

An Interactive Spreadsheet Framework for the Design of Structural Steel Members

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Abstract-Advanced computer programs used for structural analysis and design have become widely used; however, classical and easy-to-use tools, such as design charts and tables, are still preferable for students, who need simple tools instead of sophisticated and time-consuming programs. These tools help students electronically retrieve section properties-related information and use this information in the design of structural members. It is, therefore, clear that design charts, tables, and section properties should be made electronically available to engineering students. In this study, Microsoft Visual Basic, a widely-used and easy-to-use programming language, was used to develop an interactive framework that provides students with the ability to create powerful forms that can be used for different steel sections and their properties. The framework was developed to produce steel section properties provided in the AISC and CISC Manuals of Steel Construction and needed in the design charts. This paper describes how the framework was developed and presents some real-world examples to illustrate its ease-of-use and powerful capabilities over current practices. Comments and recommendations pertaining to future developments in the field are then presented in the conclusions.

Keywords- Visual Basic; Spreadsheets; Education; Structural Engineering

I. INTRODUCTION

The design of any structure, including steel structures, involves the design of the various structural members as well as the connections between the members. The integrity of the load path depends on the strength of the different members and attachments between members. The designer has a choice of several steel sections in several types of connections; welded, bolted, riveted, or combination of the above. Load calculations are quite complex and lend themselves well to the use of a spreadsheet. Spreadsheets have evolved into sophisticated computation and presentation tools with a tremendous potential for use as design tools. This paper discusses the design of a steel plate girder and how spreadsheets and Basic Visual programming can facilitate the iterative design process by incorporating the steel section properties needed. The spreadsheet is designed for stand-alone use for many common situations [1-4].

Spreadsheets have become widely used among structural engineers because of their ease of use and the simplicity with which repetitive calculations can be done for a series of variables [5, 6]. When a design spreadsheet needs information for different steel sections, the most efficient way to get this information is to link the design spreadsheet to the AISC or CISC databases. Microsoft Visual Basic [7] offers users with the ability to create database that can be used for different steel sections and their properties. This database stores the dimensions and properties for each steel section listed in the Manual of Steel Construction. Accessing this database allows users to automatically lookup and input data that would otherwise need to be manually referenced and entered into a spreadsheet. This simple automation process will allow a job to be done faster and will lower the possibility for errors to occur, particularly for students. Only a section's designation needs to be entered into a design spreadsheet, which can be programmed to retrieve the necessary information from the database. In this paper, an overview of spreadsheets and its macros programming capabilities was first presented and an interactive framework was then developed using Visual Basic programming language. The developed framework can be used to provide students with an easy access to retrieve steel section properties that can be used for different structural steel members. The framework was developed to store and modify the different steel section properties as provided in the AISC and CISC Manuals of Steel Construction and needed in the design charts. This paper describes the main components of the developed framework and presents a real-world example to illustrate its ease-of-use and powerful capabilities over current practices. Comments and recommendations pertaining to future developments in the field are then presented in the conclusions.

II. SPREADSHEETS

Spreadsheets are becoming increasingly popular [8]. Although spreadsheet programs developed by various software firms have their own special features, they are based on the same working principles and, most of them, are compatible with each other. The spreadsheets developed for the graphic-based operating systems have commonly and efficiently been used in recent years. A user can move around among cells and write information on them. The information may be numeric or alphanumeric values or formulae. Values of variables are written on the cells. The cells or the group of cells can be named if required and formulations can be expressed clearly with the help of these names. All operations concerning spreadsheets are conducted by a core program. This program scans all the filled cells in the sheet and searches for logical relations and updates the operations at once when entering new information into the cells. This feature is called automatic interaction. One of the important concepts

of spreadsheets is the range. A range covers one or more rectangular cells of a sheet. The address of a range can be defined by the addresses of both ends of its diagonal. The addresses representing the ranges can be used as parameters. Some formulations can also be written on their defined range. These types of formulations are used particularly in matrix operations. One of the most powerful tools of spreadsheets is the use of Macros. Macros are small and powerful code programs which can be written and executed in spreadsheets. This makes it convenient for students as it provides them with the spreadsheet environment while, at the same time, provides the user with the powerful programming capabilities of visual basic. Macros defined in special sheets are called macro sheets. They use the cells of the sheets as variables. There are two kinds: command macros and function macros. Function macros assign the values of special functions used in spreadsheets while command macros need special commands to be executed.

