

A Visualization Tool for Teaching Structural Steel Connection Design

Perry S. Green¹, Patrick Veltri², and Thomas Sputo^{3,4}

Abstract

A visualization tool has been developed for educators as well as students to assist in the effective teaching and learning process of structural steel connection design. The visualization tool, referred to as “The Steel Connections Teaching Toolkit”, has as its basis the Steel Teaching Sculpture designed by Dr. Duane Ellifritt, Professor Emeritus at the University of Florida and originally constructed on campus in 1986. The teaching toolkit is comprised of a three-dimensional CAD drawing file, shear connection calculator tool, and a teaching guide document. The CAD model is arranged as a series of two-dimensional layouts and views of each connection depicted on the Steel Sculpture with each one being fully detailed and dimensioned. The calculator tool contains a series of MathCAD® worksheets that illustrate the applicable limit states for the six types of shear connections that are represented on the Steel Sculpture. The worksheets are designed to be simple to use, with few limitations, yet able to accommodate nearly any standard shear connection design while still following the design and analysis provisions prescribed in the AISC-LRFD specification. The teaching toolkit will greatly aid civil engineering students in understanding the intricacy and applicability of steel connection design checks and limit states, through visualization media that includes working AutoCAD® drawings, photographs and data figures, narrative text, and worked out example problems to demonstrate the versatility of the MathCAD® worksheets.

Introduction

Civil Engineering undergraduates in most colleges and universities have a mandatory course in basic or introductory steel design and analysis. In this class, students learn the fundamentals of engineering design with steel as the structural material. The students learn how steel is manufactured today, its use as a structural material in buildings and bridges, and about the performance of steel members, generally in the form of tension members, compression members, flexural members, and possibly beam-column members. Students are required to perform basic structural engineering design and analysis by applying knowledge gained from previous classes in statics, mechanics of materials, and structural analysis. It is usually in this first steel class, or in a complementary concrete design class, that students are first exposed to limit states or ultimate strength design. Throughout the semester, students are taught how to properly proportion steel

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members based on a required level of strength in accordance with the AISC-LRFD Specification (1993).

In a vast majority of the undergraduate steel design classes, little time is spent on the subject of steel connections beyond simple tension connections. A one-semester steel class presents a limited amount of time to cover an essentially limitless amount of subject matter. The instructor is obliged to prioritize particular topics over structural steel framing connections. The time that is spent on framing connections might involve little more than a solitary lecture or homework assignment. Often these lectures and assignments are cursory in nature. The instructor might simply reference Chapter J of the AISC-LRFD Specification (1993), or mention Volume II (Connections) of the AISC Manual of Steel Construction (1994). Rather than learning the applicable limit states and carrying out the complete design and analysis process for various types of framing connections, students may be told that connections “are typically designed for $\frac{1}{2}$ the uniformly distributed load (UDL)” they can carry. They are then shown how to look up the connection strength value in the appropriate design tables from Volume II (Connections). Students may be told that the design of steel framing connections are a detailing issue that is best left to the expertise of the fabricator. Most undergraduate textbooks tend to reinforce this ‘fact’ by placing connection design in a single chapter near the back of the book and have only a few cursory examples which usually lack sufficient detailed/dimensioned figures and/or photographs. While students may learn up to three different structural analysis software programs, few are exposed to any kind of connection design and analysis software. Finally, students are rarely shown detail or fabrication plans to get an idea of how real three-dimensional connections are represented as two-dimensional drawings.

When steel framing connection design and analysis is taught, many students have trouble understanding the behavior and performance requirements of different types of connections. One reason for this is students are accustomed to seeing idealized structures made of line elements for beams and columns and symbols that represent boundary conditions such as simple pinned, hinged, and fixed that characterize the framing connections or baseplate connections to the foundation. However, real steel structures are primarily made up of beams, girders, bracing members, and columns, all joined together with plates and angles or other detail members. Steel connections range from being extremely simple to extraordinarily complex. Steel connections are truly three-dimensional objects that can have elaborate loading and diverse geometry. The joints are composed of bolts and welds with potentially numerous plies of material that may extend into two or more planes. The load path at any individual fastener must pass through no less than three components in the connection (i.e. two steel plies being joined and the fastener: bolt or weld). Also, depending on the loading and geometry of the connection, the load paths through the connection components can involve shear, tension, compression, shear and tension, or shear and compression. The multiple plies of material, the fasteners and the assorted load paths all together make steel connection design a technical challenge due to the numerous limit states that need to be calculated and checked for all the elements that make up the connection.

