

Using Spreadsheets and VBA for Teaching Civil Engineering Concepts

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ABSTRACT

Spreadsheets are becoming increasingly popular in solving engineering related problems. Among the strong features of spreadsheets are their instinctive cell-based structure and easy to use capabilities. Excel, for example, is a powerful spreadsheet with VBA robust programming capabilities that can be a powerful tool for teaching civil engineering concepts. Spreadsheets can do basic calculations such as cost estimates, schedule and cost control, and markup estimation, as well as structural calculations of reactions, stresses, strains, deflections, and slopes. Spreadsheets can solve complex problems, create charts and graphs, and generate useful reports. This paper highlights the use of Excel spreadsheet and VBA in teaching civil engineering concepts and creating useful applications. The focus is on concepts related to construction management and structural engineering ranging from a simple cost estimating problem to advanced applications like the simulation using PERT and the analysis of structural members. Several spreadsheets were developed for time-cost tradeoff analysis, optimum markup estimation, simulating activities with uncertain durations, scheduling repetitive projects, schedule and cost control, and optimization of construction operations, and structural calculations of reactions, internal forces, stresses, strains, deflections, and slopes. Seven illustrative examples are presented to demonstrate the use of spreadsheets as a powerful tool for teaching civil engineering concepts.

Keywords: Spreadsheets, Engineering Education, VBA, Civil Engineering.

1. INTRODUCTION

Spreadsheets are among the earliest software innovations that had a profound effect on the widespread use of personal computers. Spreadsheets made their first appearance for personal computers in 1979 in the form of VisiCalc, an application designed to help with accounting tasks [1; 2]. Since that time, the diversity of applications of the spreadsheet program is evidenced by its continual reappearance in scholarly journals. Spreadsheets are, therefore, among the earliest software innovations that had a profound effect on the widespread use of personal computers. Among the strong features of spreadsheets are their intuitive cell-based structure and the simple interface that is easy to use, even for first time users [3; 4]. Underneath the structure and the interface is a host of powerful and versatile features that can be utilized in

teaching from data entry and manipulation to a large number of functions, charts, and word processing capabilities. This is in addition to its visual basic for applications (VBA) powerful programming capabilities. Newer spreadsheet versions have also added many productivity features for Internet connectivity, workgroup sharing, powerful programmability options, and a number of add-in programs. With their wide use, spreadsheets have been used as tools for developing computer models that can be used as a tool for teaching construction management concepts, for which ease of use, versatility, and productivity are the main issues. Hegazy and Ersahin [3] used Excel and VBA to develop an information system for subcontractors and small/medium-sized contractors. Their developed spreadsheet stores resource data for labor, equipment, crews, material, subcontractors, and alternative methods of construction for various tasks. In addition, a separate worksheet is designed for each project to be used for estimating and control purposes.

Ickert and Huston [5] developed a spreadsheet that can be used to analyze multiple solutions for engineering problems efficiently and accurately, and to produce graphs that convey the solution to the end users. Thiriez [6] developed several spreadsheets as educational tools for students. One example is to use the drawing capabilities of Excel to represent decision trees and where window switching and macros allow the educator to animate his presentation. Another example presented by Thiriez [6] is the use of Excel in dynamic programming, deterministic or stochastic, where Excel functions facilitate the development of specialized models. From primary to tertiary levels, the spreadsheet is gradually increasing in its importance as a tool for teaching and learning.

In this paper, Microsoft Excel 2007 [7] is used for developing spreadsheets that can be used for teaching civil engineering concepts. Two areas in civil engineering were selected namely construction management and structural engineering. Spreadsheet applications related to these two areas were developed including construction data management, time-cost tradeoff (TCT) analysis, optimum markup estimation, simulating and scheduling construction activities with uncertain durations, scheduling linear and repetitive projects, schedule and cost control, and optimization of construction operations, as well as the structural calculations of reactions, internal forces, stresses, strains, deflections, and slopes. First, the use of spreadsheets as a tool for teaching construction management and structural engineering concepts in general is discussed. Seven illustrative examples are then presented to demonstrate

how spreadsheets can be used as a powerful tool for teaching civil engineering concepts.