III. THE DEVELOPED FRAMEWORK

When using a spreadsheet for the design of structural steel members, and the design requires information for different steel sections, the most efficient way to get this information is to link the design spreadsheet to the American Institute of Steel Construction (AISC) [9] or the Canadian Institute of Steel Construction (CISC) [10] databases. In this research, an easy-to-use framework was developed for the selection of different steel members using Visual Basic. Using Microsoft Access 2007 [11], the developed framework was linked to the databases of the different steel sections listed in the AISC and CISC Manuals of Steel Construction. Engineers and students can easily access the databases which allows for automatic lookup and input of steel section properties that would otherwise need to be manually referenced and entered into a steel design spreadsheet. This helps engineers and students to easily design steel structures and allows a job done faster. It also lowers the possibility for errors to occur. Once the program runs, a user-friendly screen will appear, as shown in the screen capture of Fig. 1. The main screen was designed to allow users to easily select the required database and see all the shapes and section in the database. As shown in Fig. 1, the developed framework's main screen will also show a schematic diagram for the selected shape section.

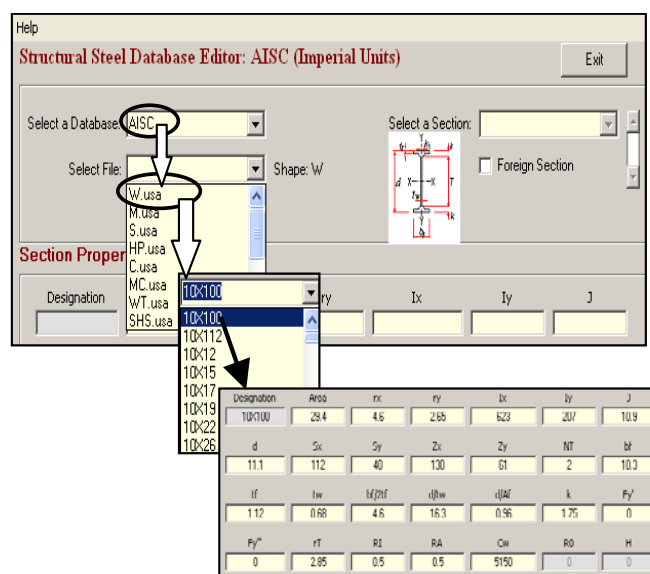


Fig. 1 The developed framework main screen

This screen capture shows the main screen of the developed framework. As shown in Fig. 1, two databases for the AISC and CISC are available and stored in the system. When a database is selected, all the available shapes will appear in the bottom left part of the screen. When a shape is selected, the different sections related to this shape will be listed and the user can select a shape section. Once a shape section is selected, all its properties will appear in the bottom part of the screen, as shown in the bottom part of Fig. 1. If any of the abbreviations of section properties is not understandable, the user can see an explanation about that particular property. If the user wants to know what a certain label means, he/she can simply place the cursor over that label to view the help related to this particular property. The explanation for the term “k”, for example, is shown in Fig. 2. Users can also modify and update existing sections, remove sections, or add new sections to the list, as shown in the figure. When an update, removal, and/or addition are made, corresponding databases are updated accordingly. Similarly, a user can also select a shape and section using the CISC and the corresponding section properties will appear as shown in Fig. 3. As shown in Fig. 3, the selected CISC shape appeared to be a foreign one. If a designer wants to use the properties of a particular steel section in the design of a particular structural element, he/she only needs to enter the database name (AISC or CISC) and the section designation into the design spreadsheet, which is programmed to retrieve the necessary information from the corresponding database, is generated by the developed framework. The system will then query the required database and show the properties of the section requested.

Help
Structural Steel Database Editor: AISC (Imperial Units) Exit

Select a Database: AISC Select a Section: W12x65 Foreign Section: ☐

Select File: W.usa Shape: W

Section Properties: (Number of available sections for the W shape= 311)

Designation	Area	rx	ry	Ix	Iy	J
12x65	19.1	5.28	3.02	533	174	2.18
d	Sx	Sy	Zx	Zy	NT	bf
12.1	87.9	29.1	96.8	44.1	2	12
tf	tw	bf/2tf	d/tw	d/Af	k	Fy
0.605	0.39	9.9	31.1	1.67	1.31	43
Fy	rx	ry	RA	Cw	Rx	H
0	3.28	0.6	0.6	5780	0	0