Steel connection design involves careful evaluation of several options and design factors. “Steel connections” is a broad term that includes the many kinds and types of connections, everything from framing connections such as shear and moment connections to axially loaded truss and bracing connections. Even within these categories there are several permutations based on the specific loading and methods of attachment. These different types of connections represent the diversity in steel connections. The final form of a particular connection is dependent on several variables: the type of loading, the level of strength and stiffness, the economy of the connection, the level of difficulty in erection, etc. A “good” connection design tends to properly balance these factors to produce a connection that is functional, safe, and economical. It is therefore easy to see why

students and young engineers (as well as more experienced engineers) many times have trouble attempting to balance these issues in a single connection design, even one that is referred to as a simple shear connection.

The Steel Sculpture

In 1985, Dr. Duane Ellifritt, Professor of Civil Engineering at the University of Florida, recognized that students in his undergraduate steel design class were having trouble visualizing how steel members are connected, i.e. beam-to-beam, beam-to-girder, beam-to-column, girder-to-column, or column-to-column. He needed to find an effective way to ‘display’ these types of connections so that their behavior could be adequately described analytically as well as visually. Dr. Ellifritt solved the visualization problem of steel connections in 1986 with the design and erection of a Steel Sculpture on the campus of the University of Florida.

The Steel Sculpture provides a convenient means to display full-scale steel connections that students can walk around and study. The sculpture exhibits over 20 different connections commonly used today in structural steel construction. The Steel Sculpture consists primarily of shear and moment connections, though there are several other types of steel connections presented (e.g. truss-to-column, shear studs, and column baseplate). The Steel Sculpture's merit has been nationally recognized as more than 100 university campuses now have erected a Steel Sculpture modeled after Dr. Ellifritt's original design at the University of Florida.

A 48-page booklet entitled “Connecting Steel Members, a Teaching Guide” was also produced by the University of Florida and published by AISC as a companion to the Steel Sculpture. The booklet was designed to be a student supplement to Volume II (Connections) of the AISC-LRFD Manual of Steel Construction. The teaching guide contained 44 drawings and 22 photographs of connections from the original Steel Sculpture. In addition to the illustrations, each connection had a short descriptive narrative associated with it.

The Need for a Visualization Tool

The purpose of this paper is to describe the development of “The Steel Connections Teaching Toolkit”, a tool for students and educators to effectively learn and teach steel connections. As previously stated, the toolkit is an attempt to take what Dr. Ellifritt's Steel Sculpture started in visualization and enhance it's effectiveness as a teaching tool, as well as use it to incorporate the fundamentals of steel connection design into a first course in structural steel design.

Engineering steel connections is often considered the task of the fabricator, however the ultimate responsibility for the design of the connections in a structure is with the Structural Engineer-of-Record (EOR), not the fabricator. Most structural failures occur due to connection deficiencies. Connections have more design limit states than other structural members (e.g. beams, columns, etc.). The designer needs to know when and what limit states are applicable to a particular connection. Additionally, most connections are sensitive to changes or errors in design parameters. Even slight changes in details may drastically influence the strength and/or performance of a connection.

The design tables contained in AISC Volume II (Connections) list only the value of the controlling load; the controlling limit state for that load is not given. Furthermore, one cannot find any other information related to the other applicable limit states or their respective strengths. This lack of pertinent information is significant because if the EOR does not know which parameter to change, it is almost impossible to maintain an optimal design if the connection design, based on a design

table, has to be modified. This lack of information also prevents any sort of comparison being made between applicable limit states for one connection design layout and another design configuration.