2. SPREADSHEET AS A POWERFUL TEACHING TOOL

Among the strong features of spreadsheets are their intuitive cell-based structure and the simple interface that easy to use even for first time users. Underneath the structure and the interface is a host of powerful and versatile features, from data entry and manipulation to a large number of functions, charts, and word processing capabilities. Newer spreadsheet versions have also added many productivity features for Internet connectivity, workgroup sharing, programmability options, and a number of add-in programs. With their wide use, spreadsheets have been used as tools for developing computer models in domains such as construction, for which ease of use, versatility, and productivity are the main issues. In this paper, a spreadsheet program, Microsoft Excel 2007, is used to develop applications to solve civil engineering problems. Several powerful and infrequently used Excel features are available and can be used to develop practical and powerful models for teaching civil engineering concepts. These features include data lists, data menu options, data filtering, referencing and searching lists, basic spreadsheet functions such as "Vlookup", and pivot table reports. In Excel, a data list is a simple structure of columns and rows that contain data. Entering data into a large spreadsheet list may become extremely tedious and prone to error. The "Data-forms" menu option in Excel provides a simple way for editing or deleting existing records in a list or adding new records. Sorting the data helps bring similar records together for visual inspection or other purposes such as preparing reports and charts. Using the "Data, Sort" menu option, the list's data can be arranged in an order that is chosen by sorting the records. Filtering the data is also a useful way to view a subset of the records that compose a list. To filter a list is to extract records from it, based on criteria set by the user. Referencing and searching the list is another important part of the data management process. In realistic systems, where several lists of data are available, a link needs to be established among them (similar to the relational database concept). One simple and important spreadsheet function "Vlookup" can be used to link separate lists of information by making a reference to where the original data are. Accordingly, it is possible to determine the a cost of a certain project item, for example, by using a Vlookup function to search the original list and determine its associated rate per hour value. The "Match", "Index", and "Offset" are other functions that provide further control over the data in a list. Reporting is another essential requirement for obtaining summary data. In Excel, the pivot table wizard provides an automated report generator.

In addition to the features and functions of Excel, its programming capabilities, called visual basic for applications (VBA) are very powerful and can be used to solve complex civil engineering problems. Excel can also be used in linear programming, where the solver is used, and where the spreadsheet's graphing capabilities are used both to represent the feasible set and the objective function, and to interactively animate the objective function or constraint movements. Excel can also be used in simulation, where stochastic simulation may be facilitated through the use of an add-in, and a decision support system may thus be built from scratch.

3. USING SPREADSHEETS IN TEACHING CIVIL ENGINEERING CONCEPTS

The basic paradigm of an array of rows-and-columns in Excel spreadsheets with automatic update and display of results has been extended with libraries of mathematical and statistical functions, versatile graphing and charting facilities, powerful add-ins such as Microsoft Excel's Solver, attractive and highly functional graphical user interfaces, and the ability to write custom code in languages such as Microsoft's Visual Basic for Applications. Spreadsheets with these powerful features and programming capabilities can be used as an effective tool for use in civil engineering applications. Examples include construction data management, TCT analysis, optimum markup estimation, simulating and scheduling construction activities with uncertain durations, scheduling linear and repetitive projects, schedule and cost control, optimization of construction operations, design of bolted steel connections, and analysis and design of different steel members such as beams, columns, base plates, etc. Since the core of any information system is the storage of the data and information for management operations, database capabilities in spreadsheet programs can be used as an effective tool to develop complex data management system for construction information. Few basic, but infrequently used, spreadsheet features need to be known and can be used to develop practical and powerful models, which can be used for teaching civil engineering concepts. In this study, several spreadsheets were developed to be used for teaching civil engineering concepts. In the following subsections, example applications are presented in two areas in civil engineering: 1) construction management, and 2) structural engineering.

Applications in Construction Management

Four examples are presented in this paper to demonstrate the use of spreadsheets in teaching construction management concepts. The first example illustrates the use of Excel for the management of construction information. In Excel, a data list is a simple structure of columns and rows that contain data. Entering data into a large spreadsheet list may become extremely tedious and prone to error. The "Data-forms" menu option in Excel provides a simple way for editing or deleting existing records in a list or adding new records. This option can be used to develop a construction data management system to manage information related to construction equipment, labor, material, cost, methods of construction, and bills of quantities. Sorting the data helps bring similar records together for visual inspection or other purposes such as preparing reports and charts. Using the "Data-Sort" menu option, the list's data can be arranged in an order that is chosen by sorting the records. Filtering the data is also a useful way to view a subset of the records that compose a list. To filter a list is to extract records from it, based on criteria set by the user. Referencing the list is another important part of the data management process. Also, Excel has several important and powerful functions. For Example, one simple and important spreadsheet function "Vlookup" can be used to link separate lists of information by making a reference to where the original data are. For example, consider the situation when a new list is used for estimating purposes (Figure 1) and this list refers to the "Code" of the labor being used. Accordingly, it is possible to determine the cost by

using the “Vlookup” function to search the original labor list and determine its associated “Rate/hr” value (Figure 1).