Note: Place the cursor over the label to view help

Modify Section Add New Section Remove Section Clear All

Fig. 2 An example of the properties of a selected AISC section

Help
Structural Steel Database Editor: CISC (Metric Units) Exit

Select a Database: CISC Select a Section: 100x19 Foreign Section: ☒

Select File: M.cdn Shape: M

Section Properties: (Number of available sections for the M shape= 10)

Designation	Area	rx	ry	Ix	Iy	J
100x19	2460	42.3	23.9	4.41E+6	1.41E+6	7.85E+4
Normal Use	y	d	Sx	Sy	Zx	Zy
N/A	51	102	8.64E+4	2.81E+4	9.98E+4	4.48E+4
Surface Area	bf/2	tf	tw	Cw	SEx	SEy
0.59	50	9.4	6.5	3.02E+9	0	0

Note: Place the cursor over the label to view help

Modify Section Add New Section Remove Section Clear All

Fig. 3 An example of the properties of a selected CISC section

IV. APPLICATION EXAMPLES

In this example, flexural analysis method is carried out to analyse a doubly-symmetric compact I-shaped girder loaded symmetrically to bend about its major axis and utilized in this paper as a basic design example for a steel girder bridge. The load combination used for the design of the steel beam is a combination of factored design dead (including the self-weight of the beam) and live load [12]. The design must yield a suitable selected steel beam section. This process is an iterative process where spreadsheet can become handy, especially when the steel section properties are incorporated into the spreadsheet and can be retrieved interactively by choosing one of the two databases explained above. When a shape is selected, the different sections related to this shape will be listed and the user can select a shape section. Once a shape section is selected, all its properties will appear in the bottom part of the screen, as explained above. This will start the analysis/design iterative process. The design of compact sections (rolled steel beams and channels) is covered in Section F2 of the Specifications of the AISC Steel Construction Manual [9]. The vast majority of rolled I-shaped beams and channels fall into this category. In Section *F* of the AISC Manual Figure *F-1* is used to determine the moment capacity, as a function of the girder un-braced length, L_b . The horizontal part of the curve, between $L_b = 0$ ft and L_p , indicates that the part of the girder has a strength governed by yielding. In this region, the nominal strength of the beam is the plastic moment strength which is by the AISC Specification Equation *F2-1* (or the relevant equation in the CISC if the CISC database is deployed). In the far right part of the curve, starting at L_r , the strength is governed by elastic buckling mode, and the beam strength is given by the AISC Specification Equation *F2-3* (or the relevant equation in the CISC if the CISC database is deployed). Between these regions, within the linear region of the curve (using AISC) between $M_n = M_p$ at L_p on the left, and $M_n = 0.7M_y = 0.7F_y S_x$ at L_r on the right, the strength is governed by inelastic buckling. The flexural strength in this inelastic buckling part of the steel girder is solved by referring to the AISC Specification Equation *F2-2* (or the relevant equation in the CISC if the CISC database is deployed). The sample calculations shown in this paper illustrate calculations made for service limit states.

Due to bending in a steel I-beam loaded in its major principle plane (i.e. major axis bending), one of the flanges will be subjected to compression and the other one undergoes tension. The compressed flange will therefore tend to buckle out of plane. Cause what is called flexural-torsional buckling (referred to as lateral-torsional buckling LTB) and torsion (twisting). For the design example used in this study, the bridge superstructure cross section is shown in the spreadsheet in Fig. 4 and is used to illustrate the design process using the steel section databases. The girder spacing is selected based on American Association State Highway Transportation Officials (AASHTO) Specifications. Also, when a particular section of a specific shape is selected within the spreadsheet, macros will automatically retrieve its corresponding properties from one of the databases, depending on whether the shape is an AISC or a CISC section.

