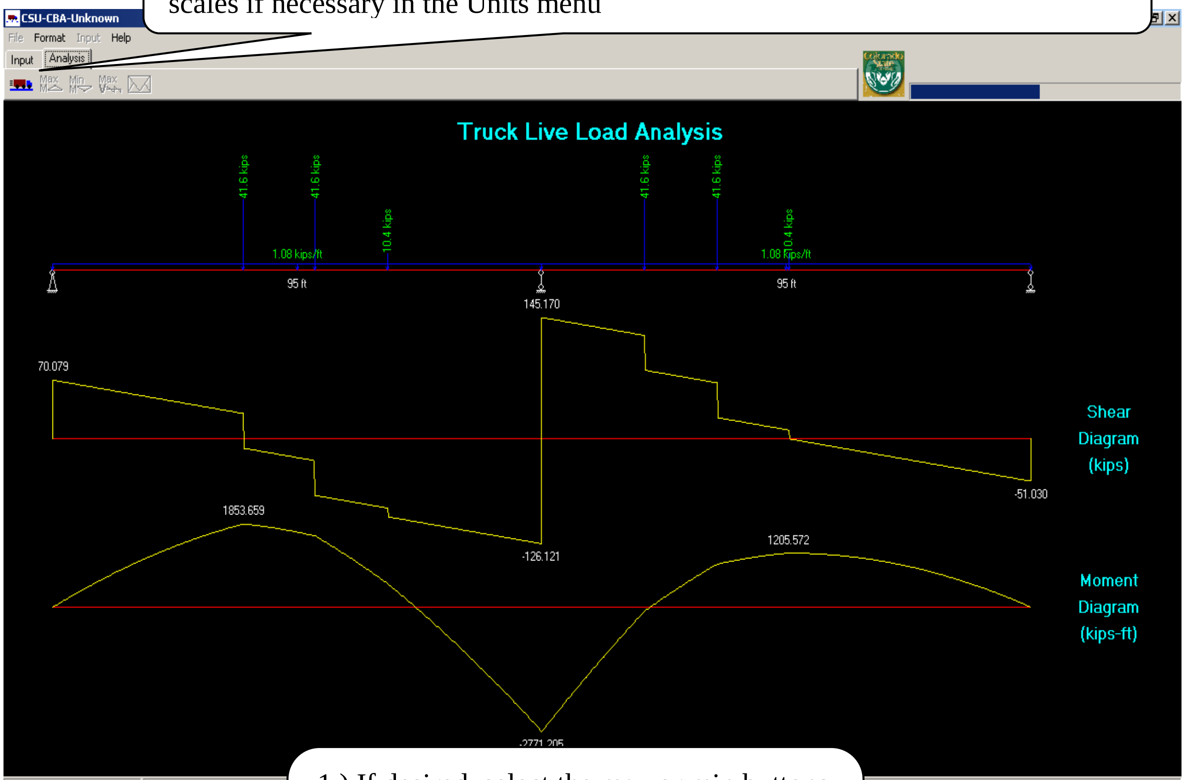
Live Loading for an Unsymmetrical Span Configuration

If the span configuration is unsymmetrical, the truck must be run in both directions to find which creates the largest extreme force.

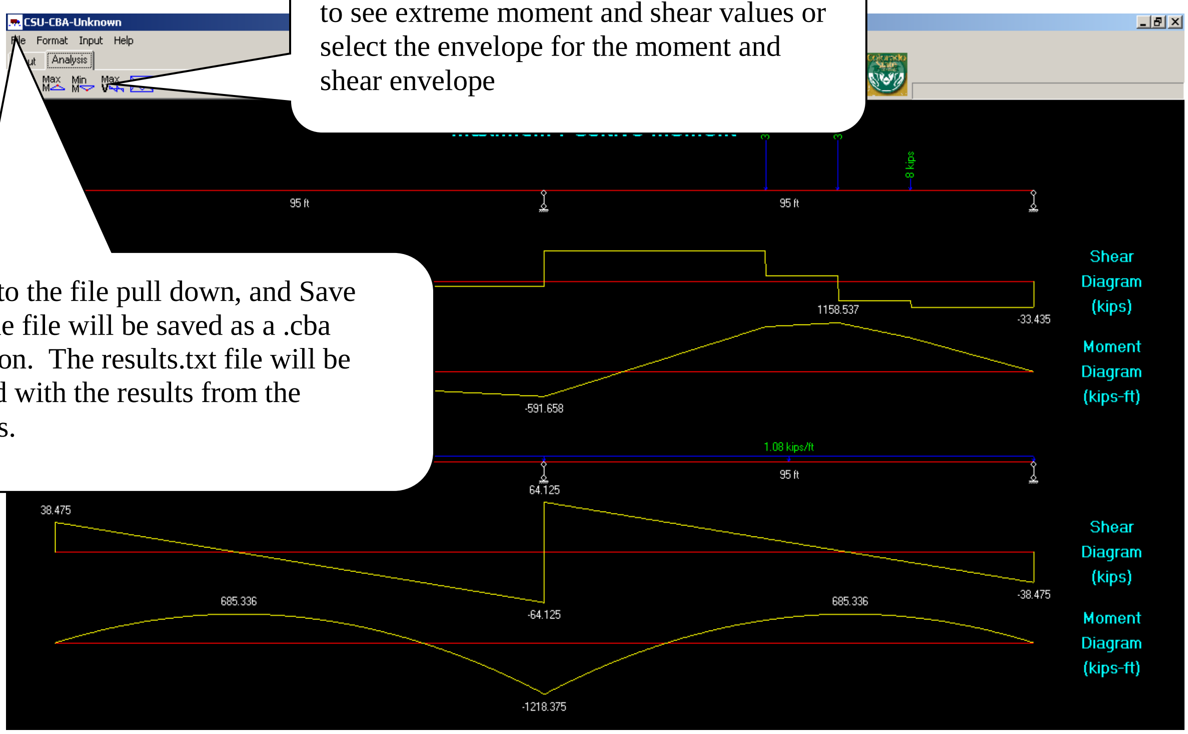


Executing the analysis

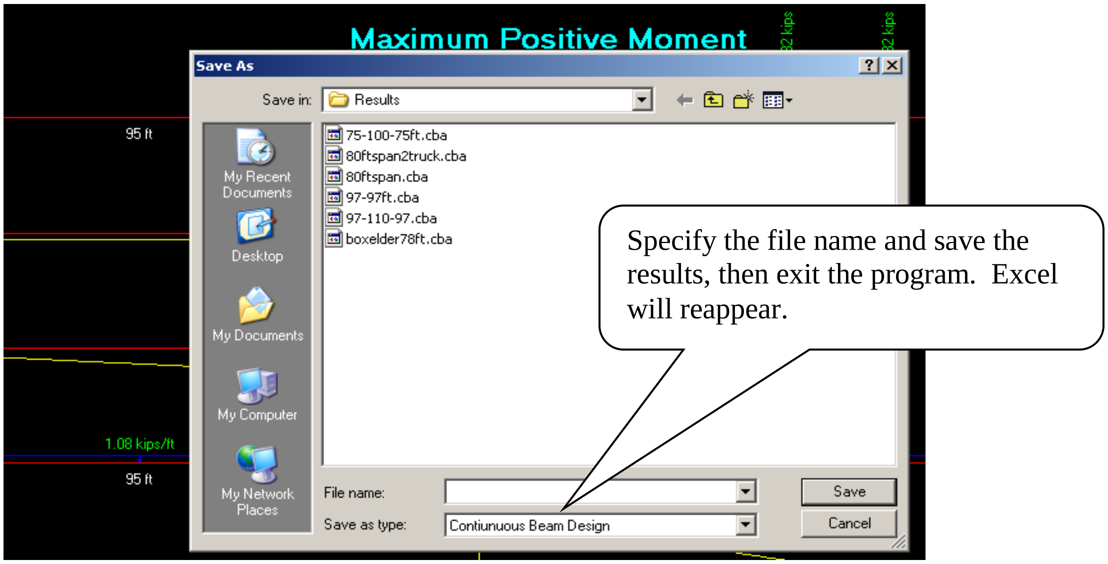
Click the truck icon to run find resulting moments and shears. Change drawing scales if necessary in the Units menu

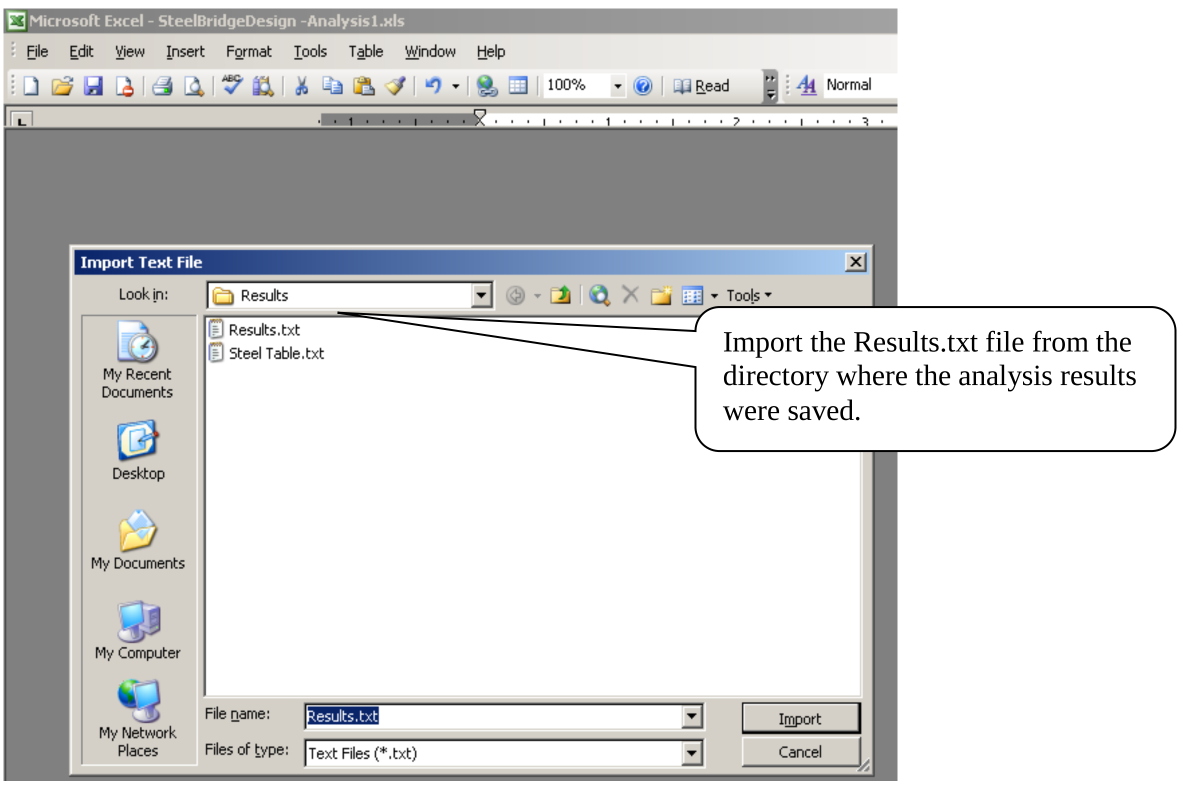


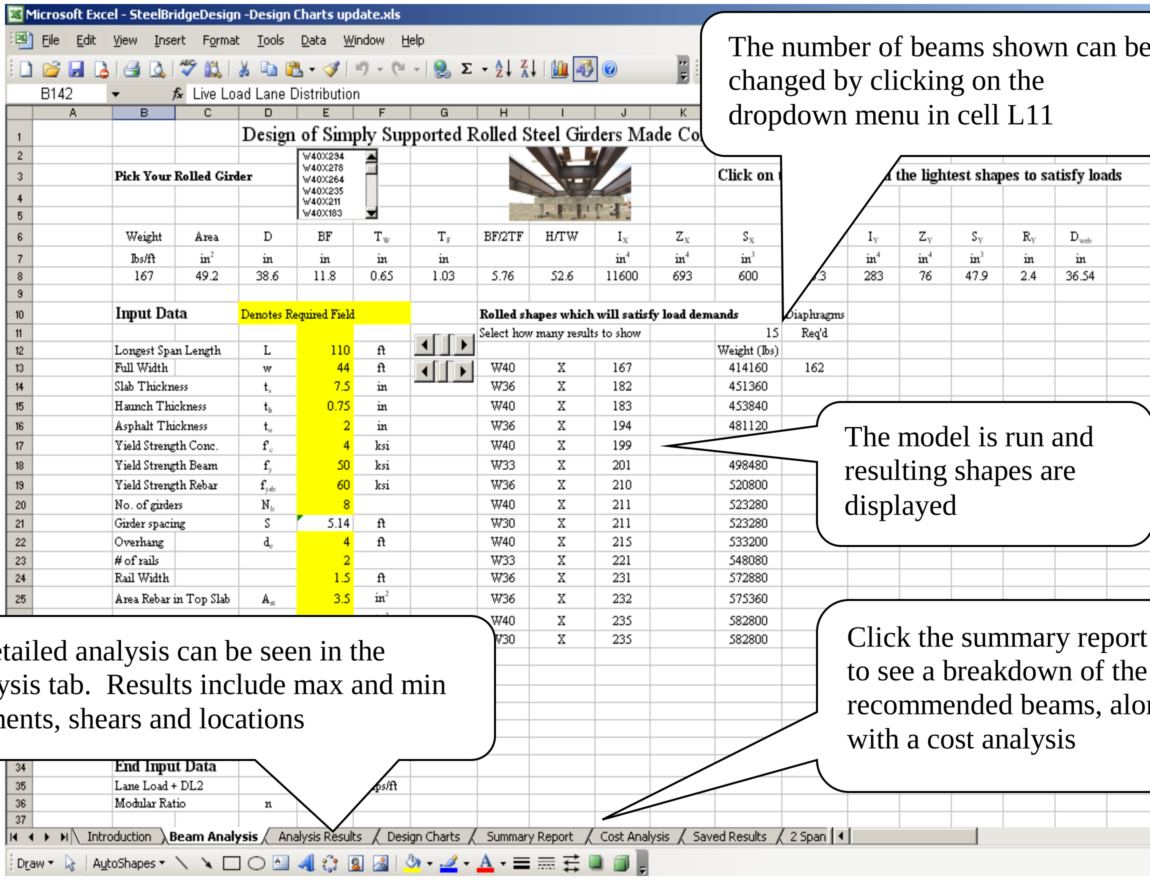
1.) If desired, select the max or min buttons to see extreme moment and shear values or select the envelope for the moment and shear envelope



2.) Go to the file pull down, and Save As. The file will be saved as a .cba extension. The results.txt file will be updated with the results from the analysis.


Maximum Positive Moment
Save As
Save in: Results
75-100-75ft.cba
80ftspan2truck.cba
80ftspan.cba
97-97ft.cba
97-110-97.cba
boxelder78ft.cba
95 ft
1.08 kips/ft
95 ft
File name:
Save as type: Contiunuous Beam Design
Save
Cancel
Specify the file name and save the results, then exit the program. Excel will reappear.


Microsoft Excel - SteelBridgeDesign -Analysis1.xls
Import Text File
Look in: Results
Results.txt
Steel Table.txt
File name: Results.txt
Files of type: Text Files (*.txt)
Import
Cancel
Import the Results.txt file from the directory where the analysis results were saved.



The number of beams shown can be changed by clicking on the dropdown menu in cell L11

The model is run and resulting shapes are displayed

A detailed analysis can be seen in the analysis tab. Results include max and min moments, shears and locations

Click the summary report tab to see a breakdown of the recommended beams, along with a cost analysis

Resulting Moments and Shears (Analysis Results Tab)

	A	B	C	D	E	F	G
1	THE RESULTS BASED	ON THE WORST CASE	OF THE COMBINATION				
2							
3	LOAD CASE RESULTS:						
4	Extreme type	Ex	treme Value Ex	treme sec	tion	Truck position	Coefficient
5		kip	s-ft or kips	ft		ft	
6	Max Moment (Lane L	oad)	667.65	269		361	1
7	Min Moment (Lane L	oad)	-967.585	100		157	1
8	Max Shear (Lane L	oad)	53.676	210		316	1
9	Max Moment (Truck	Load)	1227.876	269		361	1.3
10	Min Moment (Truck	Load)	-1306.869	100		157	1.3
11	Max Shear (Truck	Load)	79.784	210		316	1.3
12							
13	COMBINATION RESULT	S:					
14	Extreme type	Extreme Value	Extreme section	Tr	u		
15		kips-ft or kips	ft				
16	Max Moment	2263.889	269				
17	Min Moment	-2666.514	100				
18	Max Shear	157.395	210				
19	Total Length:	310	ft				
20	Longest Span:	110	ft				
21	Distributed Load:	0.88	kips/ft				
22							
23							

The Analysis Results section shows data that was entered into the analysis program and resulting moments and shears.

☑ Use IM Factor ☑ Use Service II Factors ☑ Use Strength I Factors

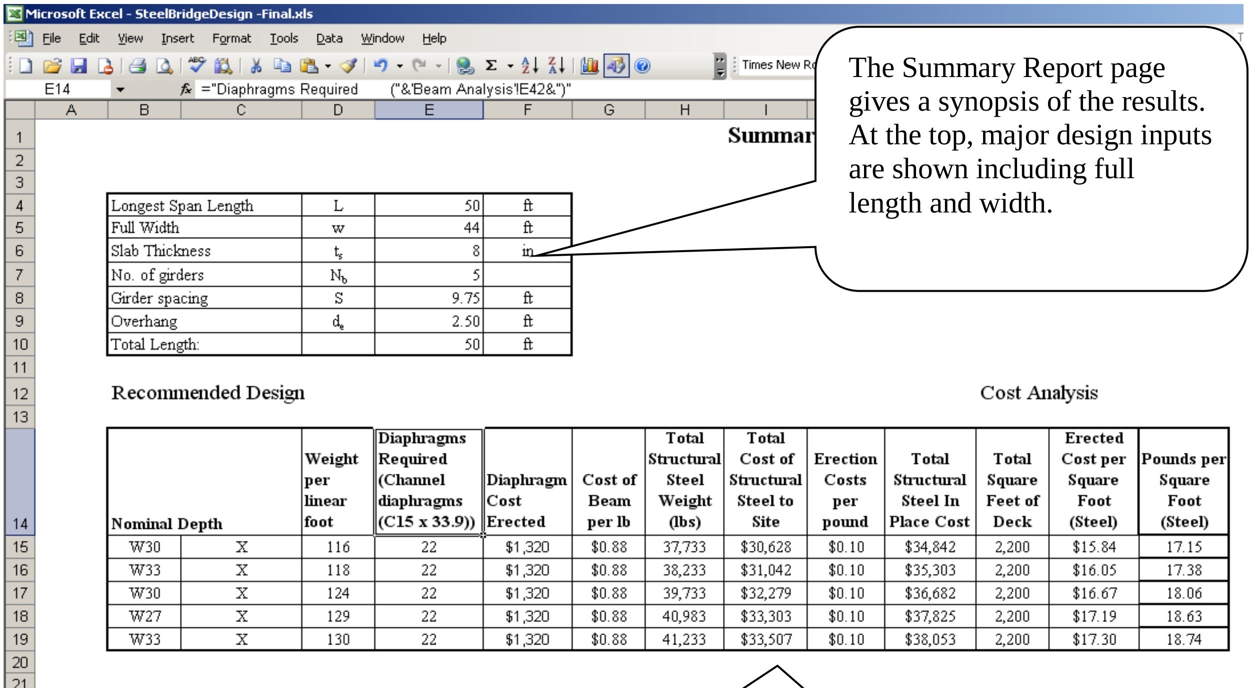
28		Unfactored Moment	IM	Service II	Strength I	Moment Distribution Factor	Factored Moment
29	**Positive Moment**	kip ft					kip ft
30	Truck Live Load	1227.88	1.33	1.3	1.75	0.463	1721.5
31	Live Lane Load	485.56	1.33	1.3	1.75	0.463	680.8
32	Dead Load II	88.44	1.3	1	1.25		147.0
33	Future Wearing Surface	93.64	1.	1	1.5		186.8
34	Dead Load I	1208.70		1	1.25		1510.9
35							
36	**Shear**						
37	Live Load	118.65		1.3	1.75	0.52	185.2
38	Dead Load II	7.32		1	1.25		12.2
39	Future Wearing Surface	7.50		1	1.5		15.0
40	Dead Load I	43.95		1	1.25		54.94
41							
42	**Negative Moment**						
43	Truck Live Load	-1306.87		1.3	1.75	0.463	32.3
44	Live Lane Load	-703.70		1.3	1.75	0.463	.6
45	Dead Load II			1	1.25		1
46	Future Wearing Surfa			1	1.5		
47	Dead Load I			1	1.25		
48							
49							
50	**Fatigue**			3.6			
51							
52	**Shear**						
53	Live Load						
54	Dead Load II						
55	Future Wearing Sur						
56	Dead Load I						
57							

Introduction

Checkboxes are only for a designer to see the factored moment in this table. If a checkbox is unchecked, the load factor will not be applied in the 'beam analysis tab'. The factored moment shown in column G is not necessarily the moment applied in the analysis.

Design moments and shears are also shown in the Analysis Results tab. The design moments use Strength I and Service II loading combinations. The dynamic loading factor, IM, and live load distribution factors are in the design moments and shears. For more information on design parameters, see Chapter II of the report.