	A	B	C	D	E
1	Cost Estimate:				
2					
3	Resource Code	No.	Rate/hr	Total Cost/hr	
4	L4	4	\$40	\$160 ← =B4*C4	

Vlookup function in Cell C4:
 = vlookup (A4, Labour!A1:C6, 3, 0)

Search value → A4
 List → Labour!A1:C6
 Column number → 3
 Exact match → 0

Figure 1: Using the Vlookup Function.

If the resource code specified in cell A4 of the estimate is changed (e.g., L5 is used), the costs will be adjusted automatically in cells C4 and D4 of the estimate. In addition to the “Vlookup” function, the “Match”, “Index”, and “Offset” functions provide further control over the data in a list. The help system of Excel can be used to obtain information about the syntax and use of these important functions. Reporting is another essential requirement for obtaining summary data on resources and operations. In Excel, the pivot table wizard provides an automated report generator. Pivot tables can be used to arrange projects’ information in the needed format, summarize long lists in a compact format, find relationships within lists that are hidden by all details, display data in the form of averages, percentages, summations, etc.

The second example illustrates the use of probabilistic models to analyze the behavior of a contractor’s competitors bidding for a job in order to optimize the markup used in bidding for a job. The probability approach has historically been the most popular technique for the construction of bidding models. Most bidding models based on probability theory have been derived from the work of Friedman [8]. Friedman claimed that, in a tender, it was possible to model each bidder’s behavior as a function of the estimated cost by means of a probability distribution. The general approach assumes that there are a number of bidders competing regularly against each other in the same market place and, given a sufficient number of opportunities to tender against known competitors, any one player can collect sufficient information to model the relationship between its own markup on future projects against the probability of submitting the lowest tender. This approach also assumes that the basic prime cost is similar for all competitors, and by comparing the competitors’ tender figures for past projects with its own estimate of prime cost, a contractor can therefore develop a probability distribution for each of its competitors showing the likelihood of winning future tenders with different markups. Using Friedman’s model, the probability of winning against a range of contractors $P(win_{all})$ is the product of the chances of beating them each individually, and the maximum expected profit (EP) can be calculated as follows:
 Expected profit (EP) = Profit x $Pwin_{all}$
 Where: $P(win_{all}) = Pwin_1 \times Pwin_2 \times \dots \times Pwin_n$
 and n: is the number of competitors.

Gates [9], on the other hand, suggested that by comparing its own bid to the winning bid a contractor could calculate the markup which would have been needed in order to win the contract. Again this implies that cost is the most important criterion:

$$P(win_{all}) = \frac{1}{[(1-P(win_1))/P(win_1)] + \dots + [(1-P(win_n))/P(win_n)] + 1}$$

To illustrate this concept, the two approaches were modeled using Excel and a spreadsheet was developed to calculate the optimum markups using both Friedman and Gates approaches. When a contractor bids for a new job, it is assumed that he/she knows other competitors bidding for the same job. To estimate the optimum markup for the contractor, the user will only enter the number of previous bids for each competitor bidding for the job, the competitors’ bid values for these bids, and the contractor’s estimated cost. Excel then counts the number of bids for each competitor and the bid to cost ratio for each bid and for each competitor. It also calculates the mean and standard deviation of the bid/cost for previous bids of each competitor. The mean is calculated based on the summation of the bid price to bid cost ratios for all available bids for each competitor divided by the number of available bids. Excel will also calculate the probability to win each competitor separately and the probability to win all competitors (Figure 2), using Friedman and Gates models. For both models, the maximum expected profit (max. EP) is found using the “Max” function. As shown in Figure 2, the maximum expected profit using Friedman’s model is found to be \$2,389.47 (cell I27) and using Gate’s model is \$23,361.82 (cell J27). Excel will then find the markup corresponding to the maximum expected profit for both Friedman and Gates models using the “Vlookup” function. For example, the “Vlookup” function used to calculate the markup corresponding to the maximum expected profit for Friedman’s model (Cell I28) = Vlookup(I27, I15:K25, 3, 0). For the example in hand, the optimum markups using Friedman and Gates models were found to be 3% and 7%, respectively.