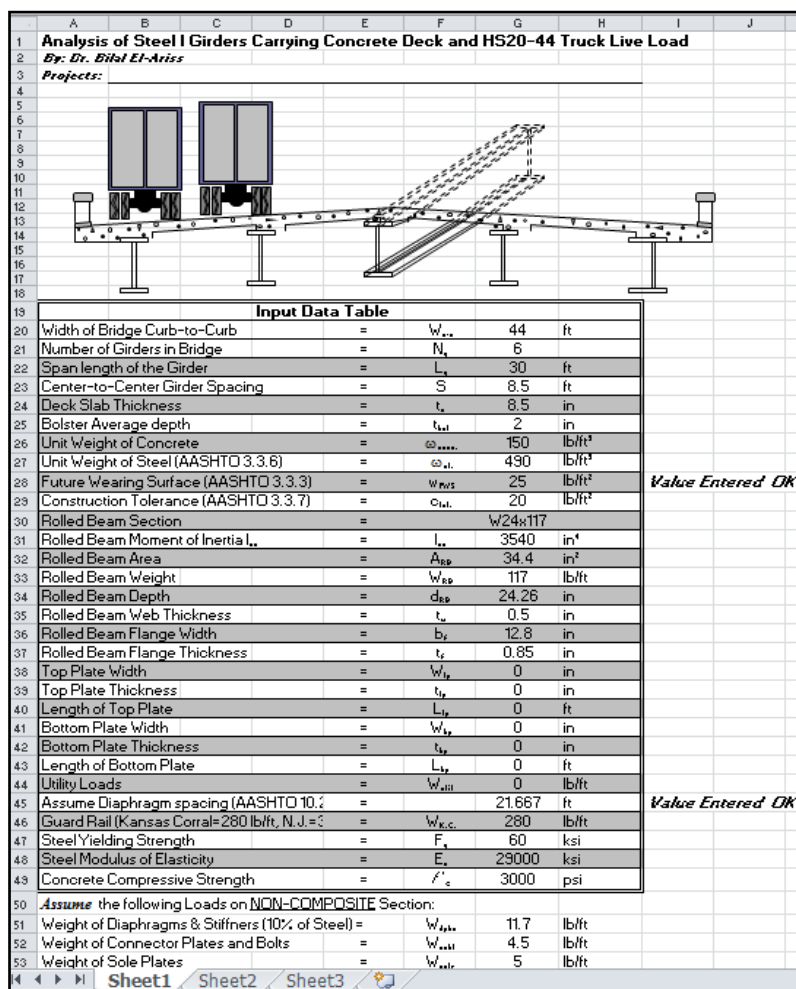
A. Bridge Girder Analysis/Design

The default procedure is to select a steel section and check if it satisfies the design requirements. Otherwise, another section is chosen and iterations are performed. A list of sections sorted by size and from two databases is implemented into a spreadsheet via macros. The list could start with the lightest section or the heaviest, depending on how it is implemented in the spreadsheet, and then works up to the first section that satisfies all the limit state criteria of the problem. This search process is easily programmed with VBA code in Excel, as explained above. Since the superstructure in this example is eventually composite, then cross section properties for non-composite and composite section must be identified. The initial dead loads (or the non-composite dead loads) are applied to the girder section only. The superimposed dead loads are applied to the composite section, girder section and part of the slab section. A modular ratio of 3n is usually preferred for the superimposed dead loads as it gives higher stresses in the steel section. The modular ratio of n is typically the ratio between the modulus of elasticity of two different members/materials (deck and girder). Both exterior and interior girders are analysed and designed,

and usually the controlling design is used for all girders, both interior and exterior. For this example, the interior girder controls. Therefore, only the interior girder analysis is presented in this example. For the exterior girder, the computation of the live load distribution factors and the moment and shear envelopes is also computed but not shown in this paper. In the design of a girder, the shear must also be checked at the critical sections. If the shear is not satisfied, then the girder section web must be stiffened.

B. Compact or Non-compact Section and Cover Plates

The steel girder section properties at the critical positive moment location are computed automatically using the spreadsheet as shown in Fig. 5 (Parts 2 and 3). The distance to the centroid is measured from the bottom of the girder. Similarly, the girder section properties at the critical negative moment location are computed as well. The distance to the centroid is measured from the bottom of the girder. The girder must be designed to resist the load combination of dead and live load effects, in this example.