Summary of Results (Summary Report Tab)



Longest Span Length	L	50	ft
Full Width	w	44	ft
Slab Thickness	t_s	8	in
No. of girders	N_b	5	
Girder spacing	S	9.75	ft
Overhang	d_e	2.50	ft
Total Length:		50	ft

Recommended Design

Cost Analysis

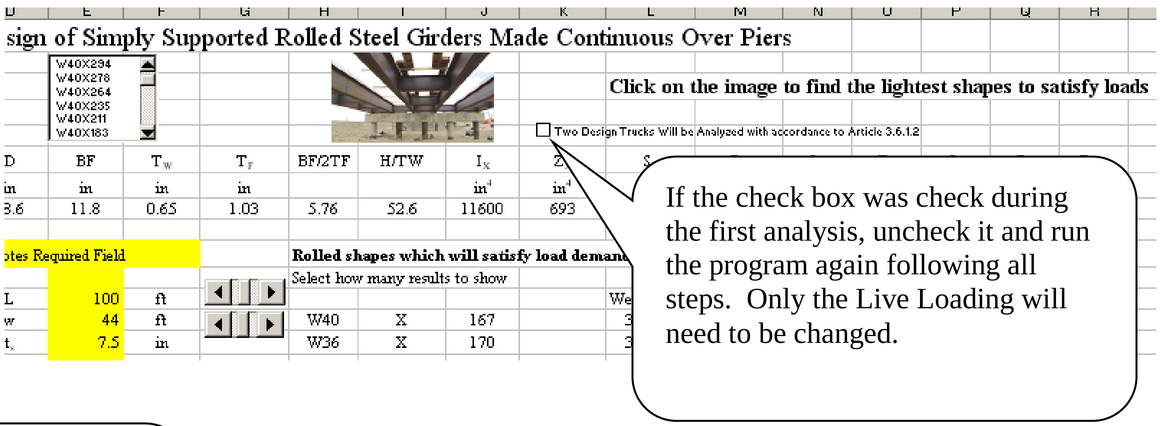
Nominal Depth		Weight per linear foot	Diaphragms Required (Channel diaphragms (C15 x 33.9))	Diaphragm Cost Erected	Cost of Beam per lb	Total Structural Steel Weight (lbs)	Total Cost of Structural Steel to Site	Erection Costs per pound	Total Structural Steel In Place Cost	Total Square Feet of Deck	Erected Cost per Square Foot (Steel)	Pounds per Square Foot (Steel)
W30	X	116	22	$1,320	$0.88	37,733	$30,628	$0.10	$34,842	2,200	$15.84	17.15
W33	X	118	22	$1,320	$0.88	38,233	$31,042	$0.10	$35,303	2,200	$16.05	17.38
W30	X	124	22	$1,320	$0.88	39,733	$32,279	$0.10	$36,682	2,200	$16.67	18.06
W27	X	129	22	$1,320	$0.88	40,983	$33,303	$0.10	$37,825	2,200	$17.19	18.63
W33	X	130	22	$1,320	$0.88	41,233	$33,507	$0.10	$38,053	2,200	$17.30	18.74

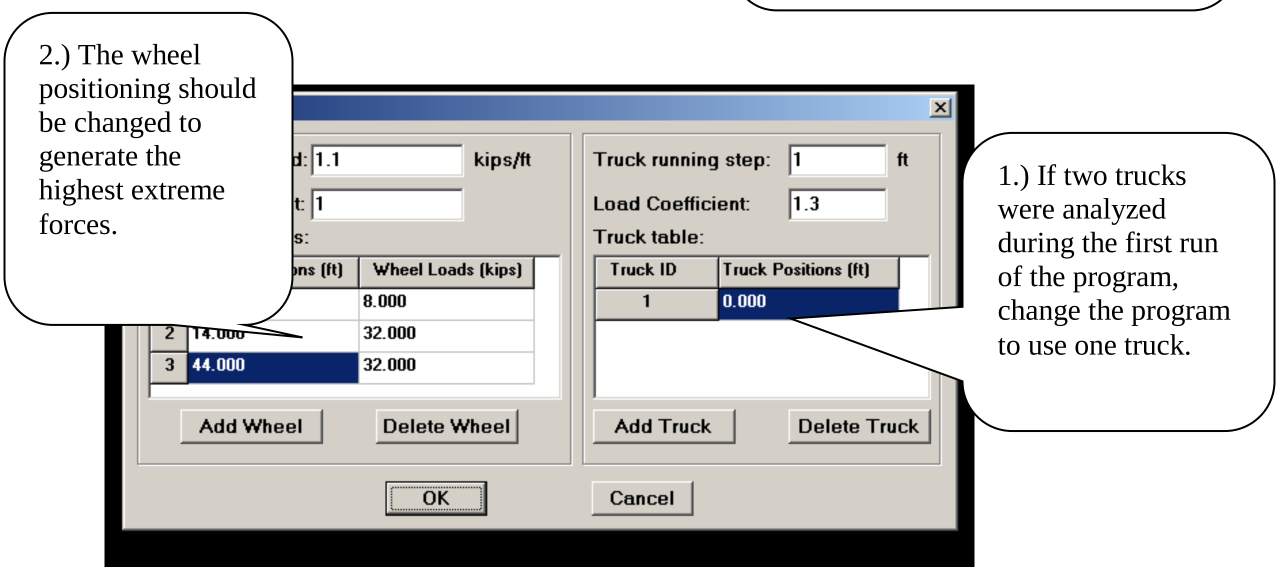
The Summary Report page gives a synopsis of the results. At the top, major design inputs are shown including full length and width.

The summary also includes the recommended beams with the associated costs and weight. Cost breakdowns are given and a final erected cost and weight per square foot is shown.

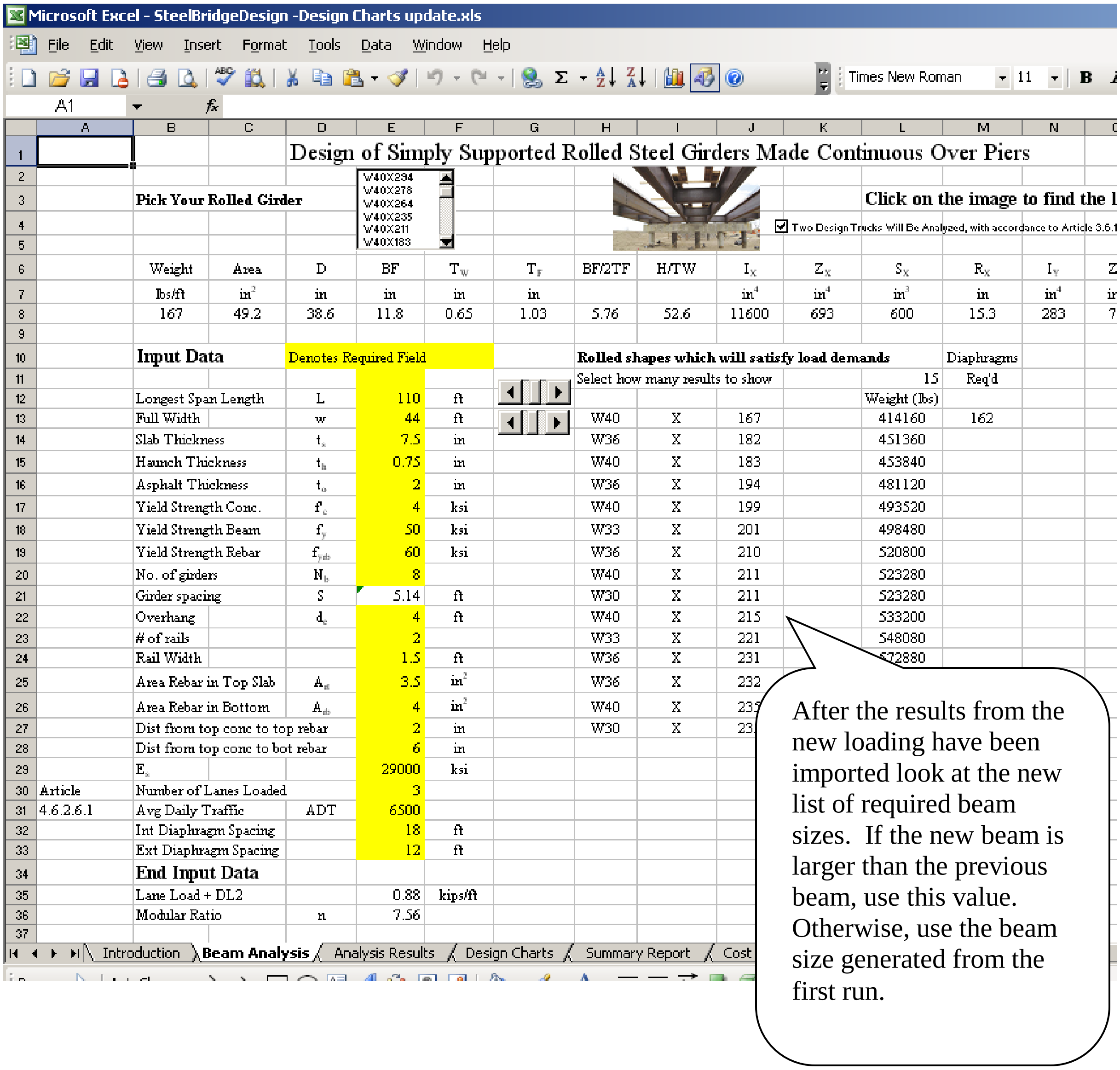
Running the program again for a complete analysis

NOTE: For a complete analysis, the program must be run at least twice. If the check box to analyze two trucks was checked when the program was run the first time, uncheck the box. Repeat all steps above, except only use one truck in the Live Loading prompt. Also, use a variable spacing on the rear axle which will generate the highest extreme force. Article 3.6.1.3 states that the rear axle can be varied between 14 and 30 feet.





Again, run the program to find the moments and shears generated from the new live loading. Save the program and import the results.txt file as before.



Weight	Area	D	BF	T_W	T_F	BF/2TF	H/TW	I_X	Z_X	S_X	R_X	I_Y	Z
lbs/ft	in²	in	in	in	in			in⁴	in⁴	in³	in	in⁴	ir
167	49.2	38.6	11.8	0.65	1.03	5.76	52.6	11600	693	600	15.3	283	7

	Input Data	Denotes Required Field			**Rolled shapes which will satisfy load demands**				Diaphragms
					Select how many results to show			15	Req'd
	Longest Span Length	L	110	ft				Weight (lbs)	
	Full Width	w	44	ft	W40	X	167	414160	162
	Slab Thickness	t_s	7.5	in	W36	X	182	451360	
	Haunch Thickness	t_h	0.75	in	W40	X	183	453840	
	Asphalt Thickness	t_a	2	in	W36	X	194	481120	
	Yield Strength Conc.	f'_c	4	ksi	W40	X	199	493520	
	Yield Strength Beam	f_y	50	ksi	W33	X	201	498480	
	Yield Strength Rebar	$f_{y,rb}$	60	ksi	W36	X	210	520800	
	No. of girders	N_b	8		W40	X	211	523280	
	Girder spacing	S	5.14	ft	W30	X	211	523280	
	Overhang	d_e	4	ft	W40	X	215	533200	
	# of rails		2		W33	X	221	548080	
	Rail Width		1.5	ft	W36	X	231	572880	
	Area Rebar in Top Slab	A_{st}	3.5	in²	W36	X	232		
	Area Rebar in Bottom	A_{sb}	4	in²	W40	X	235		
	Dist from top conc to top rebar		2	in	W30	X	23		
	Dist from top conc to bot rebar		6	in					
	E_s		29000	ksi					
Article	Number of Lanes Loaded		3						
4.6.2.6.1	Avg Daily Traffic	ADT	6500						
	Int Diaphragm Spacing		18	ft					
	Ext Diaphragm Spacing		12	ft					
	End Input Data								
	Lane Load + DL2		0.88	kips/ft					
	Modular Ratio	n	7.56						

CSU-CBA

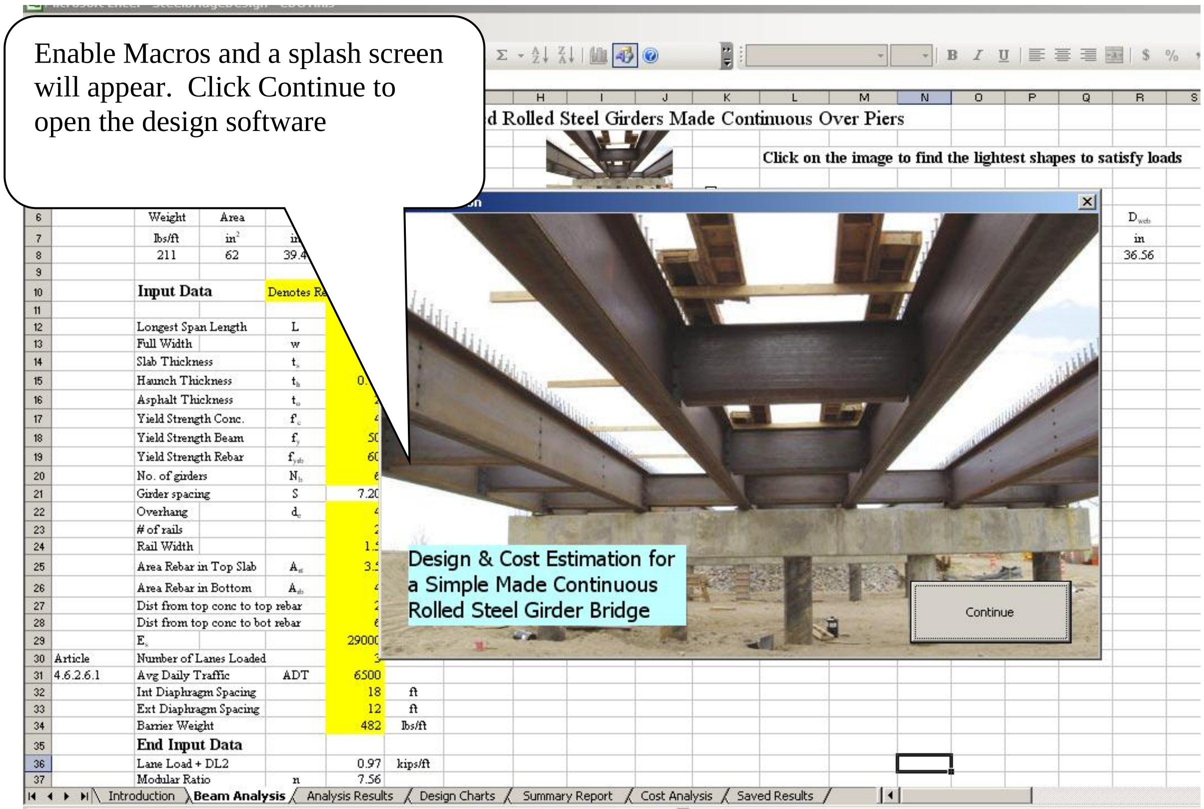
(Colorado State University-Continuous Beam Analysis)

Program Examples Guide

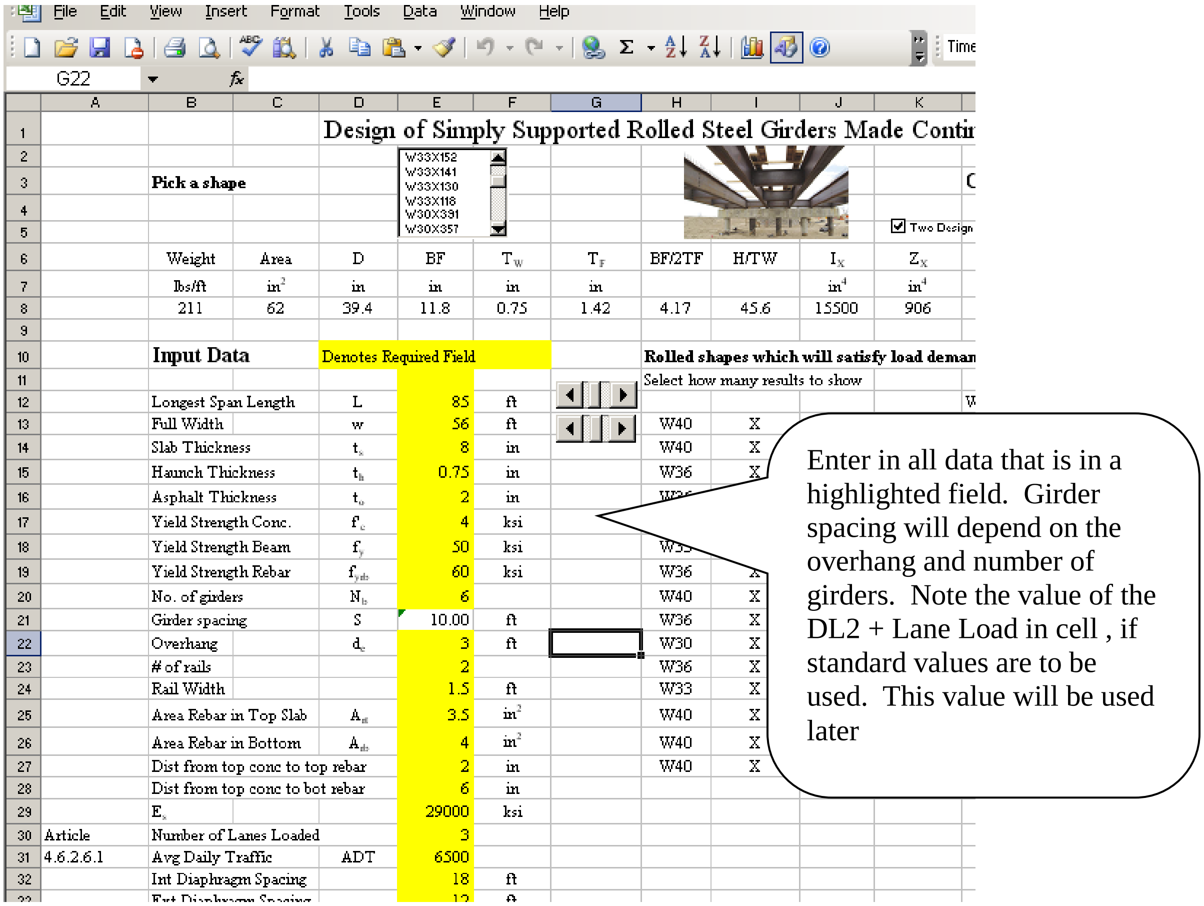
Alex Stone
John W. van de Lindt
Thang N. Dao

Design of a two span equal length steel bridge (85 – 85-ft. length by 56-ft. width)

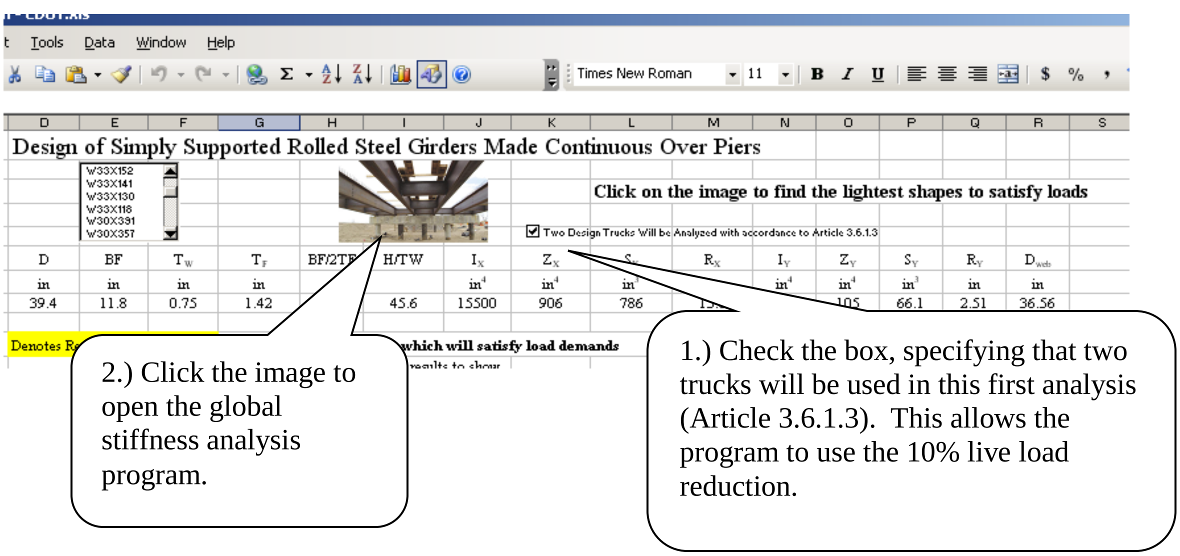
Step 1: Open CSU Steel Bridge Design Excel Spreadsheet

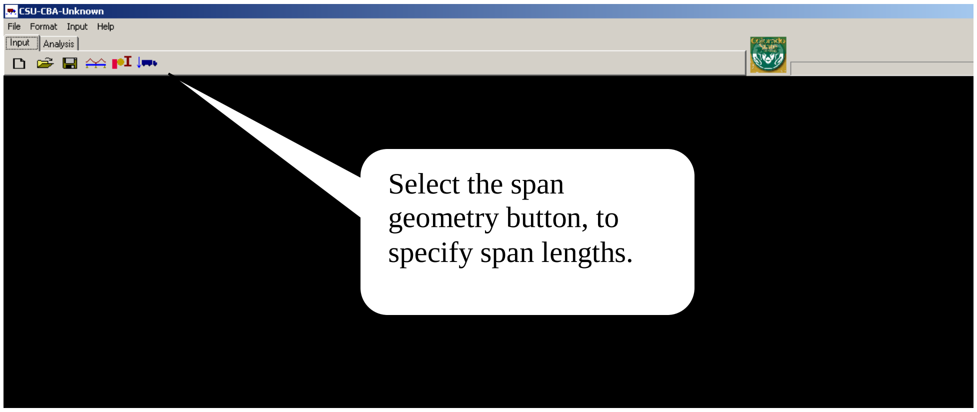


Step 2: Input basic bridge data

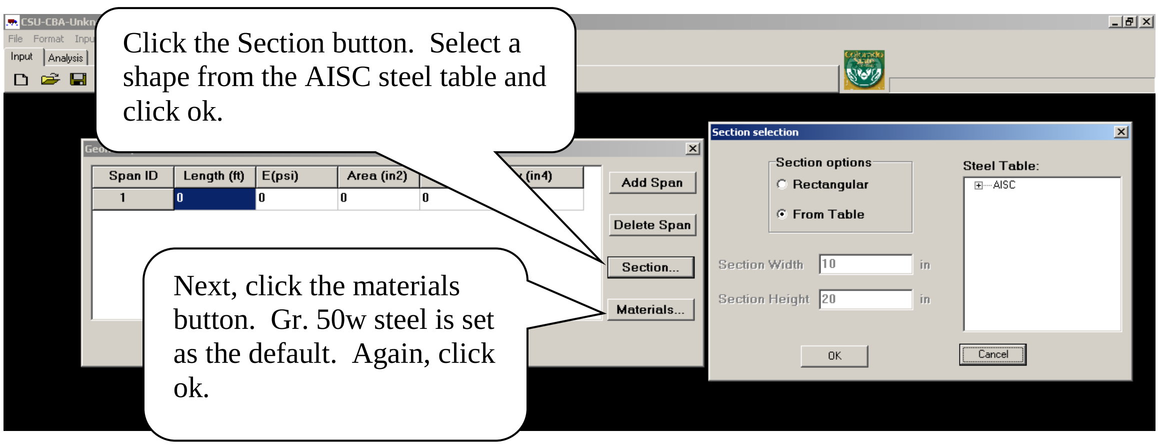


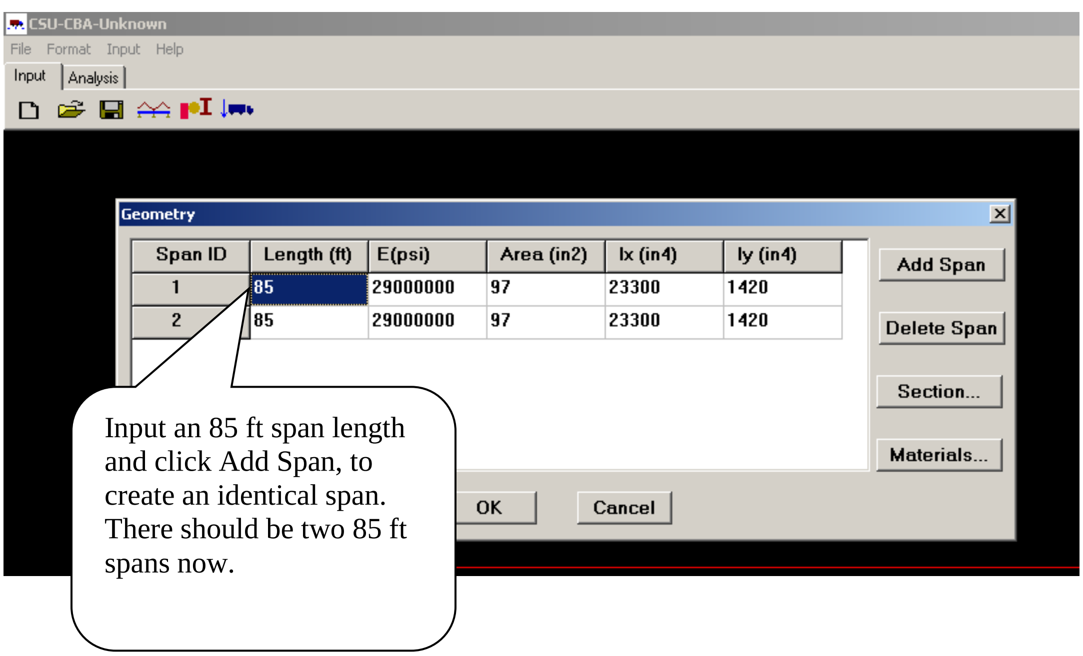
Step 3: Run CSU-CBA.exe global stiffness analysis