	G	H	J	K	L
	Friedman	Gates	Friedman	Gates	
15	Pwin_{all}	Pwin_{all}	EP	EP	Markup
16	0.0288	0.1411	1437.72	7053.28	0.01
17	0.0216	0.1260	2156.90	12595.30	0.02
18	0.0159	0.1120	2389.47	16798.41	0.03
19	0.0116	0.0991	2316.04	19826.43	0.04
20	0.0083	0.0873	2070.92	21834.18	0.05
21	0.0058	0.0766	1748.79	22967.24	0.06
22	0.0040	0.0667	1412.06	23361.82	0.07
23	0.0027	0.0579	1098.21	23144.75	0.08
24	0.0018	0.0499	826.51	22433.42	0.09
25	0.0012	0.0427	603.79	21335.71	0.10
37	Max. EP:		2389.47	23361.82	
38	Optimum Markup:		3%	7%	

Figure 2: Optimum Markup Estimation Sheet.

The third example illustrates the use of spreadsheets for scheduling construction activities with uncertain durations using the Program Evaluation and Review Technique (PERT). Using this technique, each activity has three durations; the optimistic time (a), the pessimistic time (b), and the most likely time (m). PERT uses a weighted average of the three times to find the overall project duration. This average time is called the

expected time (t_e), which is equal to $(a+4m+b)/6$. To determine the probability of a project to be completed earlier or later than expected, the variance (v) of each activity along the critical path is calculated as follows: $v = (b - a)^2/36$. Since the duration of each activity is uncertain; the time of occurrence of each activity is also subject to uncertainty. The measure of uncertainty of the final event in a PERT diagram is the standard deviation of the expected time (σ_{TE}). The σ_{TE} for the last event is the square root of the sum of the variance of all activities along the critical path. Also the expected time of the last event in the project is denoted as T_E . To determine the probability of completing a project earlier or later than expected, the deviation (z) needs to be calculated; where $z = (T_S - T_E)/\sigma_{TE}$ and T_S is the scheduled time to finish the project. A spreadsheet was developed to illustrate the PERT concept using MonteCarlo simulation. For the five-activity project shown in Figure 3 (b), the user needs to enter two times only (a and b) for each activity and their corresponding variances ($v = \sigma^2$) will then be calculated automatically.

	C	F	G	H	I	J
1	Duration					
2	Activity	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
3	1-3	19.90	20.22	20.21	19.60	20.78
4	1-2	9.19	9.66	9.23	9.02	9.42
5	2-3	11.83	11.47	11.84	11.31	11.14
6	3-4	12.96	13.93	15.62	14.84	12.49
7	4-5	11.34	13.24	12.21	11.77	13.23

(a) Input of Activities' Durations.

	A	B	C	D	E
1	PERT (MonteCarlo Simulation):				
2					
3	$\sigma^2 =$	Activity	Min duration (a)	Max duration (b)	
4	0.444	1-3	19	23	
5	0.028	1-2	9	10	
6	0.028	2-3	11	12	
7	0.444	3-4	12	16	
8	0.25	4-5	11	14	
9					
10					
11					
12					

(b) Activities Random Durations.

Figure 3: Activities' Durations Using PERT.

Several iterations are used by selecting random numbers between the optimistic and pessimistic times using the Excel "rand()" function. For the purpose of this example, four iterations are used. Each path in the network is then identified and, following the logic of the network, the critical path is automatically calculated by identifying the longest path in the project. The expected time of the last event in the project (T_E) is calculated and the standard deviation (σ_{TE}) for critical activities in each path for each of the four iterations is also calculated.

Excel then calculates the average expected time (T_E) and the average standard deviation (σ_{TE}). For a scheduled time (T_S) = 47 days; for example, the probability (*Prob.*) to complete the project in this duration using iteration 2 is calculated using the "normdist" function and found to be 68.74%. For example, using iteration 2, the number of days that corresponds to completing the project with a probability of 68.74% is calculated using the "norminv" function and found to be 47 days.