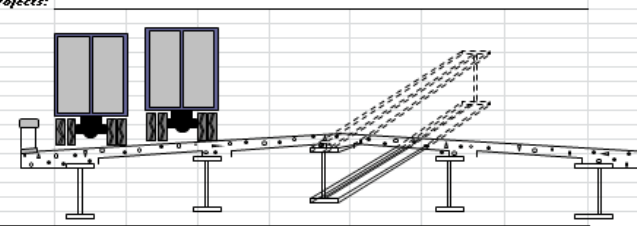
Analysis of Steel I Girders Carrying Concrete Deck and HS20-44 Truck Live Load									
By: Dr. Bilal El-Ariss									
Project:									
									
Input Data Table									
Width of Bridge Curb-to-Curb	=	W_{cc}	44	ft					
Number of Girders in Bridge	=	N_g	6						
Span length of the Girder	=	L_s	30	ft					
Center-to-Center Girder Spacing	=	S	8.5	ft					
Deck Slab Thickness	=	t_s	8.5	in					
Bolster Average depth	=	t_{bol}	2	in					
Unit Weight of Concrete	=	ω_{conc}	150	lb/ft ³					
Unit Weight of Steel (AASHTO 3.3.6)	=	ω_{st}	490	lb/ft ³					
Future Wearing Surface (AASHTO 3.3.3)	=	W_{FWS}	25	lb/ft ²				Value Entered OK	
Construction Tolerance (AASHTO 3.3.7)	=	C_{tol}	20	lb/ft ²					
Rolled Beam Section	=		W24x117						
Rolled Beam Moment of Inertia I_x	=	I_x	3540	in ⁴					
Rolled Beam Area	=	A_{RP}	34.4	in ²					
Rolled Beam Weight	=	W_{RP}	117	lb/ft					
Rolled Beam Depth	=	d_{RP}	24.26	in					
Rolled Beam Web Thickness	=	t_w	0.5	in					
Rolled Beam Flange Width	=	b_f	12.8	in					
Rolled Beam Flange Thickness	=	t_f	0.85	in					
Top Plate Width	=	W_{tp}	0	in					
Top Plate Thickness	=	t_{tp}	0	in					
Length of Top Plate	=	L_{tp}	0	ft					
Bottom Plate Width	=	W_{bp}	0	in					
Bottom Plate Thickness	=	t_{bp}	0	in					
Length of Bottom Plate	=	L_{bp}	0	ft					
Utility Loads	=	W_{util}	0	lb/ft					
Assume Diaphragm spacing (AASHTO 10.4)	=		21.667	ft				Value Entered OK	
Guard Rail (Kansas Corral=280 lb/ft, N.J.=0)	=	W_{GR}	280	lb/ft					
Steel Yielding Strength	=	F_y	60	ksi					
Steel Modulus of Elasticity	=	E_s	29000	ksi					
Concrete Compressive Strength	=	f'_c	3000	psi					
Assume the following Loads on NON-COMPOSITE Section:									
Weight of Diaphragms & Stiffeners (10% of Steel)	=	W_{dst}	11.7	lb/ft					
Weight of Connector Plates and Bolts	=	W_{cpl}	4.5	lb/ft					
Weight of Sole Plates	=	W_{spl}	5	lb/ft					

Fig. 4 Bridge steel girder input data spreadsheet

The dead load components, as shown in Fig. 4, consist of dead loads that are resisted by the non-composite section, as well as dead loads that are resisted by the composite section. In addition, some dead loads are factored with the assigned structural component dead load factor, and the wearing surface dead load is factored with the assigned wearing surface load factor. After the load factors and load combinations have been established, the section properties are computed, and all of the load effects are, in turn, computed.

The girder steel section is then verified whether it is compact or non-compact, and thus the relevant AISC steel construction manual equation is utilized to compute the strength of the girder. In this example, the steel member section is behaving as a non-compact section at the support locations and compact section throughout the length of the girder.

In this example, to enhance the flexural capacity of the girder in the high moment areas, steel plates (cover plates) are considered and added to the flanges (top and bottom) of girder, Fig. 5 (Part 2). The use of these added plates in regions of high moment only, instead of the full length of the girder, yields a lighter member. This results in material cost savings. Fig. 5 shows a typical bridge girder cross-section with cover plates (top and bottom) and diaphragms. This technique is used for compact sections not subject to lateral torsional buckling (LTB).