Steel connections have a major influence on the overall cost of a steel framing system, as well as its ease or difficulty in erection. Due to the labor costs to deposit it, weld metal is the most expensive component (by weight) in a steel building. Even when connection design is efficient in the use of materials, it may still be cost prohibitive due to erectability considerations. By using repetitive connection designs, a significant cost savings may be obtained in steel structures. Typically, the most efficient connections use the least number of fasteners or least amount of weld material and are generally simple to fabricate and erect while still meeting the required performance criteria.

The design of the connections will have a global influence on the behavior of a structure. Beams with relatively stiff boundary conditions have lower flexural moments that govern their design, but the connection design may be more complex, having to transfer the supported beam end moment to the supporting member or column. However, one needs to realize that the relationship between the rigidity of the connection and the beam end moment is not linear. Many factors are present (that make up the connecting elements) between the supported and supporting members that will influence the connection behavior and ultimately the overall structure. Depending on the loading, a beam with infinitely stiff connections (full rotational restraint) has its bending moment reduced between one-third and one-half compared to connections that are infinitely flexible (true pin connections). In summary, when engineers understand the issues of performance, economics, and erectability of steel connections, they can invariably design safer and more practical steel structures.

The Teaching Toolkit

The Steel Connections Teaching Toolkit is based on the original Steel Sculpture designed by Dr. Ellifritt. The teaching toolkit includes a 3D AutoCAD® file of the Steel Sculpture, shear connection calculator tool, and a teaching guide document. The CAD file is a complete 3D AutoCAD® model of the steel sculpture (see Fig. 1) arranged as a series of 2D layouts and views as shown in Fig. 2. that are fully detailed, dimensioned, and annotated. The calculator tool takes the form of a series of MathCAD® worksheets (MathSoft, 2000) that enable the user to perform steel connection strength analysis through a comprehensive check of the required limit states for each shear connection type. The teaching guide document contains descriptions, drawings, figures, and photographs for each connection depicted on the Steel Sculpture and incorporates several design and analysis examples using the MathCAD® worksheets.

Steel Sculpture CAD Model

A full 3D AutoCAD® model of the sculpture was created using AutoCAD 2000® (AutoDesk, 2000) from the original manually drafted fabrication drawings used to build the first steel sculpture. AutoCAD 2000® was chosen to produce the model since it is a commercially available software application that is taught as part of many undergraduate civil engineering programs. The CAD model is a true 3D representation of the Steel Sculpture and is completely dimensioned and detailed. The AutoCAD file includes several layouts and views of each connection that make up the sculpture. The CAD model alone is a valuable aid to students just trying to visualize structural steel connections in two dimensions. The CAD layouts are arranged in a similar fashion to the original fabrication drawings and show how a real three-dimensional structure is represented in two-dimensional space. Also, as a digital medium, the CAD file can be used in particular applications for visualization or structural analysis. Using appropriate application software, any specific view of

the sculpture can be obtained. The user may pan, rotate, and zoom to any preferred extent. In addition, any or all parts of the digital model may be imported into compatible analysis software such as for detailed finite element modeling of the connections. This modeling could include the structural members, the connection elements such as the structural angles or plates, and the bolts, nuts and washers if it is a bolted connection or the welds if it is a welded connection.

Shear Connection Calculator Tool (MathCAD® Worksheets)

Shear connections are the most prevalent type of structural connection in steel framed building construction. As an idealized connection type, they are sometimes referred to as “simple” connections since they are assumed to carry no moment and accommodate the required member end rotations of the supported member. Shear connections, though, can exhibit complex behavior and tend to have multiple limit states and design checks across several pieces that must be considered. Moment connections, meanwhile, are designed to carry the full moment of the supported member and not allow any rotation to occur. Moment connections typically have an integrated portion of the connection designed to carry the shear component of load. The design of this part of the moment connection follows that of a simple shear connection.