The last example is a VBA application. In this example, an Excel spreadsheet was developed and a VBA macro code was written for time-cost trade-of analysis. The sheet provides information about project activities with their logical relationships and their corresponding durations, resource requirements, methods of construction, and costs associated with each method of construction. The VBA macro was developed to find the optimum method of construction for all project activities. The basic premise of the model is to allocate optional construction methods for each activity, varying from cheap and lengthy to expensive and short. Using the model, users will be able to select different construction methods and find the corresponding total project cost. The proposed model, as such, is usable not only at the planning stage but also during construction. The VBA macro then automatically generates a Microsoft Project file for the project using the data of the spreadsheet. The code was written to generate a Microsoft Project file for the project example in hand. The code copies activities' data such as activities' names, durations, and start times, construction methods, and activities' actual costs from the spreadsheet and then transfers the data to a newly generated Microsoft Project file for the project. A complete schedule for the project using the selected data is finally automatically generated.

Applications in Structural Engineering

Three examples are presented in this paper to demonstrate the use of spreadsheets in teaching structural engineering concepts. The first example illustrates the use of Excel to enhance the concept and efficiency of moment distribution method when spreadsheet is used. A continuous beam subjected to uniform distributed load was used (Figure 4) to illustrate the concept and to show that spreadsheets reduce the number of random arithmetic errors and time in doing the tedious moment-distribution computations. Moment distribution method is a classical method that has been included in every civil engineering program. It is one of the first numerical methods for structural analysis. The procedure of the method for prismatic members can be summarized as follows: 1) compute the relative stiffness $k = I/L$ for each member that is either connected or supported at both ends. This excludes overhang members; 2) compute the distribution factor (DF) for each member connected to a joint or support; 3) compute fixed end moments (FEM) for members with intermediate loads; 4) compute end moments for overhanging members; 5) pre-determine a tolerance limit; 6) balance the moments at each joint and distribute the balancing moment according to DF of each member; 7) carry over the balanced moment to the adjacent end of each member; 8) repeat steps 6 and 7 until the unbalanced moments are within the tolerance limit; and 9) sum the moments in each column for each member end.

	A	B	C	D	E	F	G	H	I	J
80										
81										
82	UNIFORM LOAD ON ZA	=	1.241	k/ft						
83	UNIFORM LOAD ON AB	=	1.241	k/ft						
84	UNIFORM LOAD ON CD	=	1.241	k/ft						
85	UNIFORM LOAD ON DZ	=	1.241	k/ft						
86										
87	LENGTH OF CANTIL ZA	=	1.00	ft						
88	LENGTH OF SPAN AB	=	30.00	ft						
89	LENGTH OF SPAN BC	=	30.00	ft						
90	LENGTH OF CANTIL. CZ	=	1.00	ft						
91										
92										
93	MOMENT DISTRIBUTION									
94	P LOAD	10.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	
95	DIS. TOP	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	
96	JOINT	ZA	AB		BA	BC		CB	CZ	
97	DF	0	1		0.50	0.50		1	0	
98	FEM	-10.62	93.07		-93.07	93.07		-93.07	10.62	
99	DIST.		-82.45		0.00	0.00		82.45		
100	C.O.		0.00		-41.23	41.23		0.00		
113	DIST.		0.00		0.00	0.00		0.00		
114	C.O.		0.00		0.00	0.00		0.00		
115	DIST.		0.00		0.00	0.00		0.00		
116	NEG. MOM.	-10.62	10.62		134.30	134.30		-10.62	10.62	
117	UL REA.	1.241	18.61		18.61	18.61		18.61	1.241	
118	MOM. REA.		-4.12		4.12	4.12		-4.12		
119	PL REA.	10	0		0	0		0	10	
120	SUB TOT.	11.241	14.49		22.74	22.74		14.49	11.241	
121	TOTAL	Reaction @ A	25.73		Reaction @ B	45.48		Reaction @ C	25.73	

Figure 4: Moment Distribution Calculation Sheet.