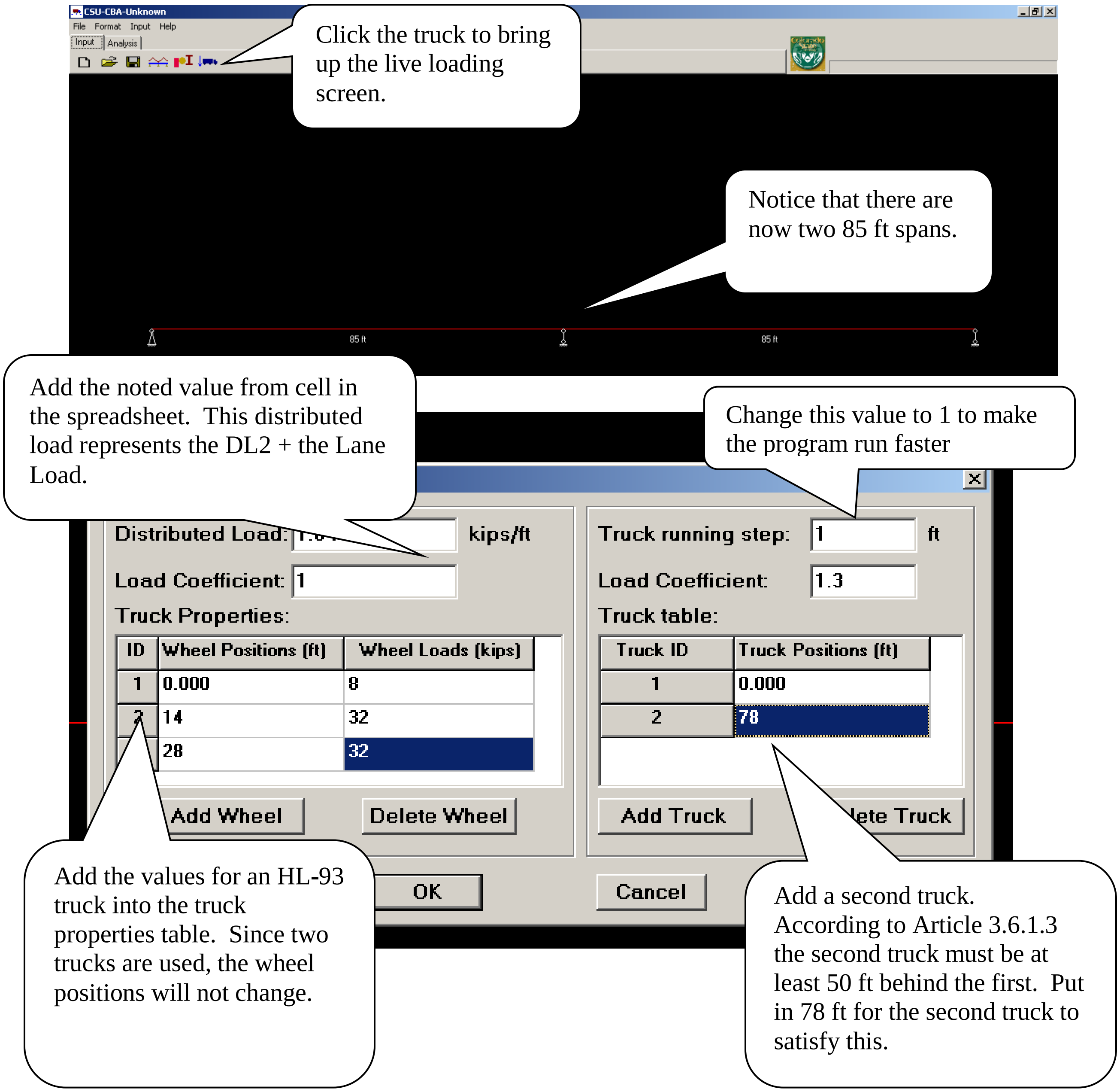


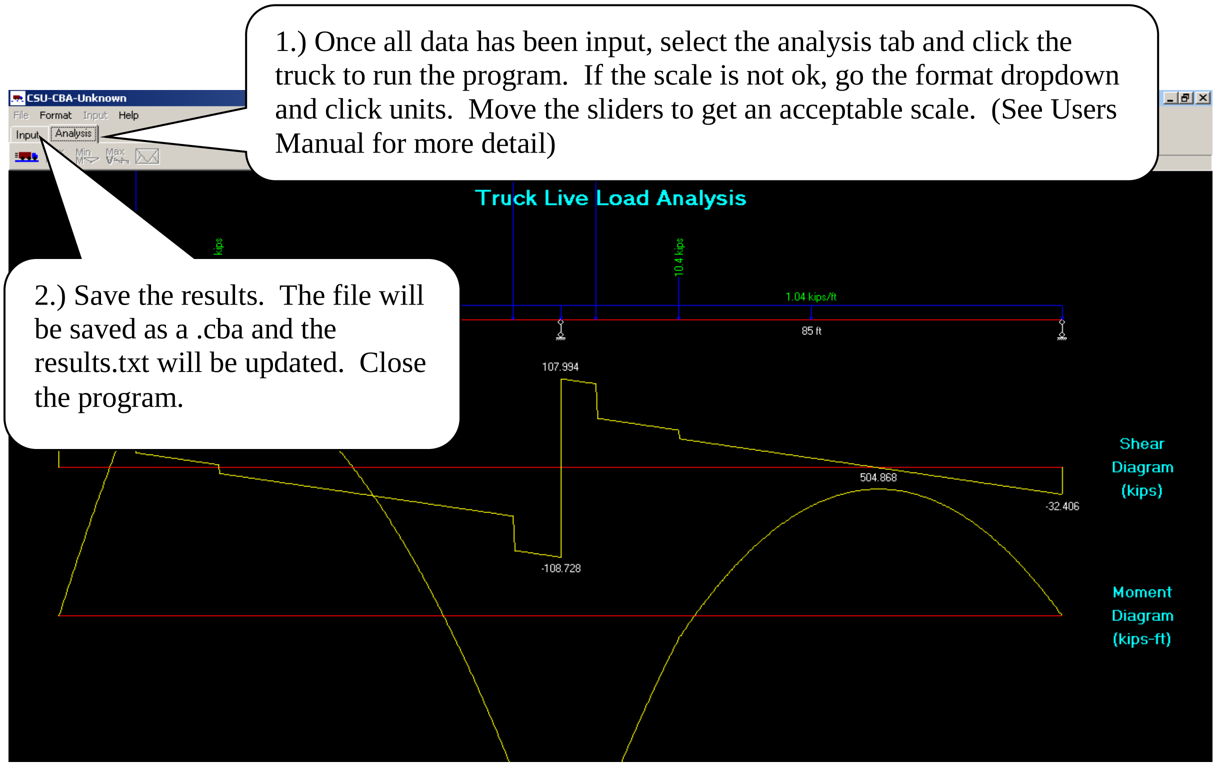


Note: Any size shape can be selected from the Section selection because only moment and shears are being found, which do not take into account elasticity or moment of inertia.

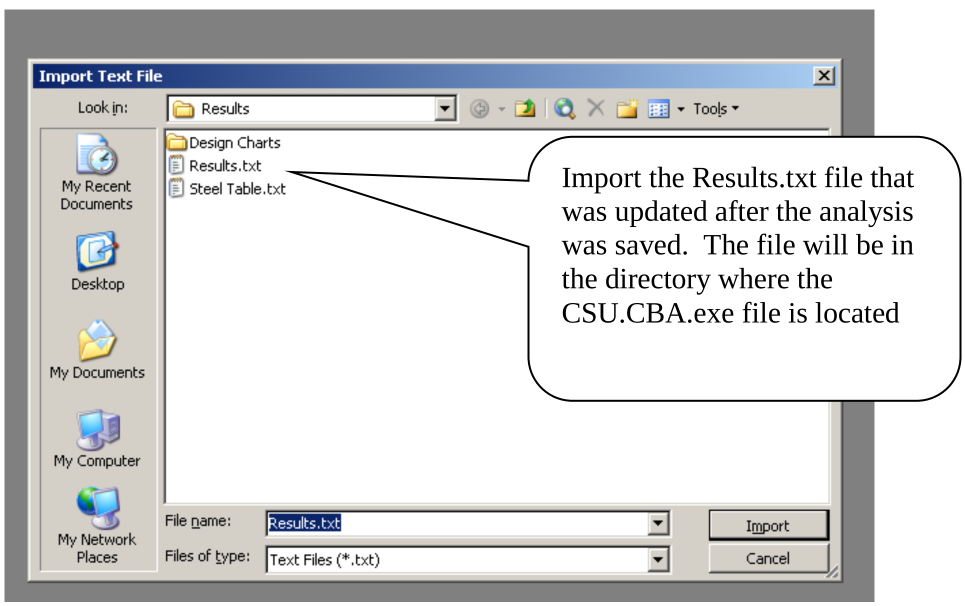





CSU-CBA-Unknown
File Format Input Help
Input Analysis
Click the truck to bring up the live loading screen.
Notice that there are now two 85 ft spans.
85 ft
85 ft
Add the noted value from cell in the spreadsheet. This distributed load represents the DL2 + the Lane Load.
Change this value to 1 to make the program run faster
Distributed Load:
kips/ft
Load Coefficient: 1
Truck Properties:
ID
Wheel Positions (ft)
Wheel Loads (kips)
1 0.000 8
14 32
28 32
Add Wheel
Delete Wheel
Truck running step: 1 ft
Load Coefficient: 1.3
Truck table:
Truck ID
Truck Positions (ft)
1 0.000
2 78
Add Truck
OK
Cancel
Add the values for an HL-93 truck into the truck properties table. Since two trucks are used, the wheel positions will not change.
Add a second truck. According to Article 3.6.1.3 the second truck must be at least 50 ft behind the first. Put in 78 ft for the second truck to satisfy this.



Step 4: Import the data to size the appropriate girders.



Step 5: Results from two truck analysis

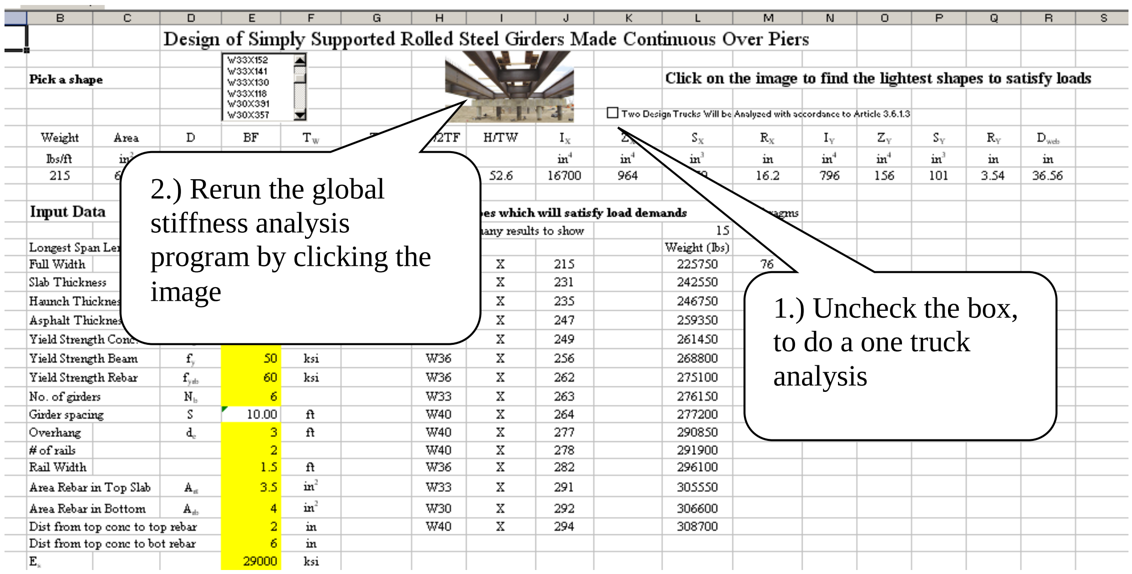
A1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1				Design of Simply Supported Rolled Steel Girders Made Continuous Over Piers										
2					W33X152									
3		Pick a shape			W33X141 W33X130							Click on the image to find		
4					W33X118 W30X391									
5					W30X357						Two Design Trucks Will be Analyzed with accordance t			
6		Weight	Area	D	BF	T_W	T_F	BF/2TF	H/TW	I_X	Z_X	S_X	R_X	I_Y
7		lbs/ft	in^2	in	in	in	in			in^4	in^4	in^3	in	in^4
8		215	63.4	39	15.8	0.65	1.22	6.45	52.6	16700	964	859	16.2	796
9														
10		Input Data		Denotes Required Field				Rolled shapes which will satisfy load demands					Diaphragms	
11								Select how many results to show				15	Req'd	
12		Longest Span Length		L	85	ft						Weight (lbs)		
13		Full Width		w	56	ft		W40	X	215		225750	76	
14		Slab Thickness		t_s	8	in		W36	X	231		242550		
15		Haunch Thickness		t_h	0.75	in		W40	X	235		246750		
16		Asphalt Thickness		t_a	2	in		W36	X	247		259350		
17		Yield Strength Conc.		f'_c	4	ksi		W40	X	249		261450		
18		Yield Strength Beam		f_y	50	ksi		W36	X	256		268800		
19		Yield Strength Rebar		f_{yb}	60	ksi		W36	X	262		275100		
20		No. of girders		N_b	6			W33	X	263		276150		
21		Girder spacing		S	10.00	ft		W40	X	264		277200		
22		Overhang		d_e	3	ft		W40	X	277		290850		
23		# of rails			2			W40	X	278		291900		
24		Rail Width			1.5	ft		W36	X	282		296100		
25		Area Rebar in Top Slab		A_{st}	3.5	in^2		W33	X	291		05550		
26		Area Rebar in Bottom		A_{sb}	4	in^2		W30	X	292		6600		
27		Dist from top conc to top rebar			2	in		W40	X	294		700		
28		Dist from top conc to bot rebar			6	in								
29		E_s			29000	ksi								
30	Article	Number of Lanes Loaded			3									
31	4.6.2.6.1	Avg Daily Traffic		ADT	6500									
32		Int Diaphragm Spacing			18	ft								
33		Ext Diaphragm Spacing			12	ft								
34		Barrier Weight			482	lbs/ft								
35		End Input Data												
36		Lane Load + DL2			1.04	kips/ft								
37		Modular Ratio		n	7.56									

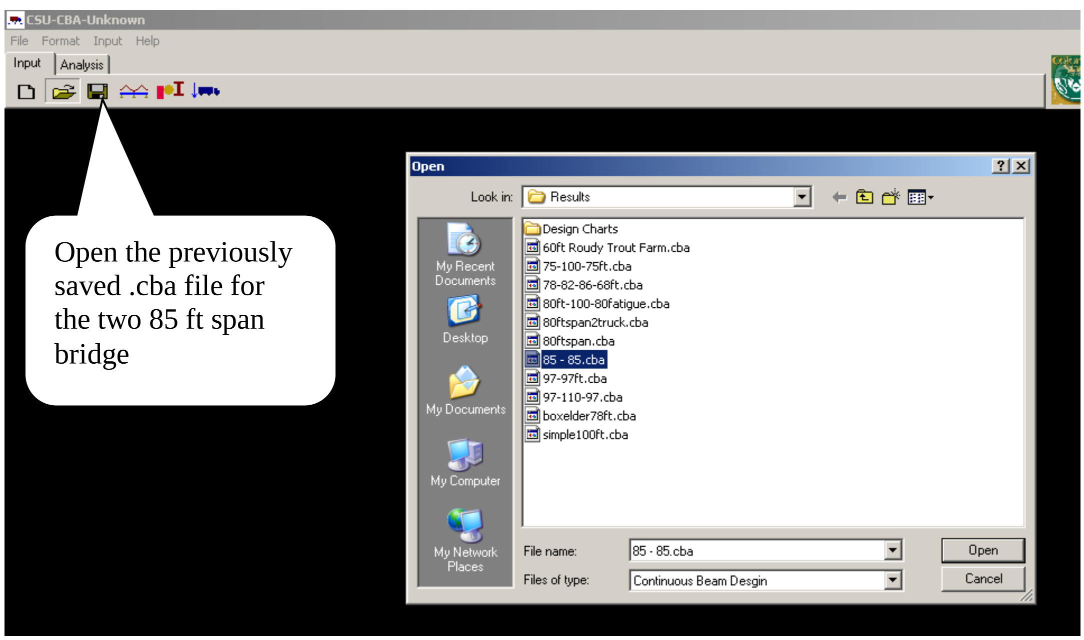
Introduction | Beam Analysis | Analysis Results | Design Charts | Summary Report

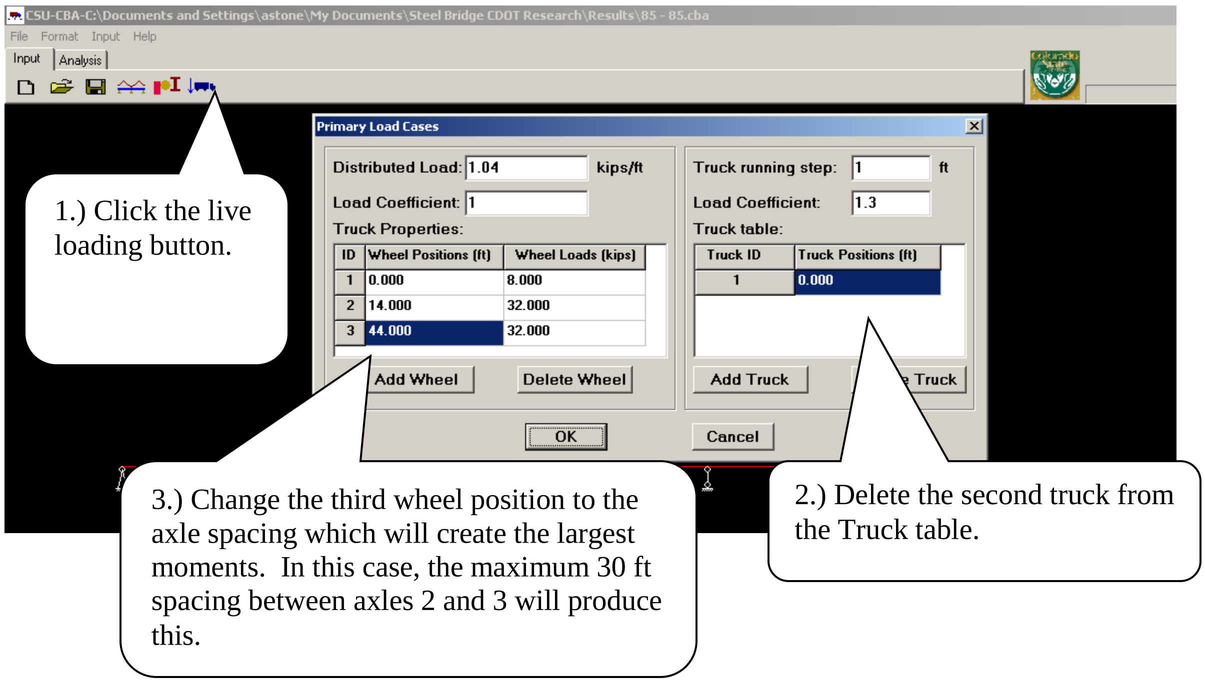
Once the results are imported, each AISC wide flange beam is subjected to extreme forces produced and compared with the AASHTO LRFD design. The lightest passing shapes are displayed here.