62	So, The Effective Flange Width, b_{eff} , is	=	7.5	ft					
63	NON-COMPOSITE DEAD LOADS (WDL NC):								
64	Deck Slab Weight	=	$t_s \cdot (b_{eff} \text{ or } S) \cdot \omega_{slab}$	=	903.125	lb/ft			
65	Construction Tolerance	=	$(b_{eff} \text{ or } S) \cdot \omega_{tol}$	=	170.000	lb/ft			
66	Bolster Weight	=	$t_{bol} \cdot b_s \cdot \omega_{bol}$	=	26.667	lb/ft			
67	Weight of Rolled Beam	=	W_{rb}	=	117.000	lb/ft			
68	Weight of Top Plate	=	$t_{tp} \cdot W_{rb} \cdot \omega_{tp} \cdot L_{tp} / L_r$	=	0.000	lb/ft			
69	Weight of Bottom Plate	=	$t_{bp} \cdot W_{rb} \cdot \omega_{bp} \cdot L_{bp} / L_r$	=	0.000	lb/ft			
70	Weight of Diaph. & Stiffeners	=	W_{ds}	=	11.700	lb/ft			
71	Weight of Connectors & Bolts	=	W_{cb}	=	4.500	lb/ft			
72	Weight of Sole plates	=	W_{slp}	=	5.000	lb/ft			
73	Weight of Shear Studs	=	W_{sst}	=	3.000	lb/ft			
74	Total Non-Composite Dea	=	W_{nnc}	=	1240.992	lb/ft	1.241	k/ft	
75									
76	UNIFORM LOAD ON ZA	=	1.241	k/ft					
77	UNIFORM LOAD ON AE	=	1.241	k/ft					
78	UNIFORM LOAD ON CC	=	1.241	k/ft					
79	UNIFORM LOAD ON DZ	=	1.241	k/ft					
80	LENGTH OF CANTIL. ZA	=	1.00	ft					
81	LENGTH OF SPAN AB	=	30.00	ft					
82	LENGTH OF SPAN BC	=	30.00	ft					
83	LENGTH OF CANTIL. C2	=	1.00	ft					
84									
85	MOMENT DISTRIBUTION								
86	P LOAD	10.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
87	DIS. TO P	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
88	JOINT	2A	AB	BA	BC	CB	C2		
89	DF	0	1	0.50	0.50	1	0		
90	FEM	-10.62	33.07	-33.07	33.07	-33.07	10.62		
91	DIST.		-62.45	0.00	0.00	62.45			
92	C.O.	0.00		-41.23	41.23	0.00			
93	DIST.		0.00	0.00	0.00	0.00			
94	C.O.	0.00		0.00	0.00	0.00			
95	DIST.		0.00	0.00	0.00	0.00			
96	C.O.	0.00		0.00	0.00	0.00			
97	DIST.		0.00	0.00	0.00	0.00			
98	C.O.	0.00		0.00	0.00	0.00			
99	DIST.		0.00	0.00	0.00	0.00			
100	C.O.	0.00		0.00	0.00	0.00			
101	DIST.		0.00	0.00	0.00	0.00			
102	C.O.	0.00		0.00	0.00	0.00			
103	DIST.		0.00	0.00	0.00	0.00			
104	C.O.	0.00		0.00	0.00	0.00			
105	DIST.		0.00	0.00	0.00	0.00			
106	C.O.	0.00		0.00	0.00	0.00			
107	DIST.		0.00	0.00	0.00	0.00			
108	C.O.	0.00		0.00	0.00	0.00			
109	DIST.		0.00	0.00	0.00	0.00			
110	C.O.	0.00		0.00	0.00	0.00			
111	DIST.		0.00	0.00	0.00	0.00			
112	C.O.	0.00		0.00	0.00	0.00			
113	DIST.		0.00	0.00	0.00	0.00			
114	NEG. MOM	-10.62	10.62	-134.30	134.30	-10.62	10.62		
115	UL REA.	1.241	18.61	18.61	18.61	18.61	1.241		
116	MOM. REA.	4.12	4.12	4.12	4.12	4.12	4.12		
117	PL REA.	10	0	0	0	0	10		
118	SUB TOT.	11.241	14.49	22.74	22.74	14.49	11.241		
119	TOTAL	Reaction @ A	25.15	Reaction @ B	45.48	Reaction @ C	25.15		
120									
121									
122									
123									
124									

Fig. 5 Bridge steel girder analytical results (Part 1)