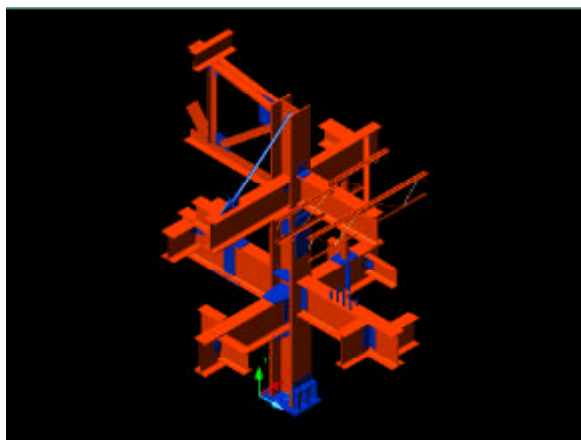


Fig. 1 Full 3D CAD Model of Steel Sculpture

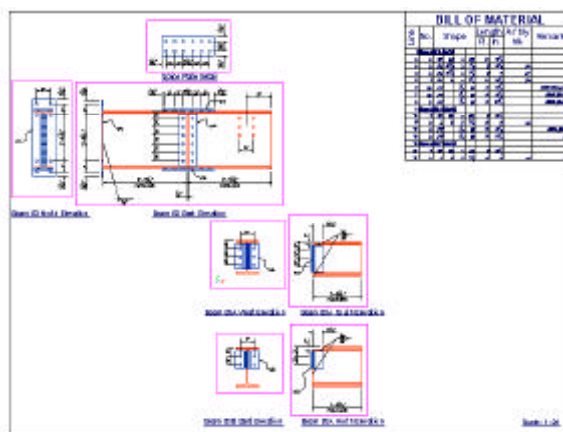


Fig. 2 Typical Fully Dimensioned and Detailed Connection Layout

The MathCAD® worksheets that have been developed are to be used as a teaching aid to students; helping them understand the intricacy and applicability of shear connection design checks and associated limit states. There is one analysis module for each of the six types of shear connections displayed on the Steel Sculpture: Double Angle, Shear End Plate, Unstiffened Seat, Single Plate, Single Angle and Shear Tee. The worksheets are designed to be simple to use, with few limitations, yet able to accommodate nearly any shear connection design configuration while still complying with the design and analysis provisions of the AISC-LRFD Specification (1993).

The MathCAD® worksheets have several features and abilities that make it an ideal teaching tool.

- There are over twenty-five limit states checks included as part of the calculator tool;
- The calculator tool performs several design, feasibility, and serviceability checks;
- The calculator tool can handle any combination of bolting and/or welding across the supported and supporting sides of the connection, including bolt and weld group eccentricity;
- The grades of bolts that can be specified are ASTM A325 or A490. Any bolt size or type of bolt hole may be used as permitted by the AISC-LRFD Specification. The thread condition of the bolts may be iNcluded or eXcluded. The bolts may be designed to be Slip Critical;

- The welds that can be specified may be either matched, under-matched or over-matched. Any one of four weld processes: SMAW, GMAW, FCAW, and SAW may be used;
- The shear connection worksheets can also handle copes, column or beam support, and offset vertical alignment;
- Any grade of steel may be input for each of the individual connection elements.

At the end of each MathCAD® worksheet are two output tables summarizing the analysis results. The first output table (Summary 1) lists the limit states and their applicability or strength for a given connection design. The second table (Summary 2) lists serviceability and/or other design checks and whether the required design criteria have been met. The calculator tool allows the user to see exactly what limit states are applicable and what the relative design strengths are between the different limit states. The user can see exactly what affect a change in a particular design parameter will have on the design checks and limit states for a given shear connection. Furthermore, the MathCAD® worksheets can aid instructors to develop example problems and learning exercises.

The following is a simple example that illustrates the use and versatility of the MathCAD® worksheets. Figs. 3 and 4 show the all-bolted double-angle connection, B1B, from the Steel Sculpture. The shear connection is composed of a W18x40 beam (the supported member) that is connected to a W18x50 girder (the supporting member). Since both members have the same nominal depth, a one inch (1") cope is provided at the top and bottom of the W18x40 beam. The connection angles are L4 x 4 x 3/8. For this example the wide-flange steel members are assumed to be ASTM A992 (50 ksi yield strength) and the angles are assumed to be ASTM A36 (36 ksi yield strength). The bolts are 3/4" A325-N with 4 rows and 3" spacing. There is a 1 1/2" inch offset between the supporting and supported vertical bolt lines. The beam setback is assumed to be a standard 1/2" setback.