Step 6: One truck analysis

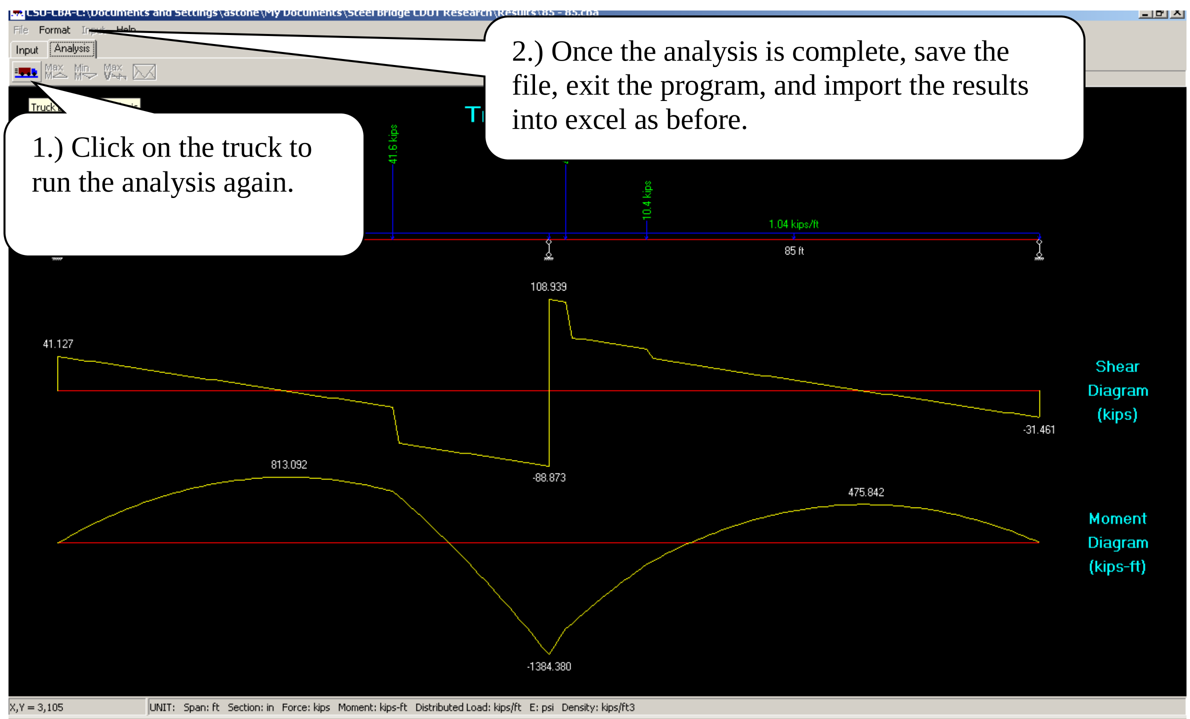


Step 7: Inputting values for one truck analysis

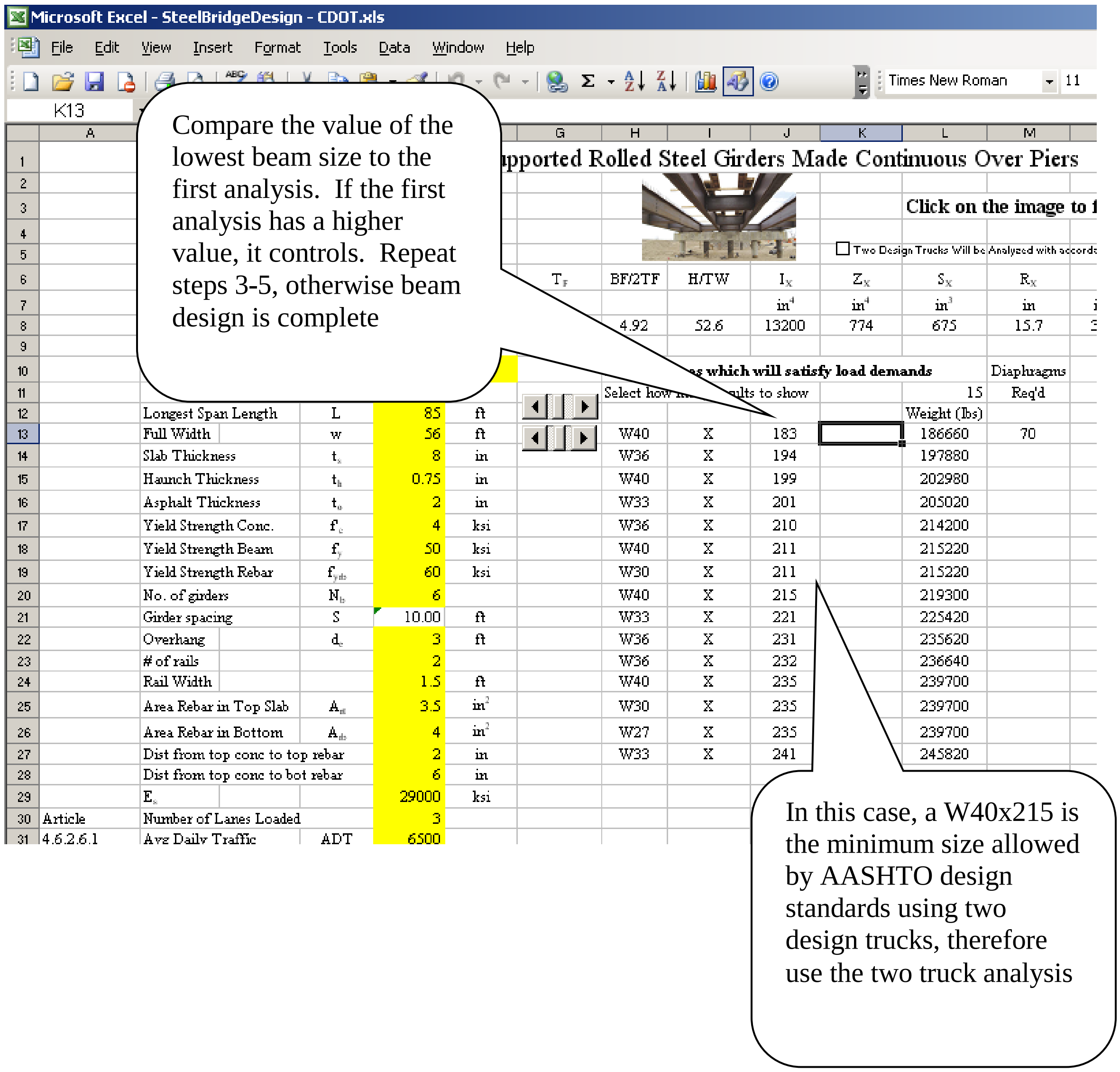




Note: If unsure of what wheel spacing will generate the largest bending moments, first start with 14 ft rear axle spacing. Run the program and click the envelope to see the extreme values. Go back to the live loading prompt and change the rear axle spacing. Again, run the program and look at the moment envelope. Repeat this process until the maximum or minimum moment values have been achieved.

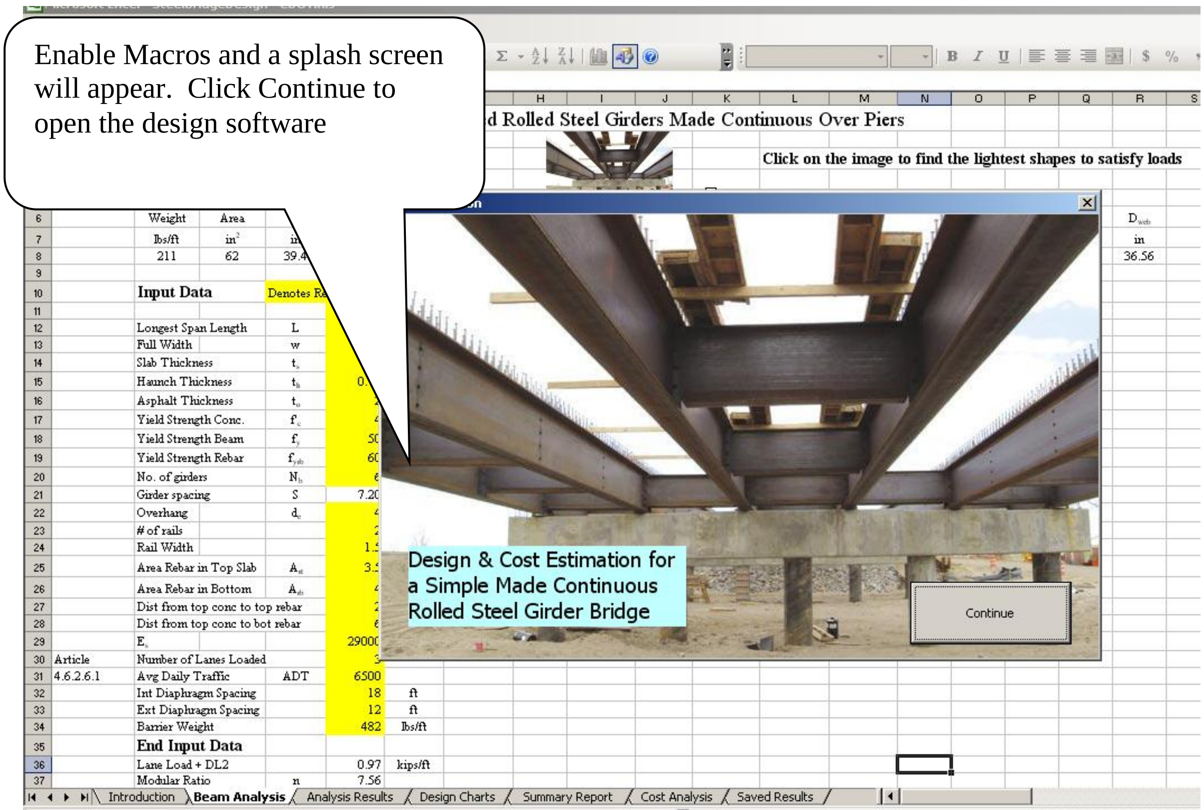


Step 8: Comparing the two analyses

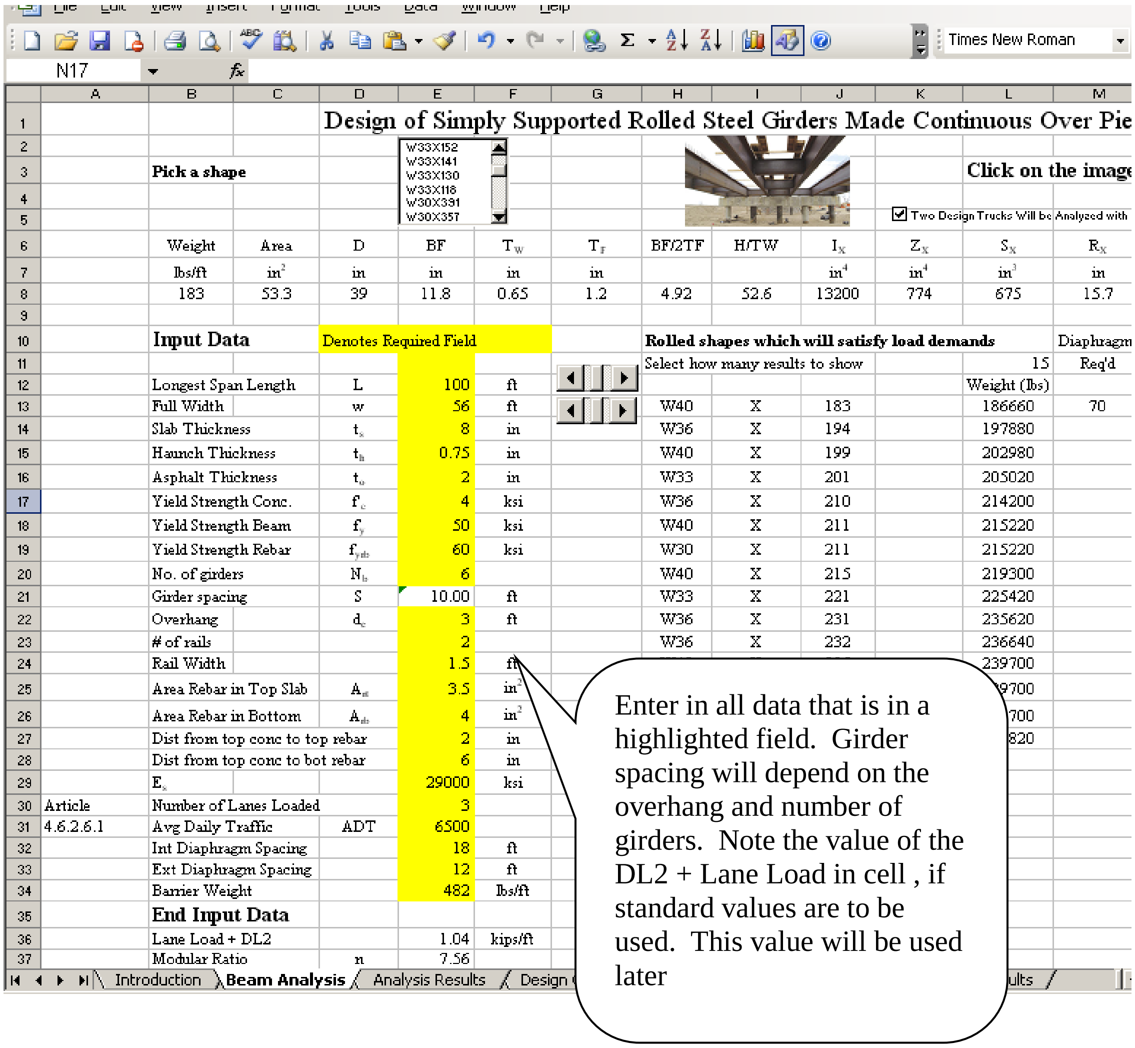


Design of a three span equal length steel bridge (40 – 100 - 40-ft. length by 56-ft. width)

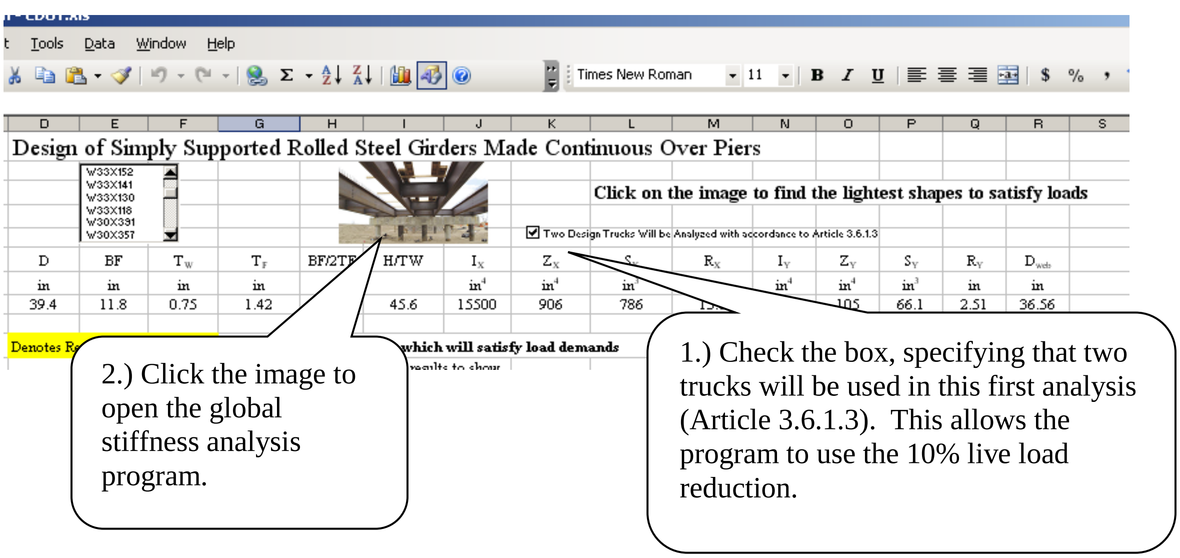
Step 1: Open CSU Steel Bridge Design Excel Spreadsheet

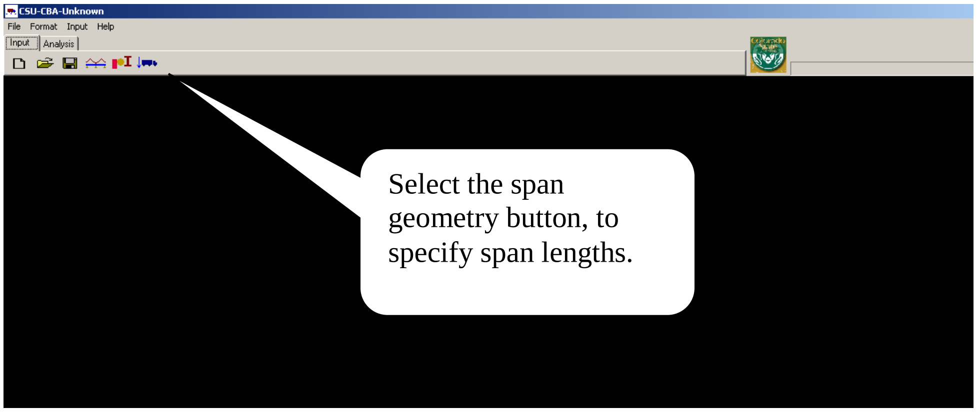


Step 2: Input basic bridge data

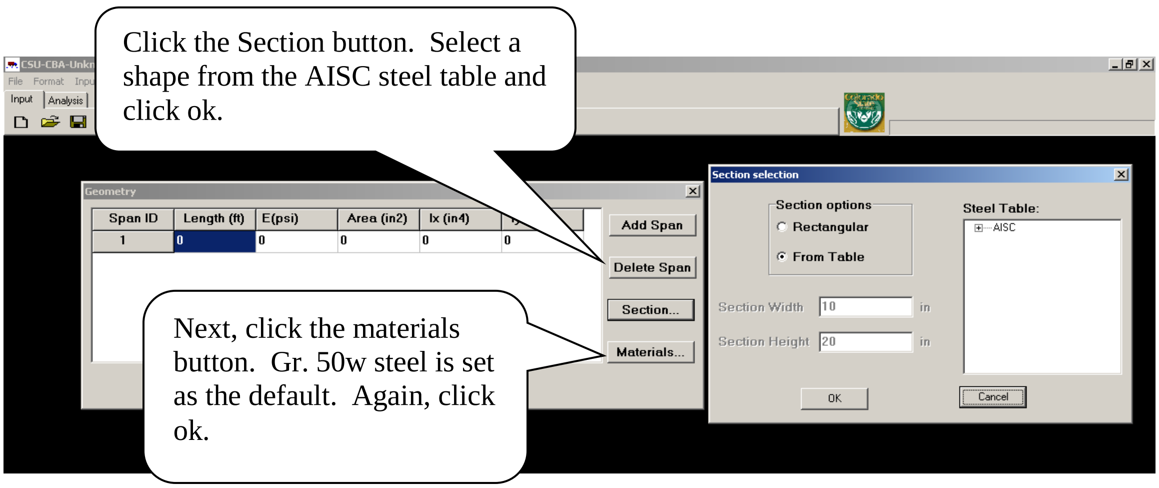


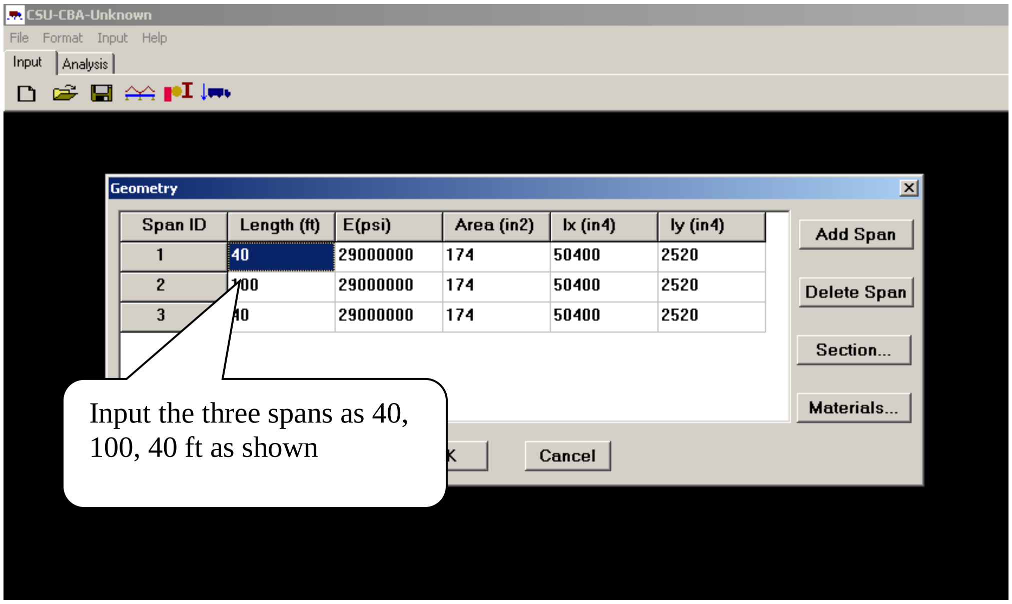
Step 3: Run CSU-CBA.exe global stiffness analysis

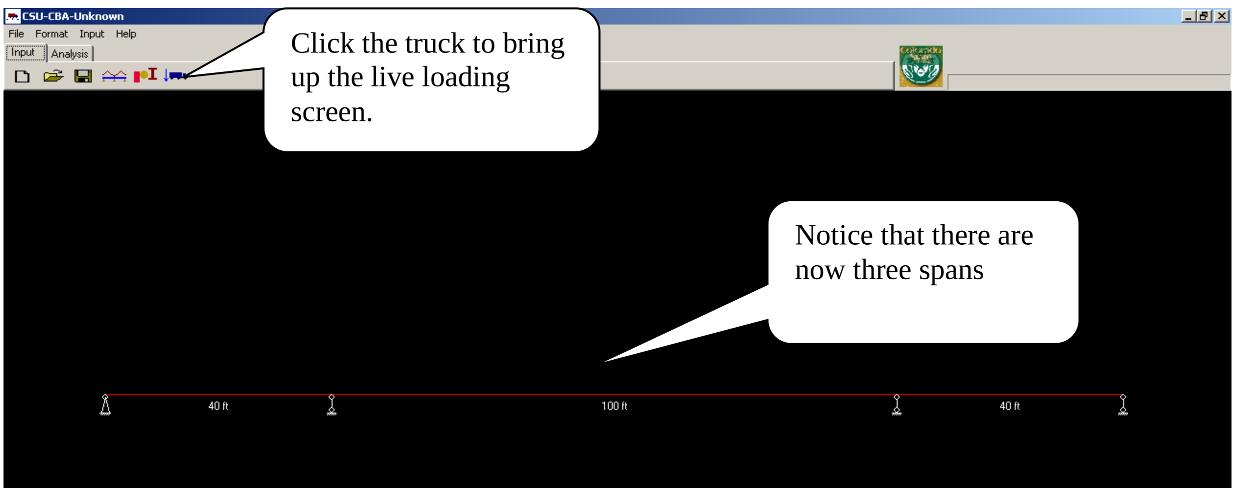




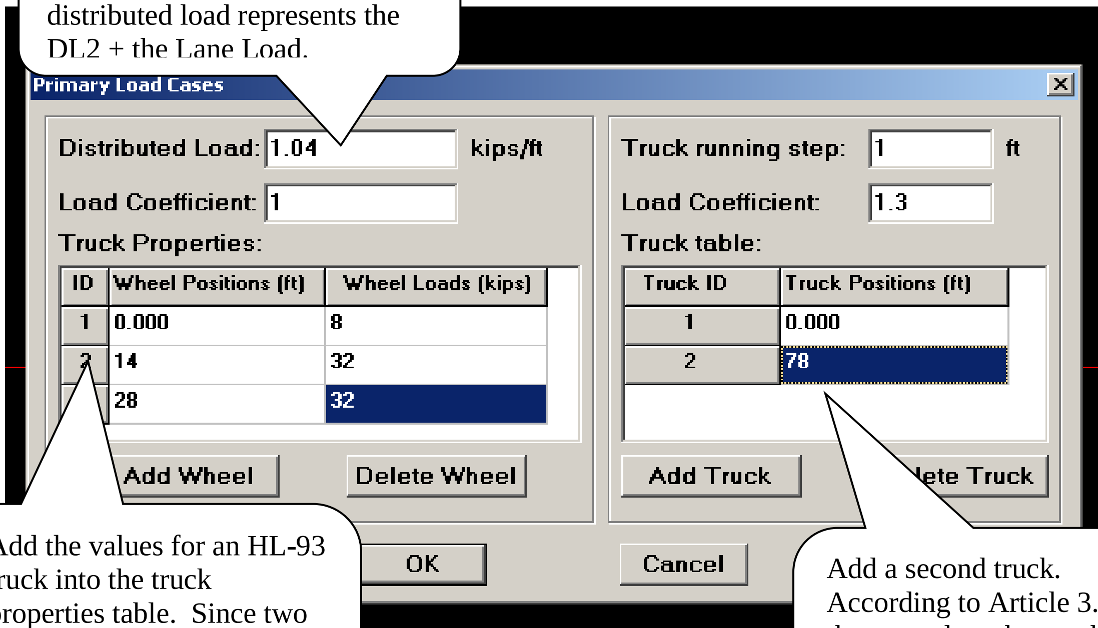
Note: Any size shape can be selected from the Section selection because only moment and shears are being found, which do not take into account elasticity or moment of inertia.