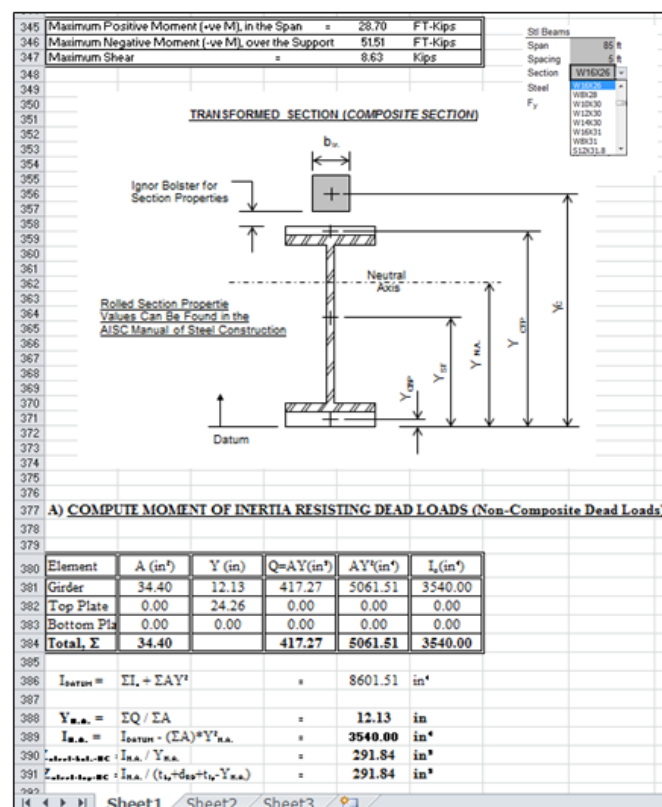
C. Sample Spreadsheet Calculations

Because the calculations above must be performed iteratively, the analysis and design calculation can be done efficiently and fast using a spreadsheet. The spreadsheet example (shown in Figs. 4 and 5) shows the analysis steps for a bridge steel girder. The database implemented in the spreadsheet using Visual Basic stores the properties for all steel sections listed in the steel construction Manual. Retrieving the steel section databases using macros within spreadsheets allows for automatic lookup and input of data that would otherwise need to be manually entered or typed into the spreadsheet.

	A	B	C	D	E	F	G	H	I	J
202	NON-COMPOSITE CROSS SECTION									
203										
204	Assume 10% of Girder Weight For Miscellaneous Steel (i.e. diaphragms, Stiffeners)									
205										
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227										
228										
229										
230	Parapet or Guard Rail (AASHTO 3.23.4.4) = $W_{p,c}$ = 280.00 lb/ft									
231	Future Wearing Surface (AASHTO 3.23.4.4) = $W_{w,s}$ = 183.33 lb/ft									
232	Weight of Utilities = $W_{u,t}$ = 0.000 lb/ft									
233										
234	Total Composite Dead Load = $W_{d,c}$ = 463.33 lb/ft = 0.463 k/ft									
235										
236	UNIFORM LOAD ON ZA = 0.463 k/ft									
237	UNIFORM LOAD ON AB = 0.463 k/ft									
238	UNIFORM LOAD ON CD = 0.463 k/ft									
239	UNIFORM LOAD ON DZ = 0.463 k/ft									
240										
241	LENGTH OF CANTILEVER ZA = 1.00 ft									
242	LENGTH OF SPAN AB = 30.00 ft									
243	LENGTH OF SPAN BC = 30.00 ft									
244	LENGTH OF CANTILEVER DZ = 1.00 ft									
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Steel Stresses									
For Positive Moment	73.93	t-Kips							
Top of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, top, nc}$					3.04007721	kci	Compressive Stress	
Bottom of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, bot, nc}$					3.04007721	kci	Tensile Stress	
For Negative Moment	134.30	t-Kips							
Top of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, top, nc}$					5.52228795	kci	Tensile Stress	
Bottom of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, bot, nc}$					5.52228795	kci	Compressive Stress	
B) COMPUTE MOMENT OF INERTIA RESISTING SUPERIMPOSED DEAD LOADS (Composite Dead Loads - 3n):									
Modular Ratio,	n	3n	28.20039			where n =	$E_s/E_c = 8.73346415$		
Element	A (in ²)	Y (in)	Q=AY(in ³)	AY ² (in ⁴)					
Girder	34.40	12.13	417.27	5061.51					
Slab	29.20	30.51	890.83	27179.29					
Top Plate	0.00	24.26	0.00	0.00					
Bottom Pl	0.00	0.00	0.00	0.00					
Total, Σ	63.60		1308.10	32240.80					
$I_{s, tot} = \Sigma I + \Sigma AY^2$				35956.59					
$Y_{n.a.} = EQ / EA$				20.5683					
$I_{n.a.} = I_{s, tot} - (EA) * Y_{n.a.}^2$				9081.1032					
$Z_{sbc, top, nc} = I_{n.a.} / Y_{n.a.}$				440.0509					
$Z_{sbc, bot, nc} = I_{n.a.} / (t_{top} + d_{slab} + t_{bot} - Y_{n.a.})$				2451.7502					
Steel Stresses									
For Positive Moment	28.69733	ft-Kips							
Top of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, top, nc}$					0.14045803	kci	Compressive Stress	
Bottom of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, bot, nc}$					0.782564	kci	Tensile Stress	
For Negative Moment	51.50917	ft-Kips							
Top of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, top, nc}$					2.11798709	kci	Tensile Stress	
Bottom of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, bot, nc}$					2.11798709	kci	Compressive Stress	
C) COMPUTE MOMENT OF INERTIA RESISTING LIVE LOADS (Composite Live loads - n):									
Modular Ratio,	n	$E_s/E_c = 8.733464$							
Positive L.L. Moment	60.000	ft-Kips							
Negative L.L. Moment	100.000	ft-Kips							
Steel Stresses									
For Positive Moment	60.00	t-Kips							
Top of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, top, nc}$					0.06190807	kci	Tensile Stress	
Bottom of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, bot, nc}$					1.46923616	kci	Tensile Stress	
For Negative Moment	100.00	t-Kips							
Top of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, top, nc}$					4.11186441	kci	Tensile Stress	
Bottom of Steel:	$f_{sbc} = M_{sbc} / Z_{sbc, bot, nc}$					4.11186441	kci	Compressive Stress	
Total Steel									
For Positive Moments:									
Top of Steel:	$f_s = f_{sbc} + f_{scl} + f_{scc} = 3.118627$	kci							
Bottom of Steel:	$f_s = f_{sbc} + f_{scl} + f_{scc} = 5.291877$	kci							
For Negative Moments:									
Top of Steel:	$f_s = f_{sbc} + f_{scl} + f_{scc} = 11.75214$	kci							
Bottom of Steel:	$f_s = f_{sbc} + f_{scl} + f_{scc} = 11.75214$	kci							
Conclusion: Max. stress due to applied load									