Fig. 3 Staggered, Bolted Double-Angle Connection on Steel Sculpture (View Looking northeast) Showing Beam Copes



Fig. 4 Staggered, Bolted Double-Angle Connection on Steel Sculpture (View Looking East) Showing Double-Angle Framing

Before the calculator tool can perform an analysis, some loading must be applied to the designed shear connection. One could choose a completely arbitrary load to use in the MathCAD® worksheet or a more practical alternative is to assume a typical span-to-depth, L/d , ratio for the supported member and assume it carries some uniformly distributed loading. Therefore, for an L/d ratio of 20

and a loading equal to $\frac{1}{2}$ UDL, the W18x40 (with a nominal depth of 18") would have a span of 30 feet and a $\frac{1}{2}$ UDL value corresponding to 39 kips.

Once all the required parameters for the MathCAD® calculator tool have been established, the user opens the appropriate worksheet and inputs the necessary information. Fig. 5 shows the input section of the double angle worksheet for this analysis/design problem. The worksheet updates the output as soon as any variable or function argument is changed defining the problem. The two output tables corresponding to this analysis/design shear connection example are shown in Fig. 6.

As can be seen from the first table, Summary 1, all potential limit states are checked for the connection. Since this connection is all-bolted, those limit states that are only applicable to welded joints return a N/A (Not Applicable) response. The second table, Summary 2, lists serviceability and erectability issues. Notice for this connection the "Beam vs. Girder" check returns a flag that states, "Beam web depth is greater than girder T dimension". This check is flagged because the beam web depth is indeed greater than the T dimension, however this connection is still feasible. AISC permits some encroachment into the rolling fillets. The application only checks the beam web depth against the girder T dimension, it does not consider the allowed encroachment or the beam setback.

For this design/analysis shear connection example, the controlling limit state is bolt bearing on the outstanding angle legs with a value of 83.2 kips. The calculator tool has been developed primarily as a teaching/educational tool, rather than as a "design office" tool. The goal was to produce a product that students could use with relative ease to enhance their learning experience of structural steel connections. As such, the calculator tool does not specify the controlling limit state or determine whether a connection is satisfactory or unsatisfactory, but does provide all the necessary limit states results.

Double-Angle Connection

Input Parameters

Connection Loading (kips)

$P_u := 39$ (Minimum 10 kips)

Type of Support

Support := WEBG FLANGE: Column Flange
WEBG: Column Web
WEBG: Girder Web

Mean Slip Coefficient

$\mu := 0.33$

Setback

Setback := 0.5

Section Properties

Girder/Column

Material Strengths

$F_y_{\text{Supporting}} := 50$

$F_u_{\text{Supporting}} := 65$

Member Designation

$D_{\text{Supporting}} := 18$ $W_{\text{Supporting}} := 50$

Double Angle

Material Strengths

$F_y_A := 36$

$F_u_A := 58$

Member Designation

$\text{Leg1}_A := 4$ $\text{Leg2}_A := 4$ $t_A := \frac{3}{8}$

Member Length

$L_A := 13.5$

Beam

Material Strengths

$F_y_{\text{Supported}} := 50$

$F_u_{\text{Supported}} := 65$

Member Designation

$D_{\text{Supported}} := 18$ $W_{\text{Supported}} := 40$

Fig. 5 Typical Input Section of MathCAD® Double-Angle Shear Connection Worksheet

Supporting Side:

Column Web or Flange or Girder to Angle Legs1

Bolted or Welded Joint

Joint_Supporting := BOLTED BOLTED
WELED

Vertical Alignment

y_Supporting := 0.7 RELATIVE elevation of the mid-depth of the
connecting element with respect to the mid-depth
of the girder

(NOTE: this can be a negative value)

(NOTE: this has no effect with column support)

Welded Properties

FEXX_Supporting := 70 Weld material strength

Process_Supporting := SMAW SMAW GMAW FCAW SAW

weld_Supporting := $\frac{1}{4}$ Weld size

dweld_Supporting := 9 Height of weld (Excluding end returns)