CSU-CBA-Unknown
File Format Input Help
Input Analysis
Geometry
Span ID
Length (ft)
E(psi)
Area (in2)
Ix (in4)
Iy (in4)
1 40 29000000 174 50400 2520
2 100 29000000 174 50400 2520
3 40 29000000 174 50400 2520
Add Span
Delete Span
Section...
Materials...
Cancel
Input the three spans as 40, 100, 40 ft as shown


CSU-CBA-Unknown
File Format Input Help
Input Analysis
Click the truck to bring up the live loading screen.
Notice that there are now three spans
40 ft
100 ft
40 ft

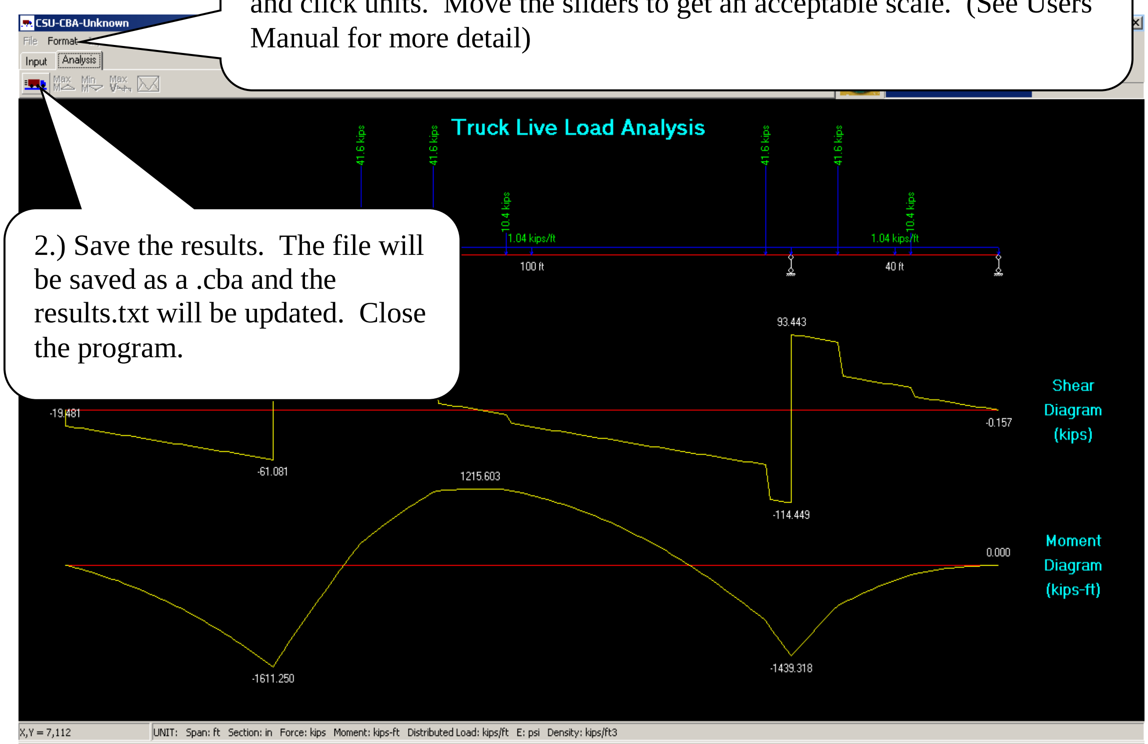
Add the noted value from cell in the spreadsheet. This distributed load represents the DL2 + the Lane Load.



Add the values for an HL-93 truck into the truck properties table. Since two trucks are used, the wheel positions will not change.

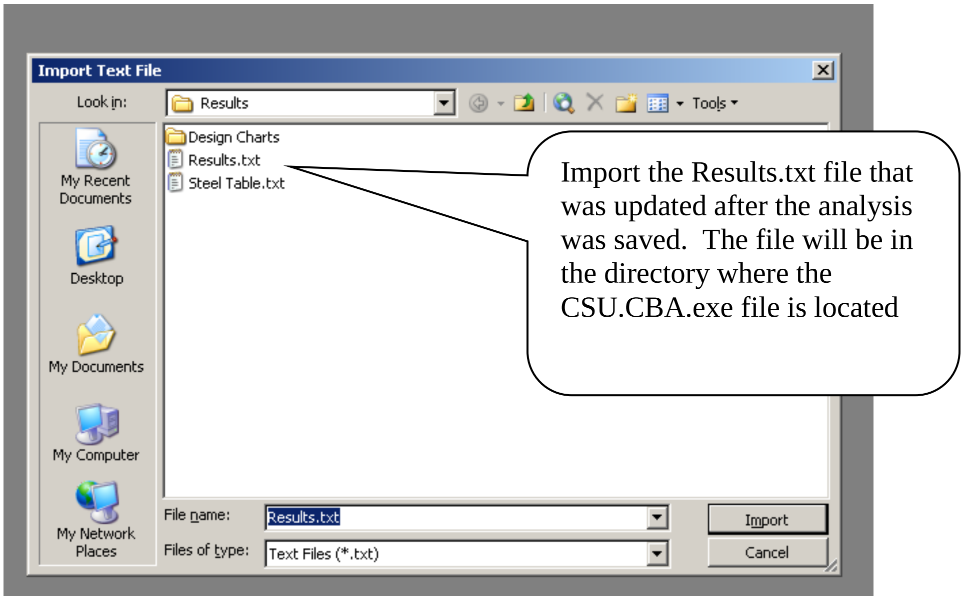
Add a second truck. According to Article 3.6.1.3 the second truck must be at least 50 ft behind the first. Put in 78 ft for the second truck to satisfy this.

1.) Once all data has been input, select the analysis tab and click the truck to run the program. If the scale is not ok, go the Format dropdown and click units. Move the sliders to get an acceptable scale. (See Users Manual for more detail)

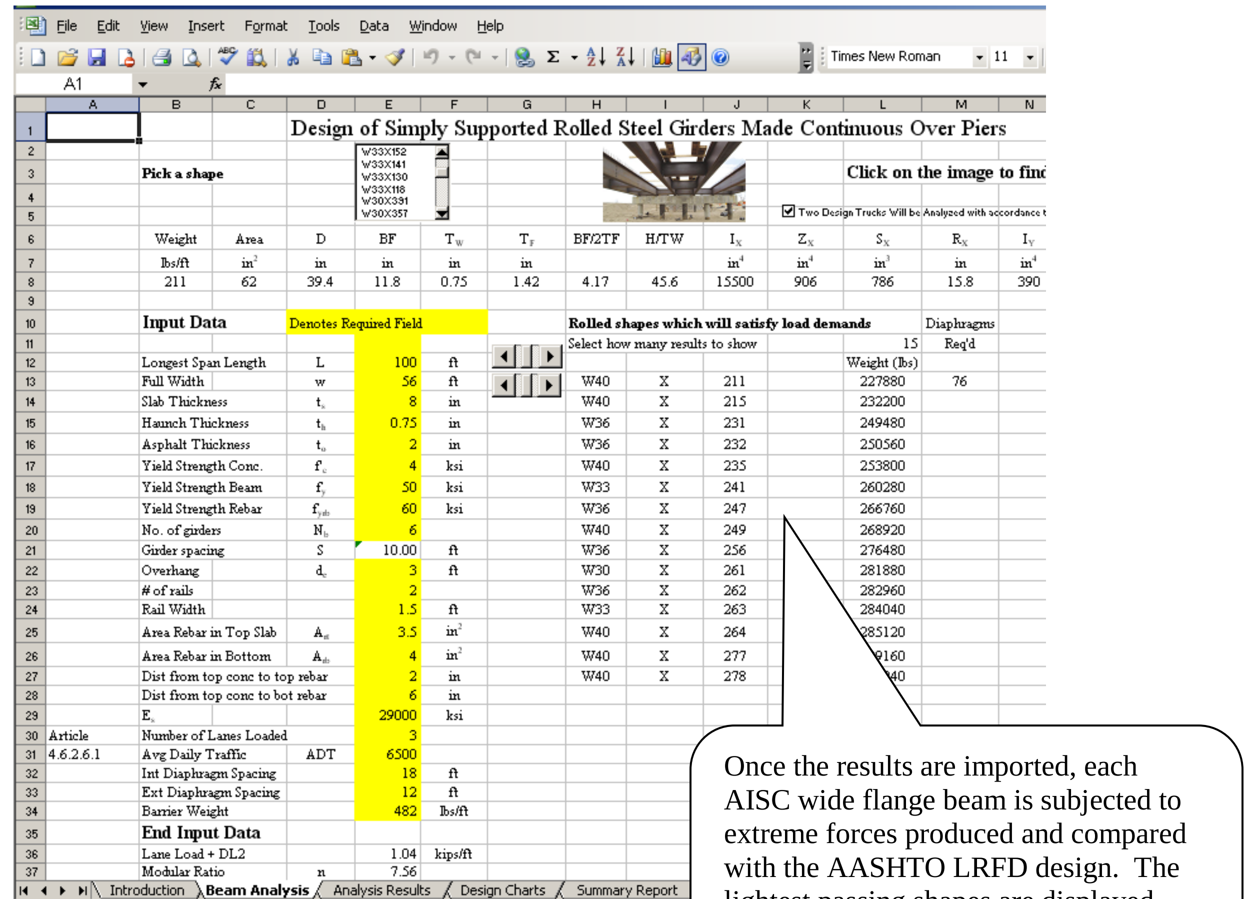


2.) Save the results. The file will be saved as a .cba and the results.txt will be updated. Close the program.

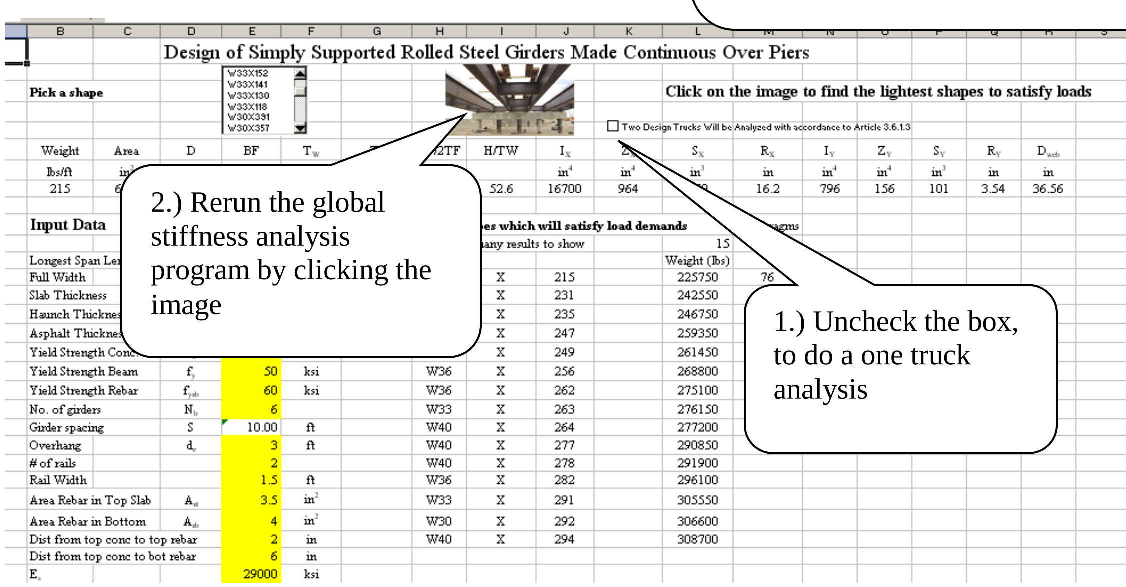
Step 4: Import the data to size the appropriate girders.



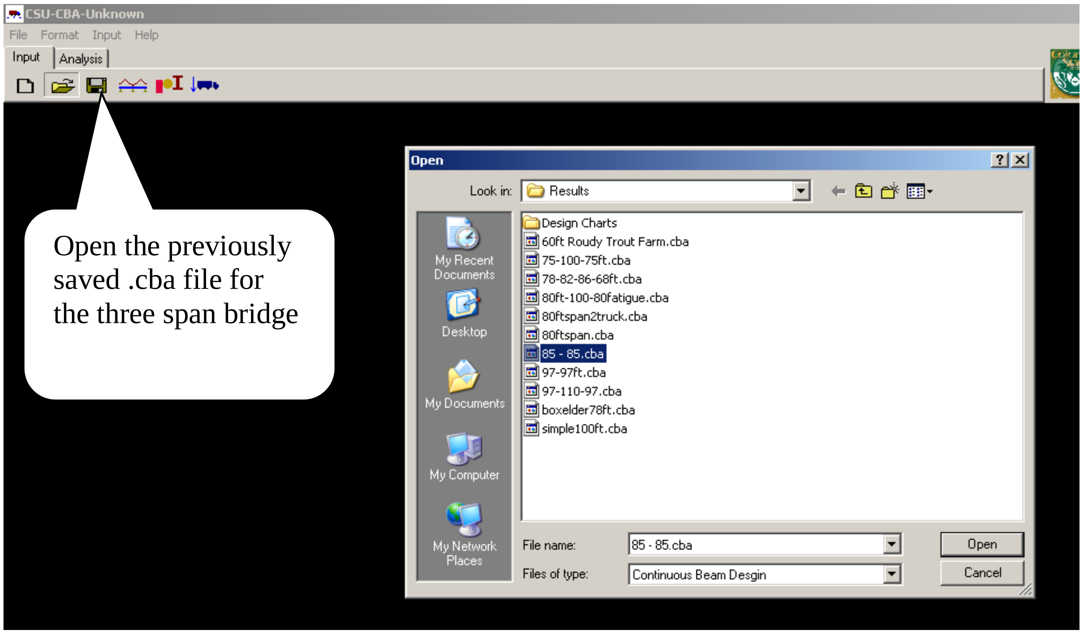
Step 5: Results from two truck analysis

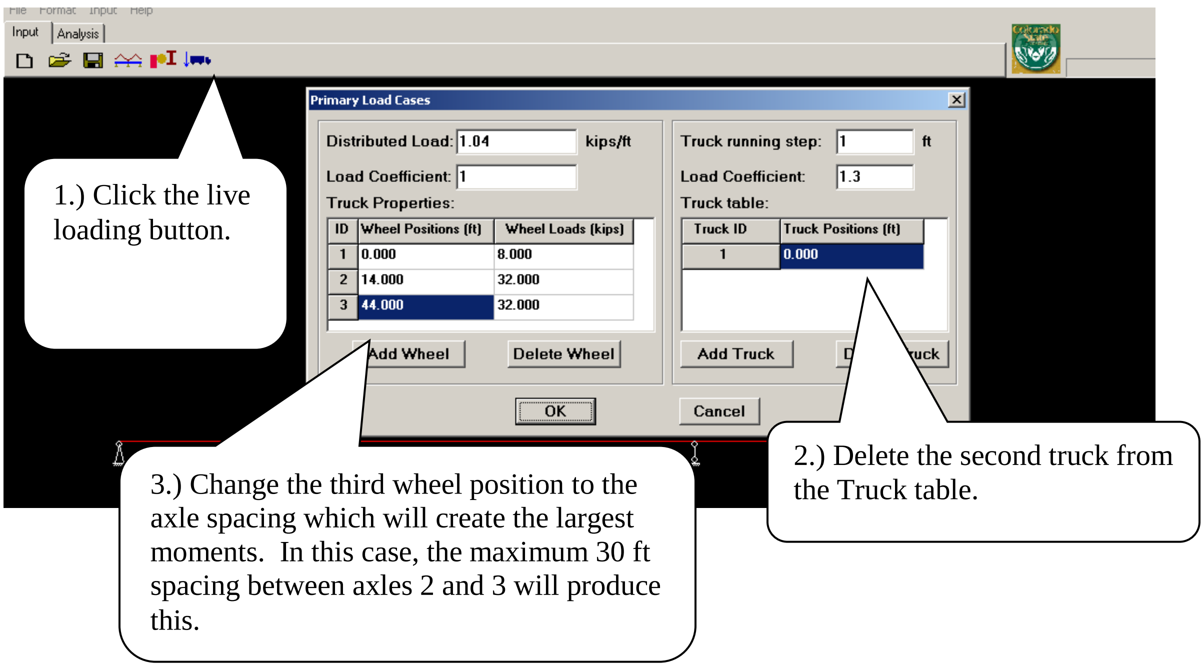


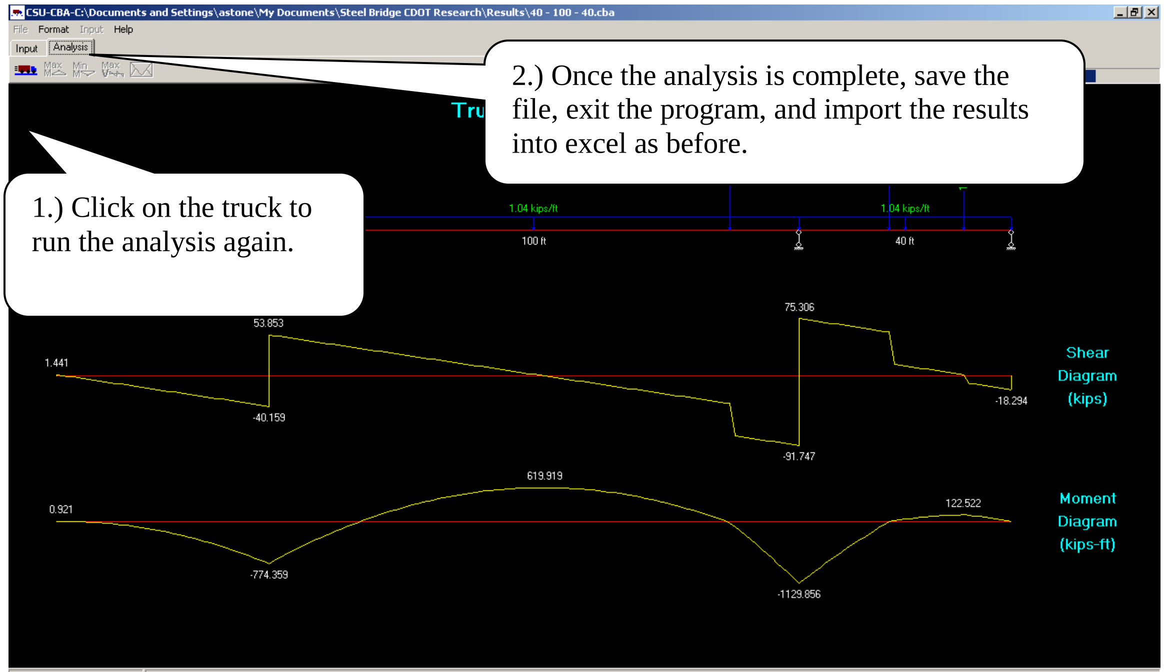
Step 6: One truck analysis



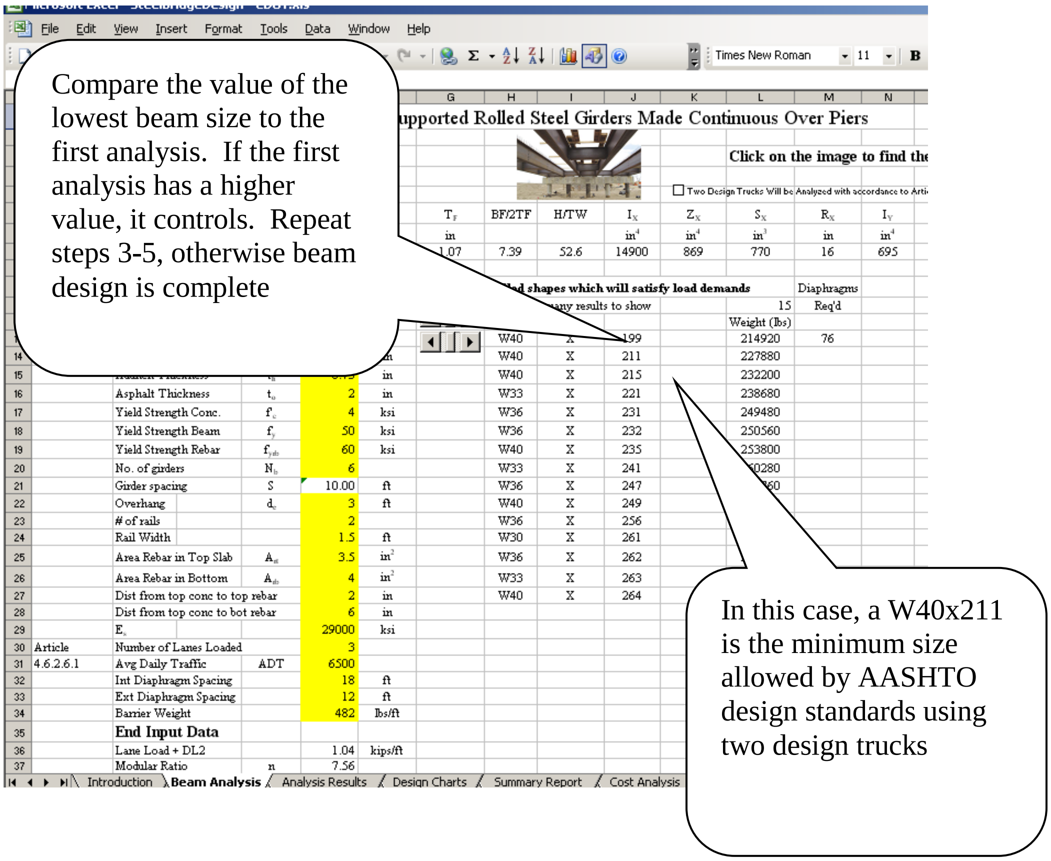
Step 7: Inputting values for one truck analysis


CSU-CBA-Unknown
File Format Input Help
Input Analysis
Open
Look in: Results
Design Charts
60ft Roudy Trout Farm.cba
75-100-75ft.cba
78-82-86-68ft.cba
80ft-100-80fatigue.cba
80ftspan2truck.cba
80ftspan.cba
85 - 85.cba
97-97ft.cba
97-110-97.cba
boxelder78ft.cba
simple100ft.cba
My Recent Documents
Desktop
My Documents
My Computer
My Network Places
File name: 85 - 85.cba
Files of type: Continuous Beam Desgin
Open
Cancel
Open the previously saved .cba file for the three span bridge


File Format Input Help
Input Analysis
Primary Load Cases
Distributed Load: 1.04 kips/ft
Load Coefficient: 1
Truck Properties:
ID Wheel Positions (ft) Wheel Loads (kips)
1 0.000 8.000
2 14.000 32.000
3 44.000 32.000
Add Wheel
Delete Wheel
Truck running step: 1 ft
Load Coefficient: 1.3
Truck table:
Truck ID Truck Positions (ft)
1 0.000
Add Truck
OK
Cancel
1.) Click the live loading button.
2.) Delete the second truck from the Truck table.
3.) Change the third wheel position to the axle spacing which will create the largest moments. In this case, the maximum 30 ft spacing between axles 2 and 3 will produce this.