Fig. 5 Bridge steel girder analytical results (Part 3)



The effective slab width and the location of the neutral axis, NA , of the girder composite cross section must be determined first in order to compute the girder flexural moment capacity. The effective slab width is usually determined from the ACI-318 code requirements, and the location of the NA is computed from the axial force equilibrium equation. Next the two internal forces, tension T_s and compression C_c , are calculated and the girder flexural moment capacity is determined from the magnitude of the couple moment formed by the two internal forces.

This simple spreadsheet interactive process is handy for designers and students to easily select steel section properties and allows the analysis and design to be carried out efficiently and fast. It also minimizes errors occurrence as well as easily tracks down any mistakes. As shown in Figs. 4 and 5, the spreadsheet was used to calculate the stresses in the steel girder section based on AISC 360-05 Chapter F4. For these calculations to take place in several sections properties need to be input to the spreadsheet. The developed framework was used to interactively retrieve the section properties once the steel section is chosen from the database. This makes it convenient for designers and students to interactively retrieve the section properties instead of typing this information into the spreadsheet. It also helps avoiding errors and mistakes resulting from manually typing in the data.

V. CONCLUSIONS

In this paper, an interactive framework was developed using Visual Basic programming language and Access database linked to Excel spreadsheet. The developed framework is intended to provide designers and students with an easy access to retrieve section properties that are needed for the steel girder analysis and design process. The framework developed was designed not only to retrieve section properties, but also to modify and store different steel shapes, shape sections, and section properties as provided in the AISC and CISC Manuals of Steel Construction and as needed in the design charts. This paper described the main components of the developed framework and presents a real-world example to illustrate its ease-of-use and powerful capabilities over current practices. The developed framework can also be used by professional engineers during the structural design of steel buildings as an automated tool to replace the manual use of steel charts and manuals. Once a design spreadsheet is programmed, a user only needs to select the database (AISC or CISC) and then input a section designation. The spreadsheet will then retrieve the required section properties for use in the design of the required steel member. This can be done quickly and accurately for a series of steel sections making spreadsheets a very powerful design tool in addition to its ease-of-use.

The authors are currently working on automating the structural design process and linking it with required design codes, standards, charts, and manuals. The developments made in this regard will be presented in a separate future paper.

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