Bolted Properties

db_Supporting := $\frac{3}{4}$ Bolt diameter

ASTM_Supporting := 325 490 325

Threads_Supporting := N N: threads included
X: threads excluded
SC: Slip critical

s_Supporting := 3 Supporting side spacing

g_Supporting := 0 Gage on **either** angle leg1

Rows_Supporting := 4 Rows on supporting side

Columns_Supporting_HF := 1 Columns **PER angle on supporting side**

Girder/Column

Holes
STD OVS SSLP SSLT LSLP LSLT
Hole_Supporting := STD

**Connection is assumed
centered across the column
web or flange (if
applicable)**

Angle Leg1

Holes
STD OVS SSLP SSLT LSLP LSLT
Hole_A_Leg1 := STD

End Distances

L_{ev_top_A_Leg1} := 1.5
L_{eh_A_Leg1} := 1.66

Supported Side:

Angle Legs2 Beam Web

Bolted or Welded Joint

Joint_Supported := BOLTED BOLTED
WELED

Vertical Alignment

y_Supported := 0.7 RELATIVE elevation of the
mid-depth of the connecting
element with respect to the
mid-depth of the beam (NOTE: this
can be a negative value)

Copes

d_{ct} := 1 Size of Top Cope (0 means no cope)

d_{cb} := 1 Size of Bottom Cope (0 means no cope)

c := 3.75 Length of Cope(s)

Welded Properties

FEXX_Supported := 70 Weld material strength

Process_Supported := SMAW SMAW GMAW FCAW SAW

weld_Supported := $\frac{1}{4}$ Weld size

dweld_Supported := 9 Height of welds (Excluding end returns)

bweld_Supported := 3 Width of top & bottom welds

Bolted Properties

db_Supported := $\frac{3}{4}$ Bolt diameter

ASTM_Supported := 325 490 325

Threads_Supported := N N: threads included
X: threads excluded
SC: Slip critical

s_Supported := 3 Supported side spacing

g_Supported := 0 Gage on supported side

Rows_Supported := 4 Rows on supported side

Columns_Supported := 1 Columns on supported side

Angle Leg2

Holes
STD OVS SSLP SSLT LSLP LSLT
Hole_A_Leg2 := STD

Edge Distances

L_{ev_top_A_Leg2} := 3
L_{eh_A_Leg2} := 1.5

Beam Web

Holes
STD OVS SSLP SSLT LSLP LSLT
Hole_Supported := STD

Fig. 5 (Cont'd) Typical Input Section of MathCAD® Double-Angle Shear Connection Worksheet

Summary1 =

"LOAD/FORCE SOURCE"	"FORCE (kips)"
"Connection Load"	39
"SLIP (BOLTED)"	"SLIP RESISTANCE (kips)"
"Supporting Side"	0
"Supported Side"	0
"LIMIT STATE"	"STRENGTH (kips)"
"Shear Yielding of Double Angle Legs"	196.8
"Shear Yielding of Beam Web (DOUBLE COPE)"	135.2
"Shear Rupture of Angle Legs 1 (BOLTED)"	195.8
"Shear Rupture of Angle Legs 1 (WELDED)"	"NA"
"Shear Rupture of Angle Legs 2 (BOLTED)"	195.8
"Shear Rupture of Angle Legs 2 (WELDED)"	"NA"
"Shear Rupture of Beam Web (DOUBLE COPE & BOLTED)"	114.3
"Shear Rupture of Beam Web (DOUBLE COPE & WELDED)"	"NA"
"Block Shear Rupture of Angle Legs 1 (BOLTED)"	179.2
"Block Shear Rupture of Angle Legs 2 (BOLTED)"	176
"Block Shear Rupture of Beam (TOP COPE & BOLTED)"	110.6
"Block Shear Rupture of Beam (TOP COPE & WELDED)"	"NA"
"Bolt Shear Supporting Side (BOLTED)"	127.2
"Bolt Shear Supported Side (BOLTED)"	160.3
"Bolt Bearing on Girder/Column (BOLTED)"	249.2
"Bolt Bearing on Angle Legs 1 (BOLTED)"	166.4
"Bolt Bearing on Angle Legs 2 (BOLTED)"	83.2
"Bolt Bearing on Beam Web (BOLTED)"	110.6
"Weld on Supporting Side (WELDED)"	"NA"
"Weld on Supported Side (WELDED)"	"NA"
"Flexural Yielding of Beam (COPE)"	117.1
"Local Web Buckling of Beam (TOP OR DOUBLE COPE)"	614.9