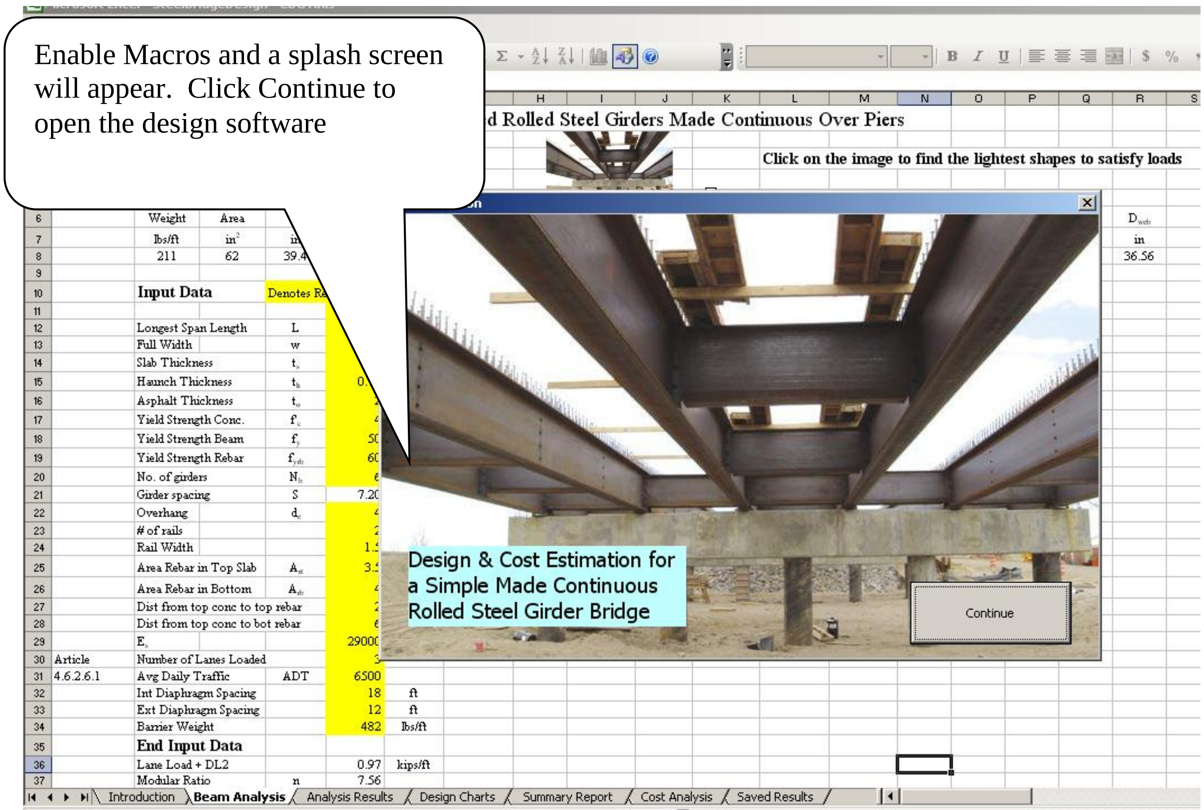


Step 8: Comparing the two analyses

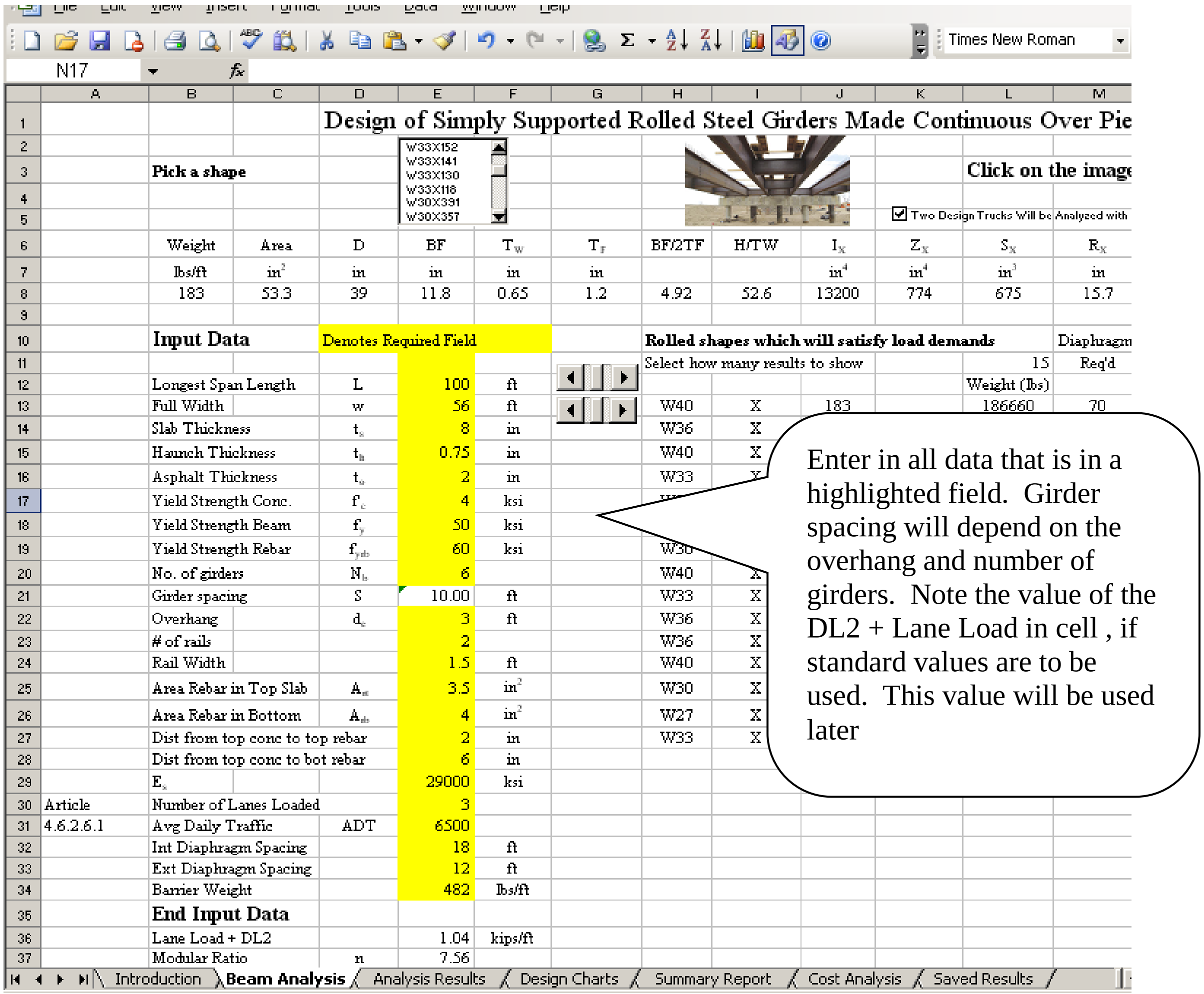

Compare the value of the lowest beam size to the first analysis. If the first analysis has a higher value, it controls. Repeat steps 3-5, otherwise beam design is complete
In this case, a W40x211 is the minimum size allowed by AASHTO design standards using two design trucks
upported Rolled Steel Girders Made Continuous Over Piers
Click on the image to find the
Introduction
Beam Analysis
Analysis Results
Design Charts
Summary Report
Cost Analysis

Design of a two span unequal length steel bridge (80 – 100-ft. length by 56-ft. width)

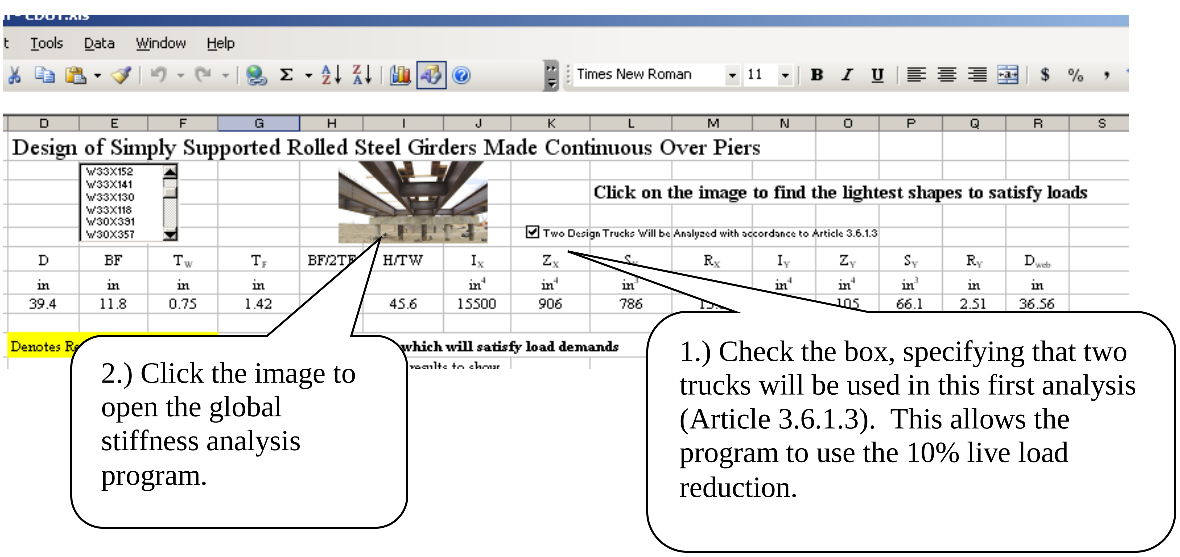
Step 1: Open CSU Steel Bridge Design Excel Spreadsheet

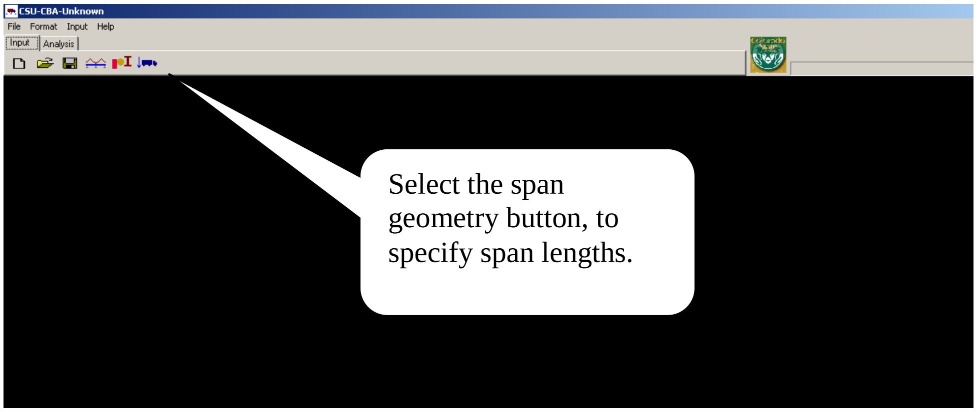


Step 2: Input basic bridge data

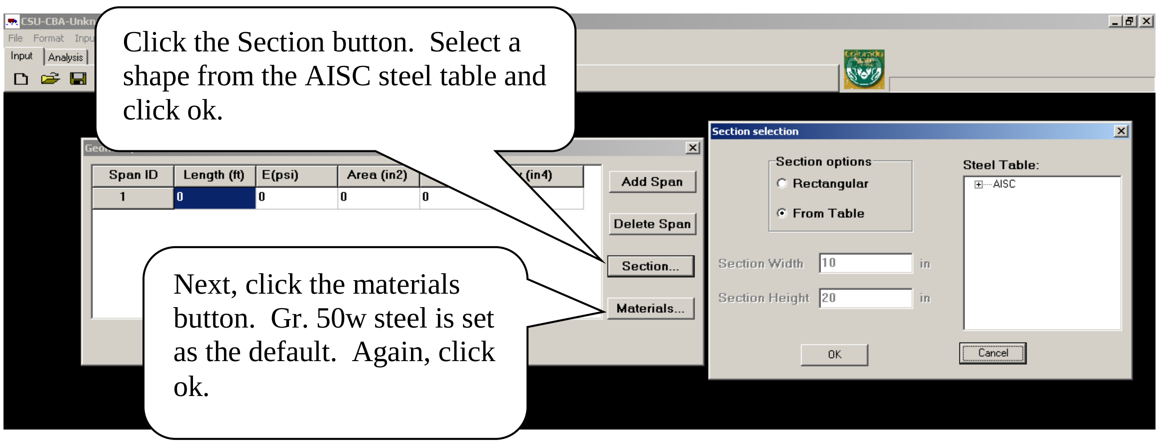


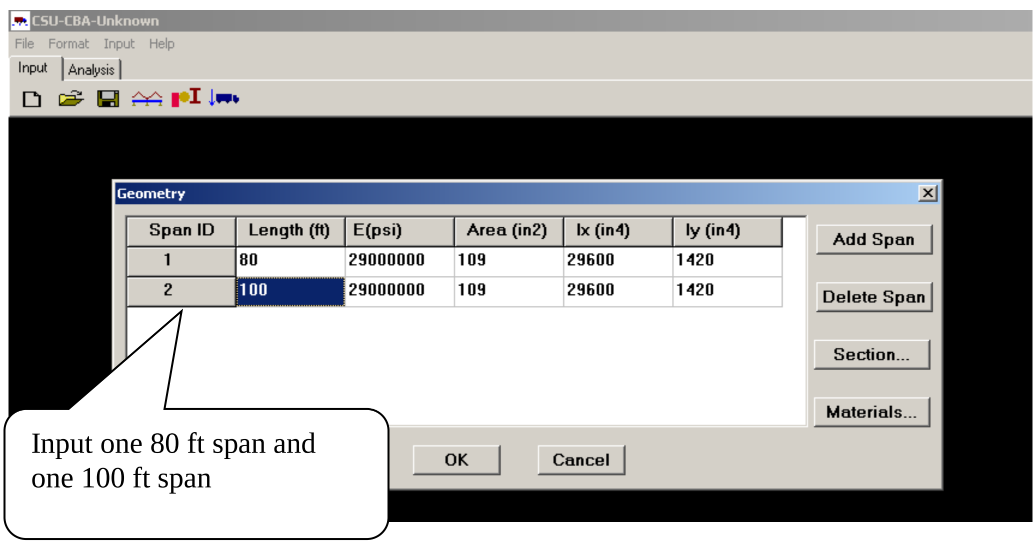
Step 3: Run CSU-CBA.exe global stiffness analysis





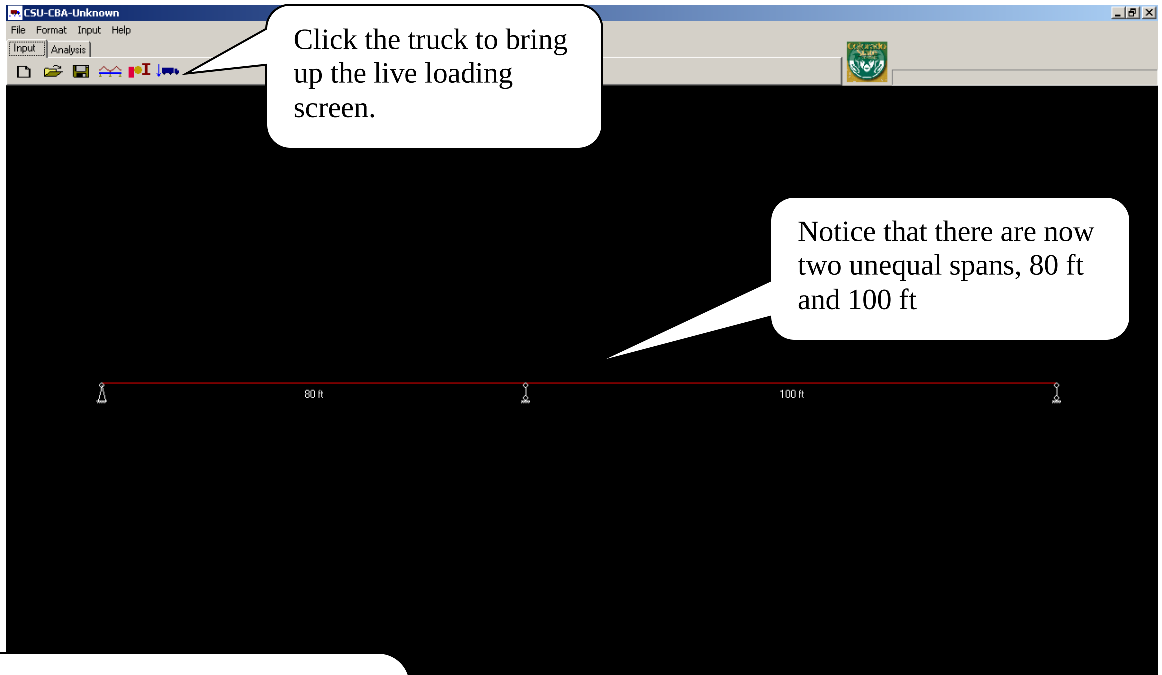
Note: Any size shape can be selected from the Section selection because only moment and shears are being found, which do not take into account elasticity or moment of inertia.





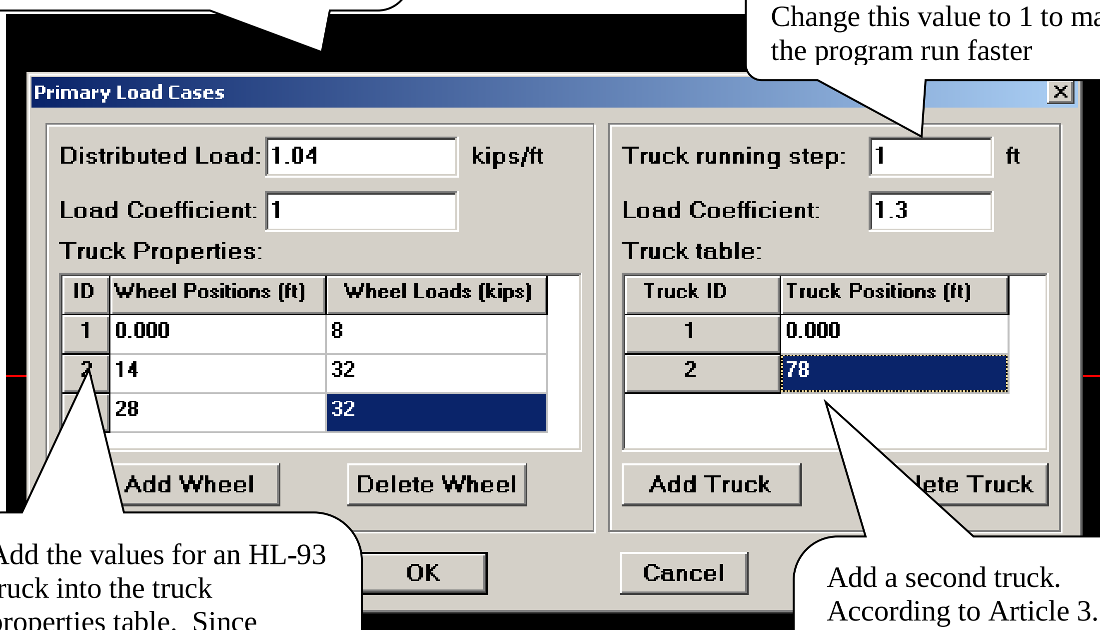
Click the truck to bring up the live loading screen.

Notice that there are now two unequal spans, 80 ft and 100 ft



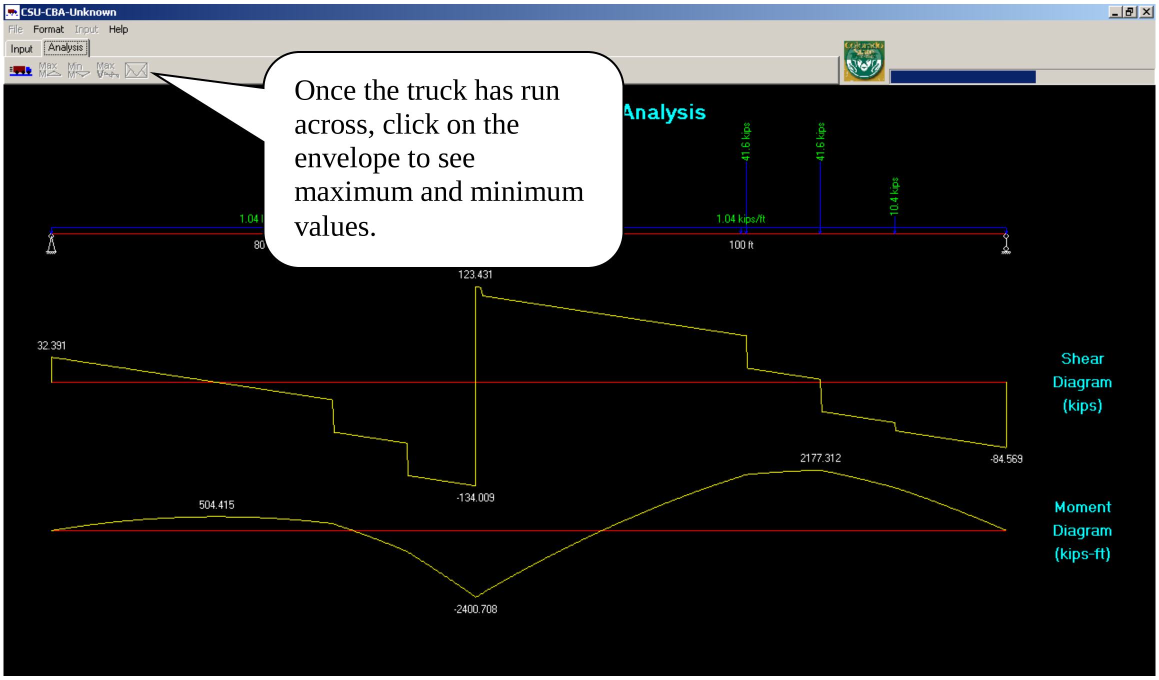
Add the noted value from cell in the spreadsheet. This distributed load represents the DL2 + the Lane Load.

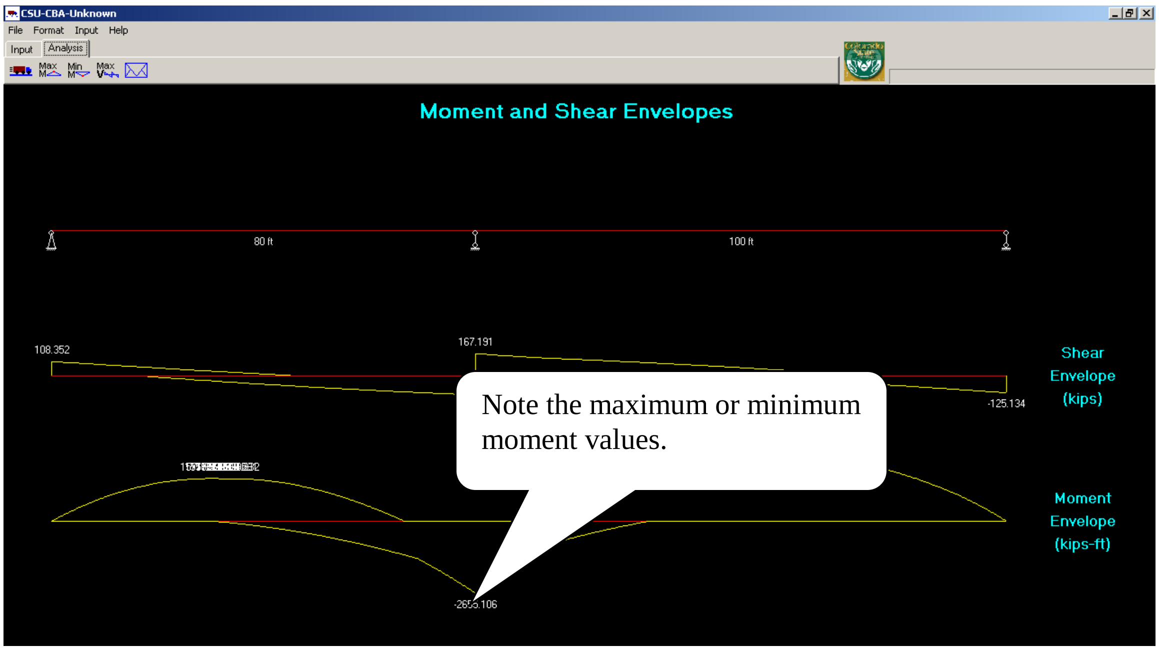
Change this value to 1 to make the program run faster



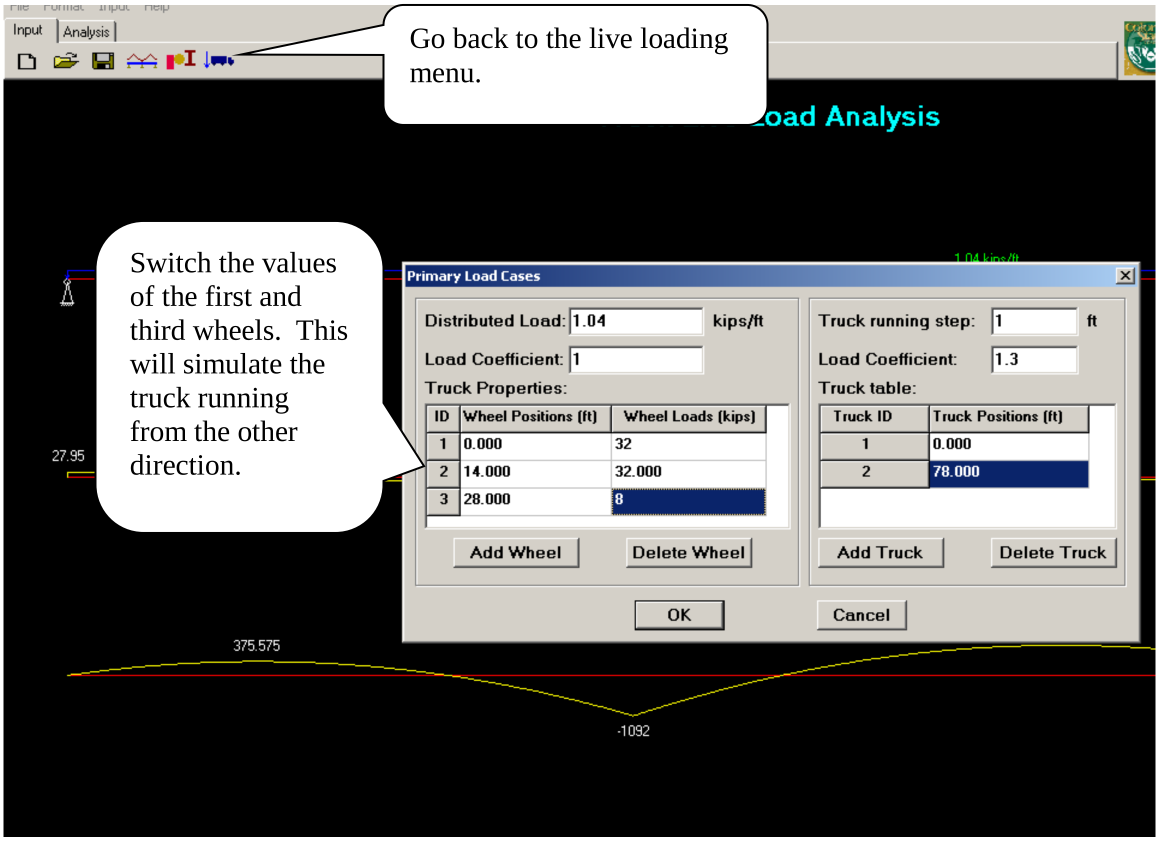
Add the values for an HL-93 truck into the truck properties table. Since identical two trucks are used, the wheel positions will not change.

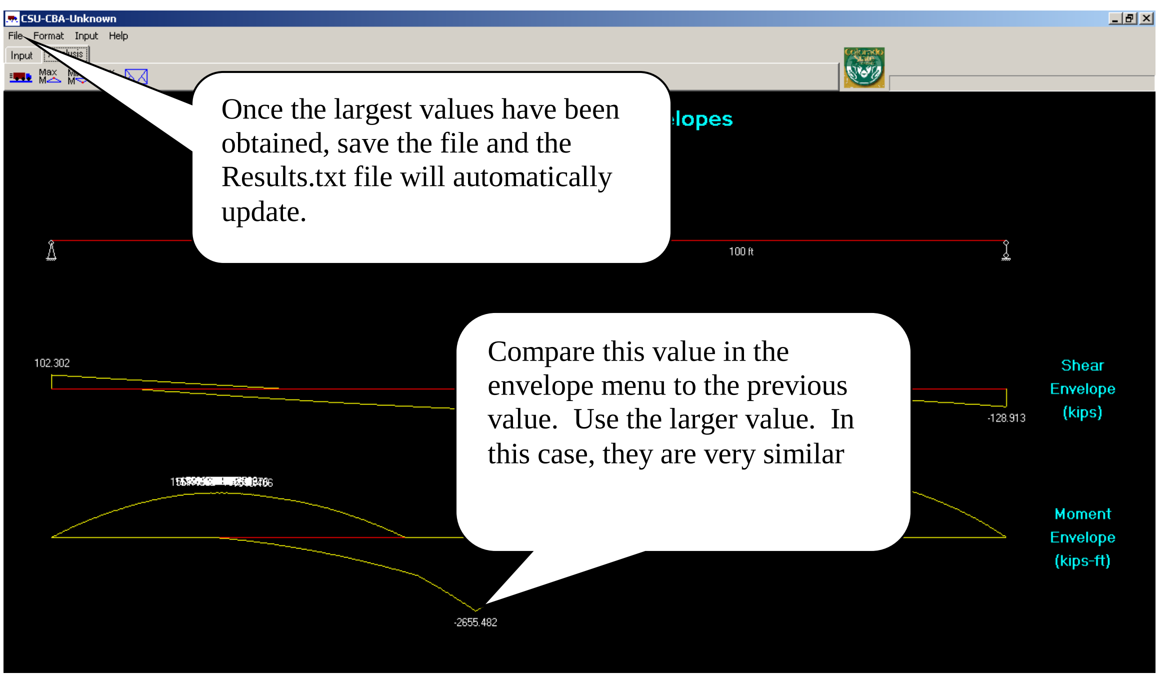
Add a second truck. According to Article 3.6.1.3 the second truck must be at least 50 ft behind the first. Put in 78 ft for the second truck to satisfy this.


CSU-CBA-Unknown
File Format Input Help
Input Analysis
Once the truck has run across, click on the envelope to see maximum and minimum values.
Analysis
41.6 kips
41.6 kips
10.4 kips
1.04 kips/ft
100 ft
123.431
32.391
-134.009
-84.569
2177.312
504.415
-2400.708
Shear Diagram (kips)
Moment Diagram (kips-ft)

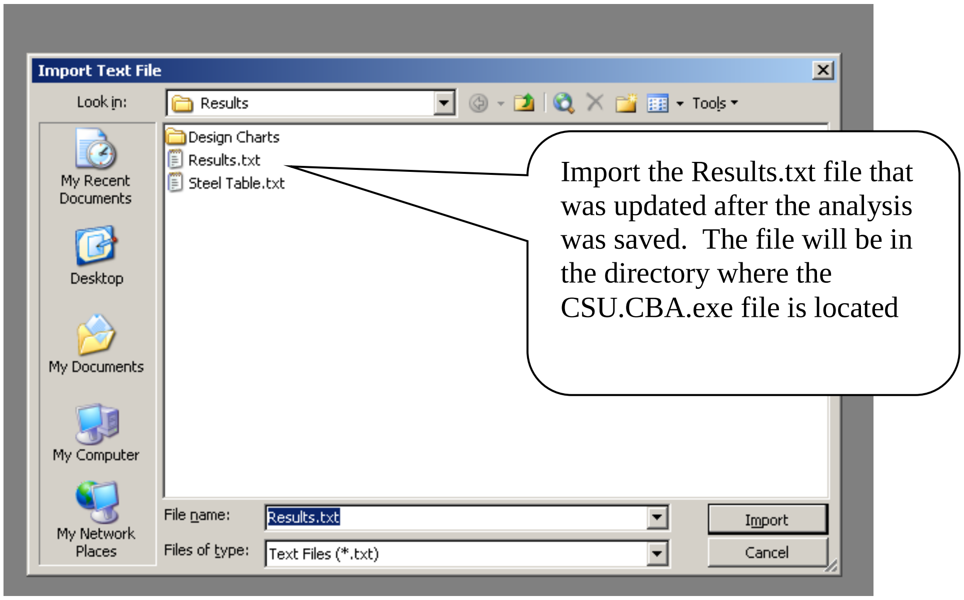

CSU-CBA-Unknown
File Format Input Help
Input Analysis
Moment and Shear Envelopes
80 ft
100 ft
108.352
167.191
-125.134
Note the maximum or minimum moment values.
-2655.106
Shear Envelope (kips)
Moment Envelope (kips-ft)

Step 4: Running the truck from both directions

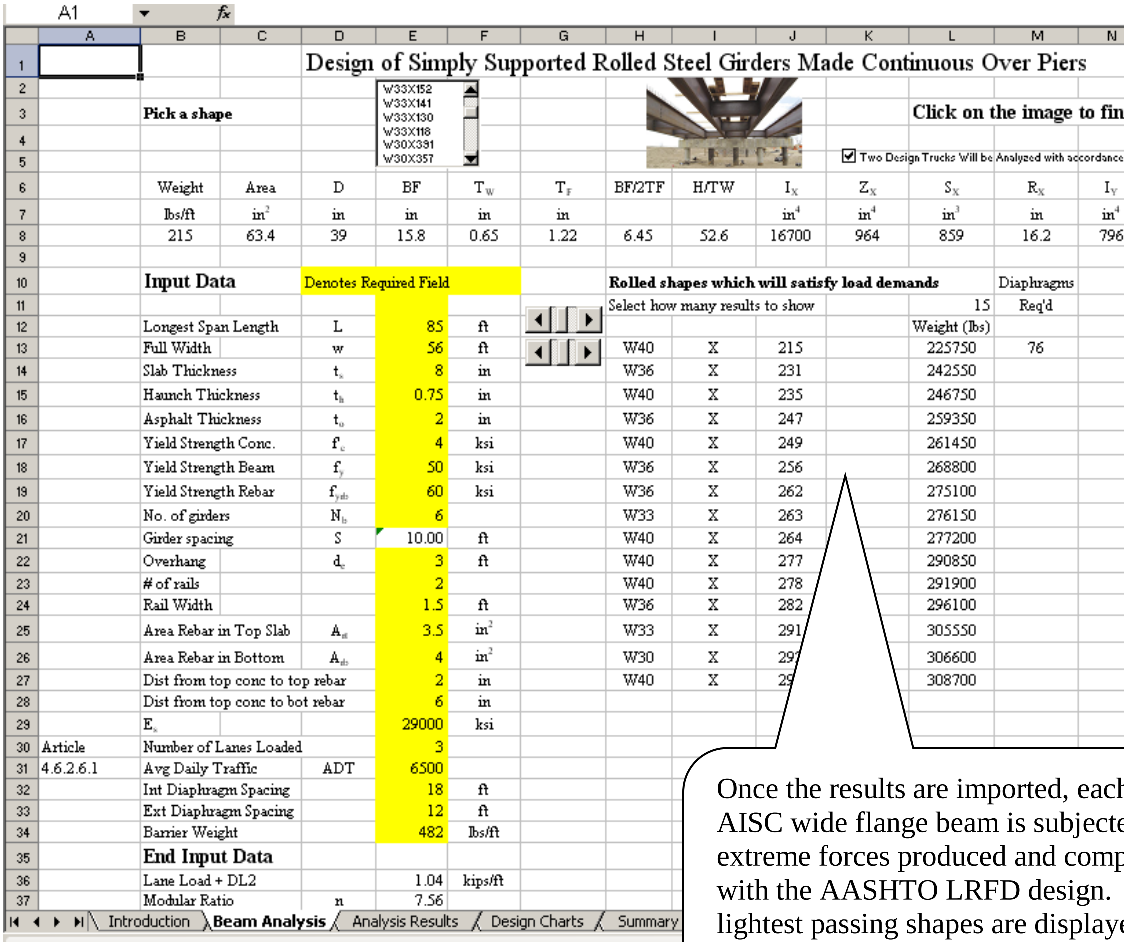




Step 5: Import the data to size the appropriate girders.



Step 6: Results from two truck analysis

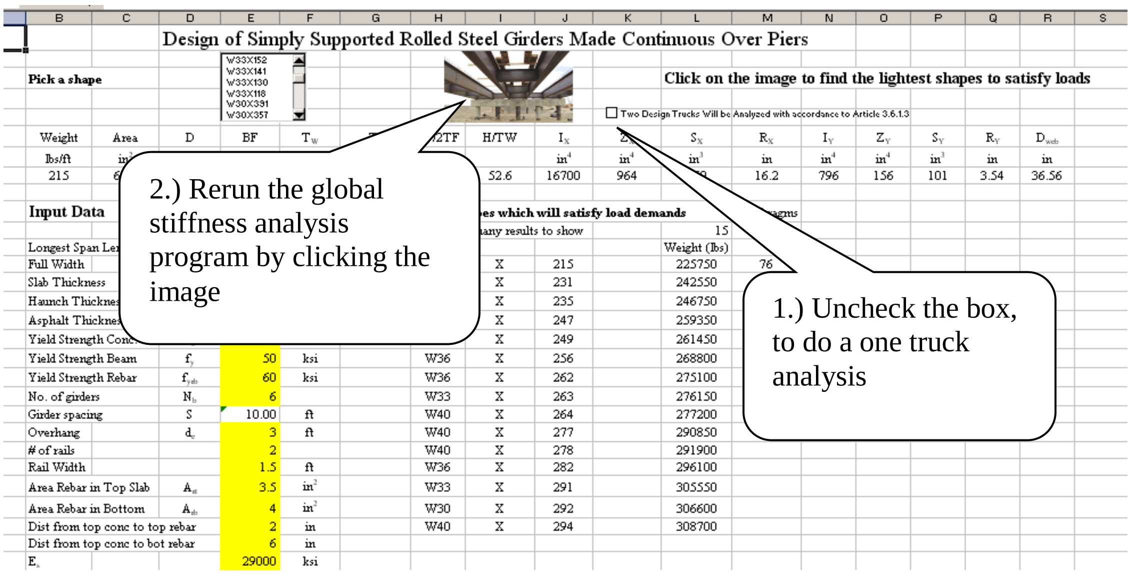


Row	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1				Design of Simply Supported Rolled Steel Girders Made Continuous Over Piers										
2					W33X152									
3		Pick a shape			W33X141							Click on the image to find		
4					W33X130									
5					W33X118 W30X391 W30X357						Two Design Trucks Will be Analyzed with accordance t			
6		Weight	Area	D	BF	T_W	T_F	BF/2TF	H/TW	I_X	Z_X	S_X	R_X	I_Y
7		lbs/ft	in^2	in	in	in	in			in^4	in^4	in^3	in	in^4
8		215	63.4	39	15.8	0.65	1.22	6.45	52.6	16700	964	859	16.2	796
9														
10		Input Data		Denotes Required Field				Rolled shapes which will satisfy load demands					Diaphragms	
11								Select how many results to show				15	Req'd	
12		Longest Span Length		L	85	ft						Weight (lbs)		
13		Full Width		w	56	ft		W40	X	215		225750	76	
14		Slab Thickness		t_s	8	in		W36	X	231		242550		
15		Haunch Thickness		t_h	0.75	in		W40	X	235		246750		
16		Asphalt Thickness		t_a	2	in		W36	X	247		259350		
17		Yield Strength Conc.		f'_c	4	ksi		W40	X	249		261450		
18		Yield Strength Beam		f_y	50	ksi		W36	X	256		268800		
19		Yield Strength Rebar		f_{yb}	60	ksi		W36	X	262		275100		
20		No. of girders		N_b	6			W33	X	263		276150		
21		Girder spacing		S	10.00	ft		W40	X	264		277200		
22		Overhang		d_e	3	ft		W40	X	277		290850		
23		# of rails			2			W40	X	278		291900		
24		Rail Width			1.5	ft		W36	X	282		296100		
25		Area Rebar in Top Slab		A_{st}	3.5	in^2		W33	X	291		305550		
26		Area Rebar in Bottom		A_{sb}	4	in^2		W30	X	29		306600		
27		Dist from top conc to top rebar			2	in		W40	X	29		308700		
28		Dist from top conc to bot rebar			6	in								
29		E_s			29000	ksi								
30	Article	Number of Lanes Loaded			3									
31	4.6.2.6.1	Avg Daily Traffic		ADT	6500									
32		Int Diaphragm Spacing			18	ft								
33		Ext Diaphragm Spacing			12	ft								
34		Barrier Weight			482	lbs/ft								
35		End Input Data												
36		Lane Load + DL2			1.04	kips/ft								
37		Modular Ratio		n	7.56									

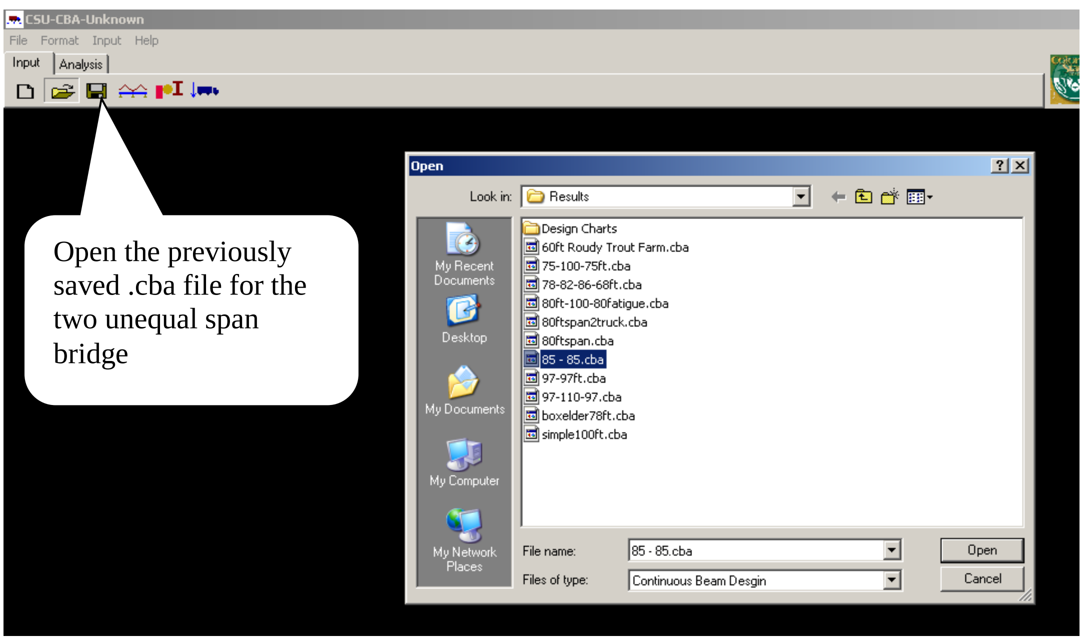
Introduction | Beam Analysis | Analysis Results | Design Charts | Summary

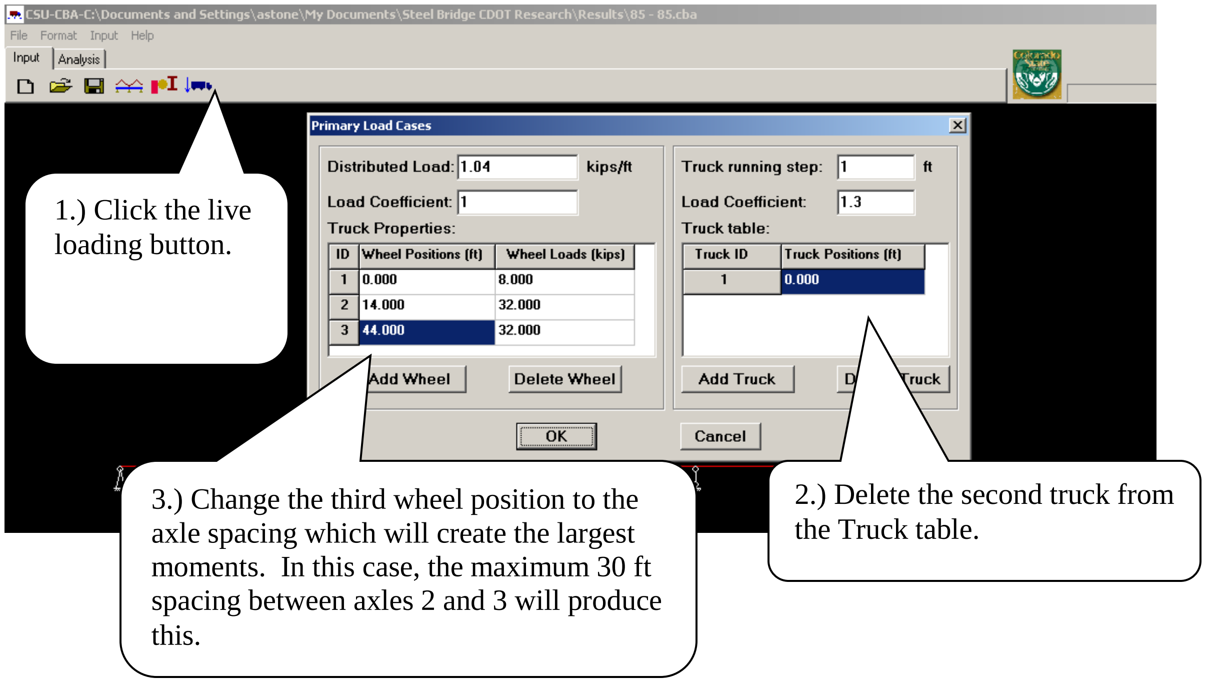
Once the results are imported, each AISC wide flange beam is subjected to extreme forces produced and compared with the AASHTO LRFD design. The lightest passing shapes are displayed here.