Summary2 =

"GENERAL DESIGN CHECK"	"CONDITION"
"Minimum Factored Load"	"OK"
"Minimum Fillet Weld on Supporting Side"	"NA"
"Minimum Fillet Weld on Supported Side"	"NA"
"Maximum Fillet Weld on Supporting Side"	"NA"
"Maximum Fillet Weld on Supported Side"	"NA"
"Bolt Hole Check on Supporting Side"	"OK"
"Bolt Hole Check on Supported Side"	"OK"
"Minimum Bolt Hole Spacing on Supporting Side"	"OK"
"Minimum Bolt Hole Spacing on Supported Side"	"OK"
"Homogeneous Fastener Use"	"OK"
"Weld Length Check on Supporting Side"	"NA"
"Horizontal Weld Length Check on Supported Side"	"NA"
"Vertical Weld Length Check on Supported Side"	"NA"
"Minimum Size of Cope(s)"	"OK"
"Cope Length"	"NA"
"Girder Alignment"	"OK"
"Beam Alignment"	"OK"
"Beam vs Girder"	"Beam web depth is greater than girder T dimension"
"Beam vs Column Web"	"NA"
"Element vs Beam"	"OK"
"Element vs Column"	"NA"
"Connection Interference"	"OK"

Fig. 6 Typical Output Section of MathCAD® Worksheet for Double-Angle Shear Connection

The Teaching Guide

The teaching guide is a 200-plus page document that contains the 3D AutoCAD® drawings and the MathCAD® worksheets as well as narrative text, data figures, photographs, and example problems that together make up the complete teaching toolkit. The introductory material presented in the guide contains general information on structural steel connections. Chapter 1 describes the Steel Sculpture and includes the types and spatial arrangements of the various members and connections that are on it. The CAD-based drawings of the Steel Sculpture are also found in this chapter. Chapter 2 documents the connection limit states and the conditions for their applicability. The most common and current methods of joining steel members, namely bolting and welding are presented in Chapter 3. For structural bolting, the guide discusses the various installation methods as well as the various types, grades, dimensions, and availability of bolts. For structural welding, the guide covers the different processes, the various types and configurations, and the strength of welds.

Chapters 4 through 7 discuss the types of connections found on the Steel Sculpture: Shear Connections, Moment Connections, Column Connections, and Miscellaneous Connections. Each specific connection portrayed on the sculpture has a narrative that discusses various issues and concerns regarding the design, erectability, and performance of that particular connection. Included with the narrative are data figures and photographs from the original sculpture. Each data figure (see Fig. 7) is comprised of two tables of information along with CAD-based illustrations and views. The first contains a list of the applicable limit states for the particular connection, and the second has a list of informative notes and/or statements addressing issues pertinent to the connection. Typically, the views include a large isometric drawing that highlights the particular location of the connection relative to the steel sculpture and two orthogonal elevations of the connection details.

The teaching guide document covers the most common types of steel connections used in practice, however more emphasis has been placed on shear connections since they are the most common type of structural steel framing connection. In addition, there are more shear connections found on the steel sculpture than all other types combined. Along with the shear connection information, MathCAD® worksheets in the form of a calculator tool are presented that provide design/analysis examples of some of the shear connections found on the Steel Sculpture. Finally, there are two appendices that contain a MathCAD® worksheets Users Guide and a resource guide that contains information: textbooks, manuals, specifications, and journal papers, related to steel connections.

Summary

The teaching toolkit provides a means for educators to effectively teach steel connection design/analysis in a first course on steel design. Since the toolkit is essentially a compilation of components, the AutoCAD® model, the MathCAD® worksheets, and/or the teaching guide document may be used in conjunction with one another or taught individually. This arrangement of materials should provide students and educators the flexibility to successfully learn and teach structural steel connections within the limited time and resources they have during a semester course. It is anticipated that the Steel Connections Teaching Toolkit will be made available through the American Institute of Steel Construction in the near future.