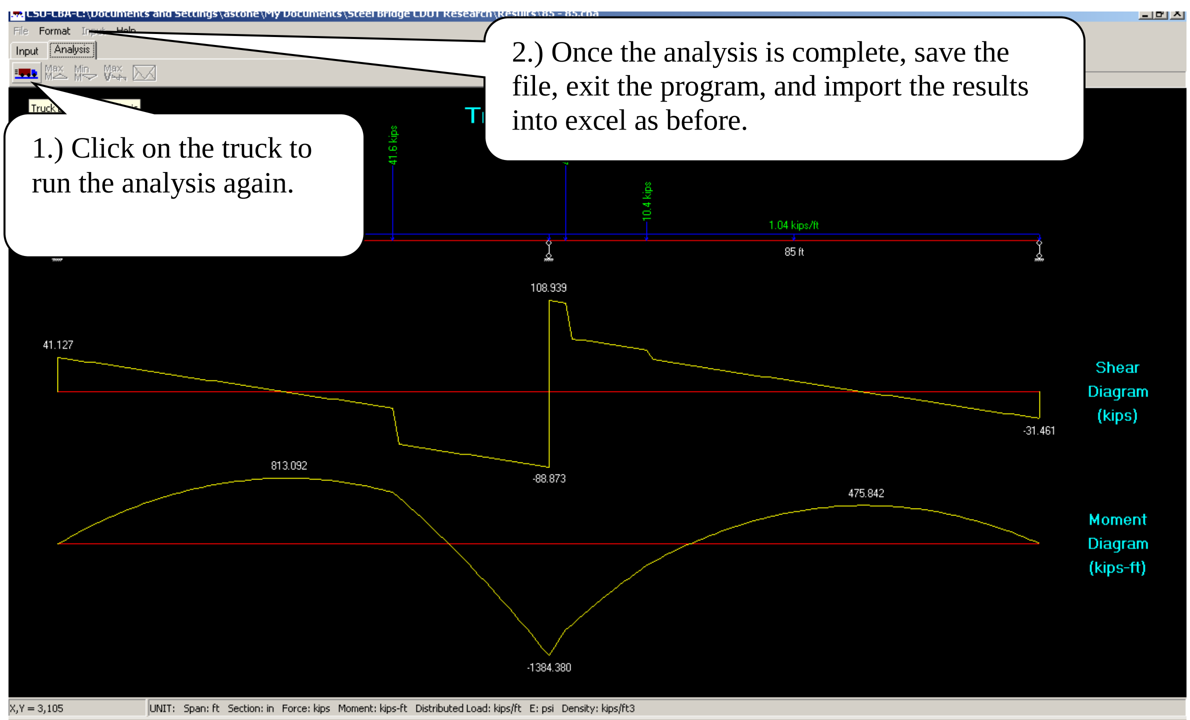
Step 7: One truck analysis



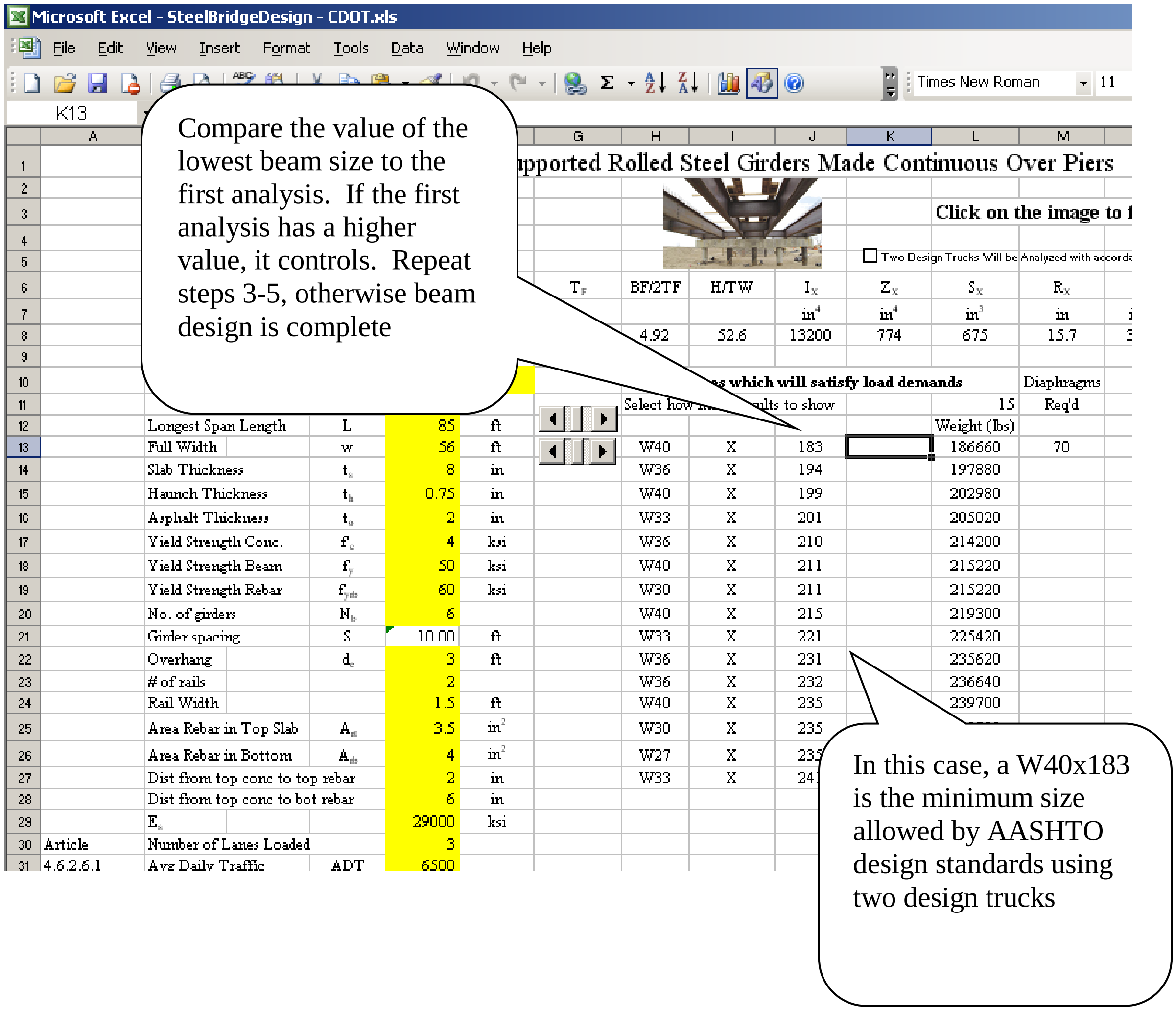
Step 8: Inputting values for one truck analysis




CSU-CBA-C:\Documents and Settings\astone\My Documents\Steel Bridge CDOT Research\Results\85 - 85.cba
File Format Input Help
Input Analysis
Primary Load Cases
Distributed Load: 1.04 kips/ft
Load Coefficient: 1
Truck Properties:
ID Wheel Positions (ft) Wheel Loads (kips)
1 0.000 8.000
2 14.000 32.000
3 44.000 32.000
Add Wheel
Delete Wheel
Truck running step: 1 ft
Load Coefficient: 1.3
Truck table:
Truck ID Truck Positions (ft)
1 0.000
Add Truck
OK
Cancel
1.) Click the live loading button.
2.) Delete the second truck from the Truck table.
3.) Change the third wheel position to the axle spacing which will create the largest moments. In this case, the maximum 30 ft spacing between axles 2 and 3 will produce this.


File Format
Input Analysis
1.) Click on the truck to run the analysis again.
2.) Once the analysis is complete, save the file, exit the program, and import the results into excel as before.
41.6 kips
10.4 kips
1.04 kips/ft
85 ft
108.939
41.127
-88.873
-31.461
Shear Diagram (kips)
813.092
475.842
-1384.380
Moment Diagram (kips-ft)
X,Y = 3,105
UNIT: Span: ft Section: in Force: kips Moment: kips-ft Distributed Load: kips/ft E: psi Density: kips/ft3

Step 9: Comparing the two analyses



APPENDIX F: COLORADO PERMIT TRUCK ANALYSIS USER'S MANUAL

CSU-CBA

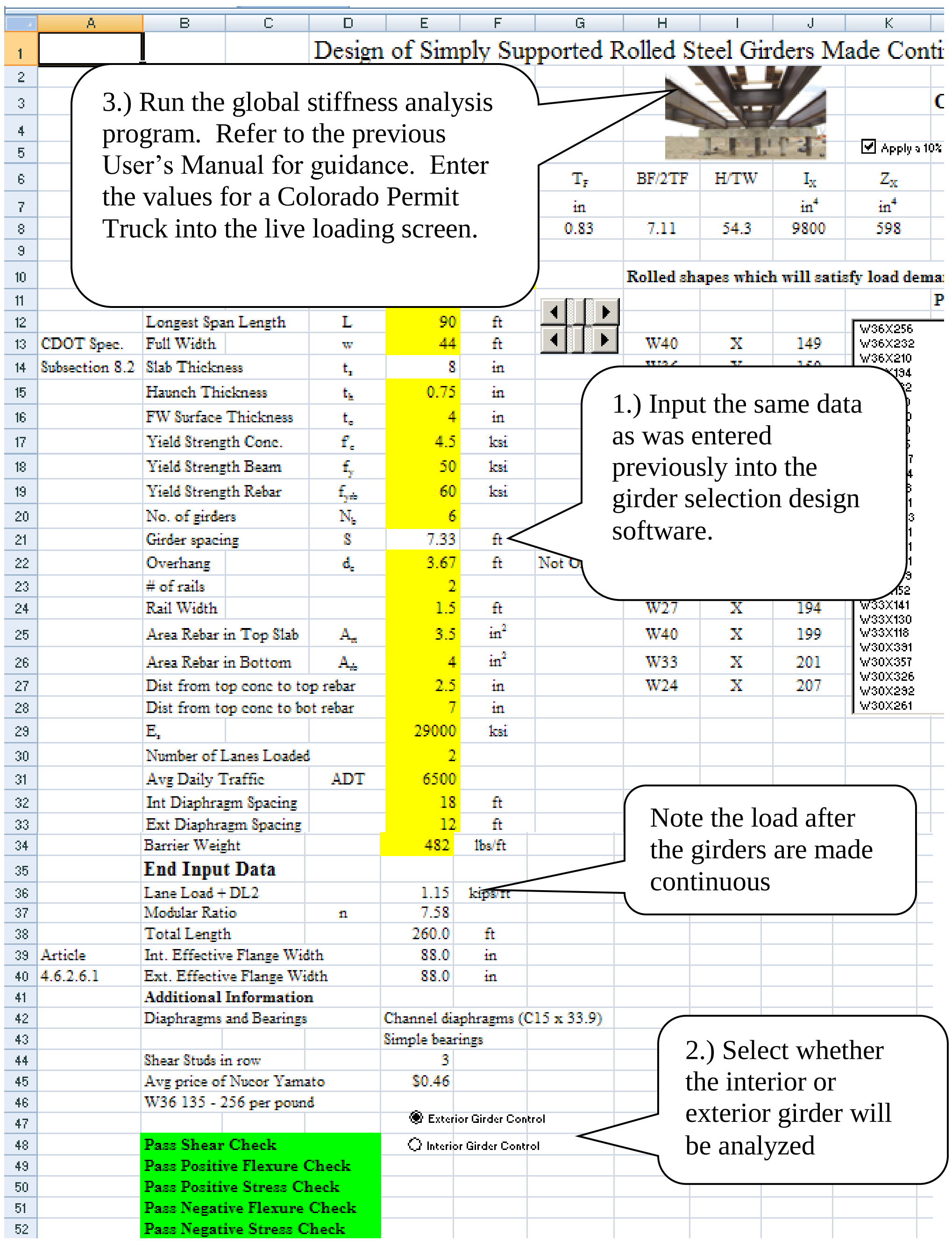
(Colorado State University-Continuous Beam Analysis)

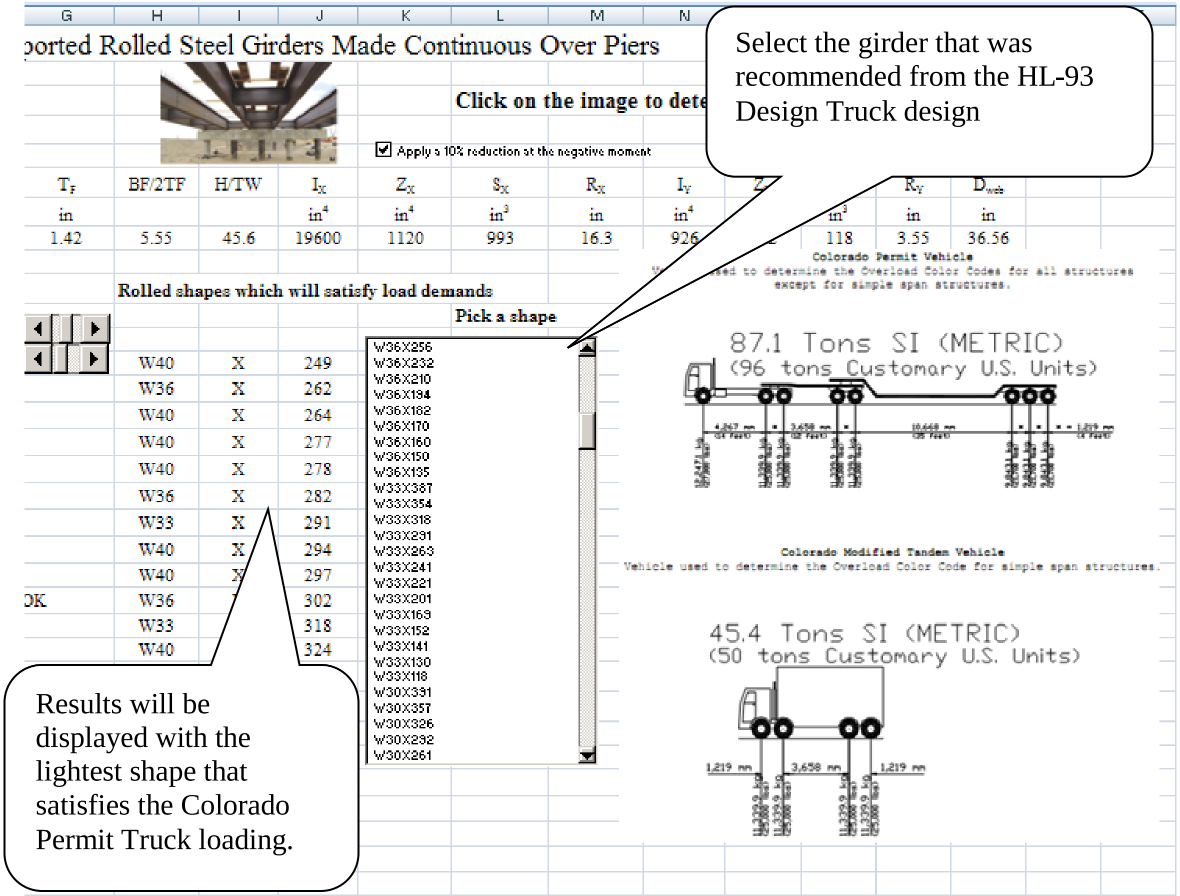
Colorado Permit Truck Analysis Program Users Guide

Alex Stone
John W. van de Lindt
Thang N. Dao

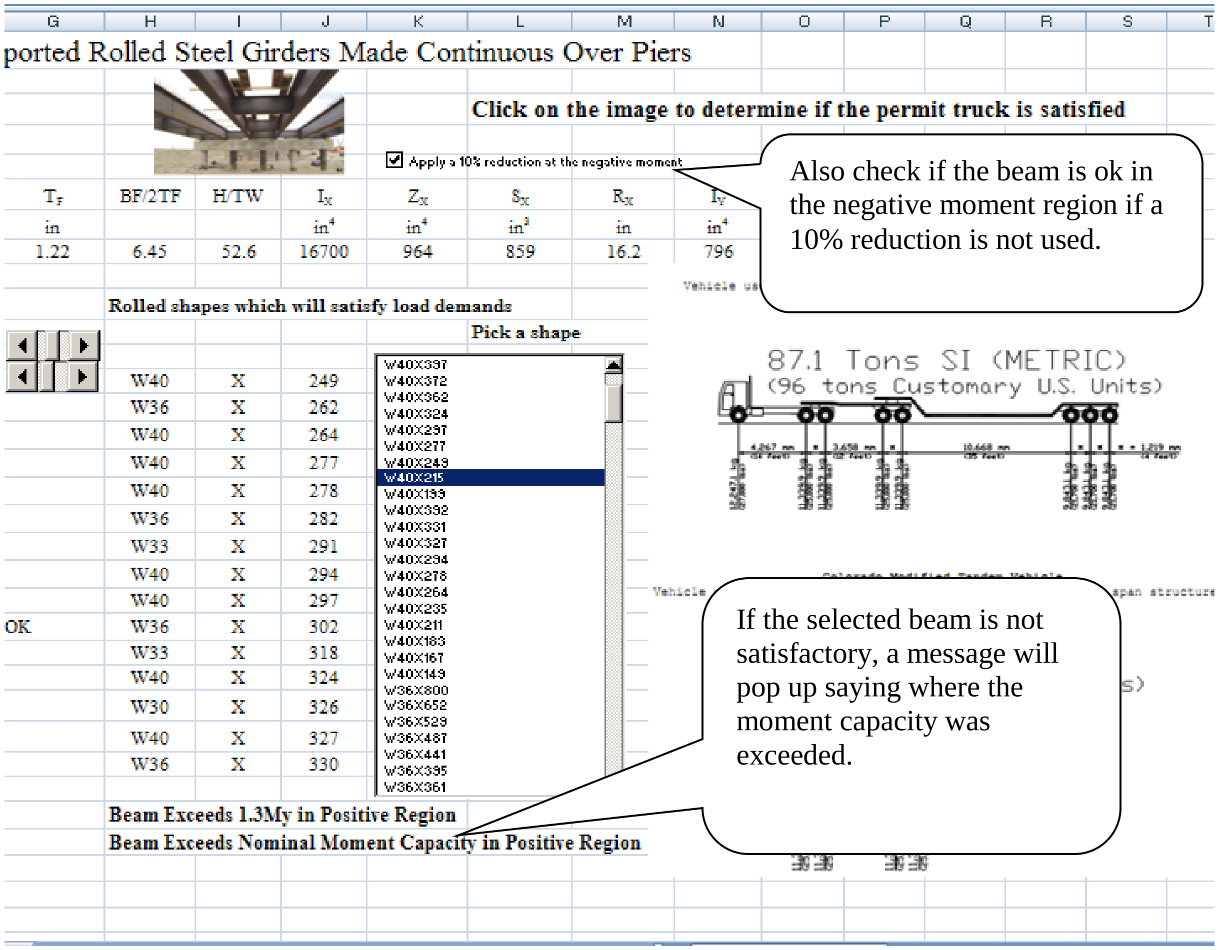
Introduction

This program analyzes a Colorado Permit Truck and determines the minimum rolled beam size required to satisfy the loading. This program will follow all of the same guidelines as the previous CSU-CBA User's Manual. The Colorado Permit Truck is only analyzed based on strength and uses Strength II load factors. This User's Manual only describes how to set up the program to analyze the Colorado Permit Truck. Refer to the previous User's Manual for a complete guideline for running the software package.





ported Rolled Steel Girders Made Continuous Over Piers
Click on the image to dete
Apply a 10% reduction at the negative moment
Select the girder that was recommended from the HL-93 Design Truck design
Rolled shapes which will satisfy load demands
Pick a shape
Colorado Permit Vehicle
87.1 Tons SI (METRIC)
(96 tons Customary U.S. Units)
Colorado Modified Tandem Vehicle
Vehicle used to determine the Overload Color Code for simple span structures.
45.4 Tons SI (METRIC)
(50 tons Customary U.S. Units)
Results will be displayed with the lightest shape that satisfies the Colorado Permit Truck loading.



If the girder that was selected in the previous software to satisfy the HL-93 design truck does not meet the demands of the Colorado Permit Truck, use the minimum beam size required by the Colorado Permit Truck.

If the selected beam only exceeds the yield moment by 1.3 or greater, further analysis should be conducted to determine if the beam should be selected.

APPENDIX G: GIRDER SELECTION DESIGN SOFTWARE LOGIC

The following presents the logic that is used to create the girder selection design software.

Loads

- Dead Load 1 moments and shears are generated for a simply supported beam.
- All other loads are put into CSU-CBA and moments and shears are found.
- In the 'Analysis Results' tab, the moments and shears found from the CSU-CBA analysis are broken down into their respective categories, i.e., DL2, LL, FW. This is done by using ratios from the total distributed load. For example, the lane load moment would be .64lbs/ft / total inputted load multiplied by the total distributed load moment.
- The factored moment in column G is not necessarily the moment used for calculations.

Live Load Lane Distribution

- The live load lane distribution follows provisions from Article 4.6.
- Moment and shear distribution factors are found for both interior and exterior beams.
- The appropriate factor is applied depending on inputted data.
- These factors are applied to the moments and shears for flexure, shear, and stress checks.
- In cell E47, the user can choose if the exterior or interior girder will control the design.

Flexure

- The plastic moment capacity of the composite section is found in both the positive and negative regions following Appendix D6.
- Forces from the flanges, web, slab, and reinforcement are found. Using these values, the neutral axis location is determined and used to find the plastic moment capacity. In the positive section, longitudinal reinforcement is conservatively neglected. In the negative section, the slab does not contribute to the strength of the composite section because it is in tension.
- The nominal moment capacity is calculated by reducing the plastic moment capacity according to Article 6.10.7.1.2.
- The yield moment is found and limited to 1.3My.
- Strength I factors are applied to the extreme moment values found in both the positive and negative sections. These values are compared to the nominal moment capacity, and it is determined if the given cross section is ok in flexure. The maximum Strength I factored loads must be less than the nominal moment capacity and 1.3My to pass.

Shear

- The nominal shear capacity is found following Article 6.10.9.2.
- It was assumed that all logical shapes to be used are compact sections. If the shape is a W40x149, W36x135, or W33x108, the designer should recheck the shear design because these shapes are non-compact.
- Holes in the web are not accounted for in the shear capacity. If holes are present, the shear capacity should be rechecked.
- The program determines if bearing stiffeners are required by finding if the maximum factored shear is less than 75% of the nominal shear capacity.

Stress

- Elastic section properties are calculated for the positive short and long term sections and negative sections of the composite section.
- The long term section is greater than the short term section by a factor of 3.
- The moment of inertia and section modulus are found for all three sections.
- The negative section only uses the area of steel and reinforcement, while the positive section uses the concrete and steel.
- Once the elastic section properties are found, permanent deformations in the flanges are found in both the positive and negative sections.
- This is done by using the mechanics equation Mc/I, with the I value referring to the appropriate value found in the elastic section properties.
- Service II load factors are applied to the live load.
- Stresses are limited to 95% of the yield strength of the steel.
- The negative section has no contribution of stress from the dead load 1.