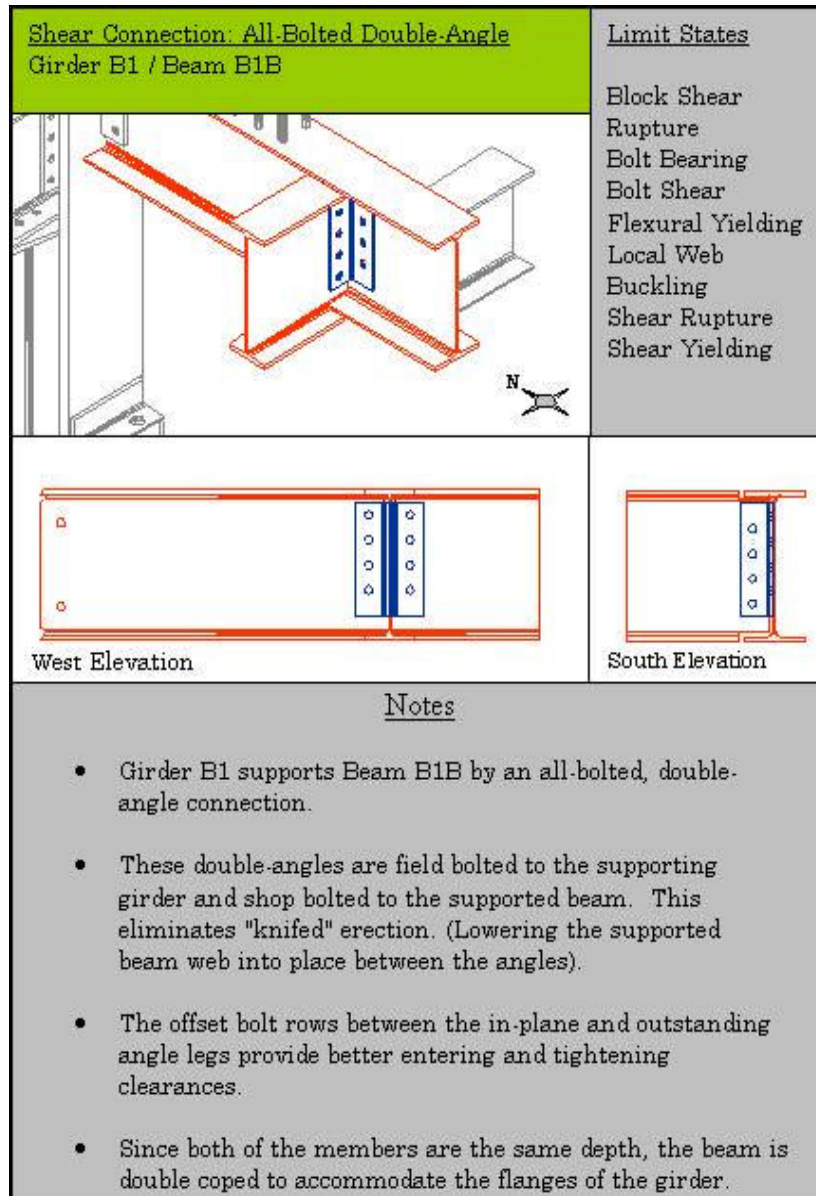


Fig. 7 Typical Data Figure from the teaching guide worksheet

Acknowledgments

The authors would like to thank AISC for providing the funding for the development of "The Steel Connections Teaching Toolkit". The authors would also like to thank Dr. Duane Ellifritt and his Steel Sculpture for the impetus and inspiration to take on this project.

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Since 1987, Thomas Sputo has been a consulting engineer with Sputo Engineering, a structural engineering design firm located in Gainesville, FL. He was awarded a B.S. in Civil Engineering (Cum Laude) from The Citadel in 1982, and a Master of Engineering and Ph.D. from the University of Florida in 1983 and 1990 respectively, with a concentration in Structural Engineering. Between graduate degrees, Sputo served as a commissioned officer in the U.S. Army Corps of Engineers. Since 1991, Sputo has held adjunct appointments at the University of Florida in the M.E. Rinker School of Building Construction and the Department of Civil and Coastal Engineering. He has been a registered Professional Engineer since 1987, specializing in structural engineering.