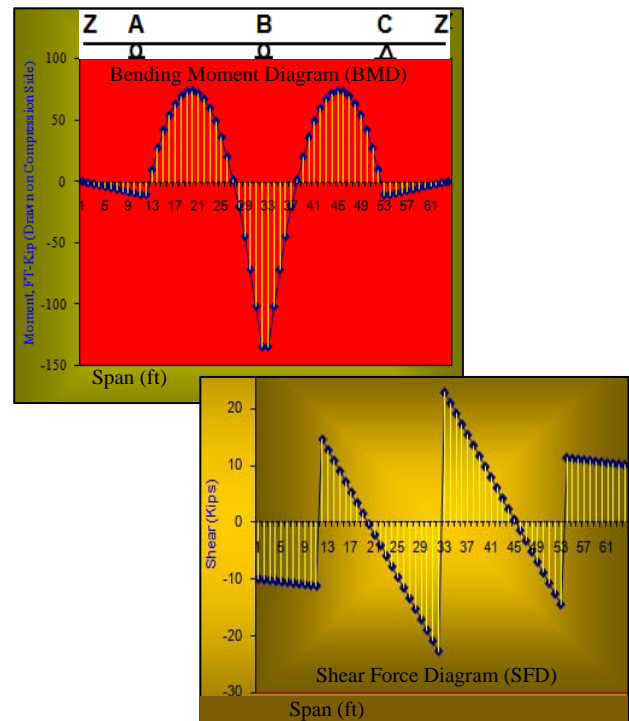
The second example illustrates the construction of the shear force and bending moment diagrams for any structural member using a spreadsheet. Figure 5 shows the shear force and bending moment diagrams for the continuous beam used in the first example (the moment distribution example). Beams are long and slender structural elements that support transverse as well as axial loads. Figure 5(a) shows the bending moment and shear force values at different span distances while Figure 5(b) shows the bending moment and shear force diagrams.

These diagrams are important in structural engineering as they show not only the variation of the internal forces along the length of the structural member but also the most critical values that the structural engineer needs to design the relevant structural member. They are the most popular techniques to show the changes in the internal forces of a structural member along its length. These diagrams are obtained using the relationships between the external loads on the member and the internal forces generated in the member and the free body diagrams (FBD's) to the left or right of sections that cut the member transversely and show all the forces on those FBD's. Then equations of equilibrium are applied to ensure equilibrium is satisfied. The shearing forces and the ending moments obtained are basically the internal stress distribution resultants. Typical examples of beams include bridges, roof structural elements, floor beams, machine elements such as levers, cranks, manipulator arms, etc.

The third example illustrates the use of Excel in calculating the internal stresses and deflection in a beam. Having calculated the design bending moment and shear force for the beam above, all that remains to be done now is to assess the size and strength of the beam. The process involved in a selection depends on whether the construction material behaves elastically or inelastically. For the demonstration in this paper, elastic behavior has been presented. The calculation of the internal stresses, whose resultants are the shearing forces and bending moments produced by the external loads, and the deflections in a beam of known section and geometry uses the section modulus (S) and the cross section area (A) and its moment of inertia (I).

	Span-Distance along span	Moment	Shear
1	0.00	0.00	-10.00
2	0.10	-1.01	-10.12
3	0.20	-2.02	-10.25
4	0.30	-3.06	-10.37
5	0.40	-4.10	-10.50
6	0.50	-5.16	-10.62
7	0.60	-6.22	-10.74
8	0.70	-7.30	-10.87
9	0.80	-8.40	-10.99
10	0.90	-9.50	-11.12
11	1.00	-10.62	-11.24
12	0.00	-10.62	14.49
13	1.50	9.72	12.63
14	3.00	27.27	10.77
15	4.50	42.03	8.91
16	6.00	53.99	7.05
17	7.50	63.17	5.18
18	9.00	69.55	3.32
19	10.50	73.14	1.46
20	12.00	73.93	-0.40
21	13.50	71.94	-2.26
22	15.00	67.15	-4.12
23	16.50	59.57	-5.98
24	18.00	49.20	-7.85
25	19.50	36.03	-9.71
26	21.00	20.08	-11.57
27	22.50	1.33	-13.43
28	24.00	-20.21	-15.29

(a) Bending Moment and Shear Force Values.



(b) Bending Moment and Shear Force Diagram.

Figure 5: Bending Moment and Shear Force.

As shown in Figure 6, the spreadsheet reduces the arithmetic errors of computing the S , A , and I , the frustrations, and the time doing the tedious stress calculations. The procedure for

computing stress briefly involves: 1) computing the maximum moment and determine the required section modulus (S) using the flexural formula, $S = M/f_b$; 2) selecting the most economical (lightest) structural steel shape using the AISC Allowable Stress Design Method; 3) checking the beam for shear by comparing the actual shearing stress and the allowable shearing stress; and 4) computing the maximum deflection due to the design load and compare it to the allowable deflection.

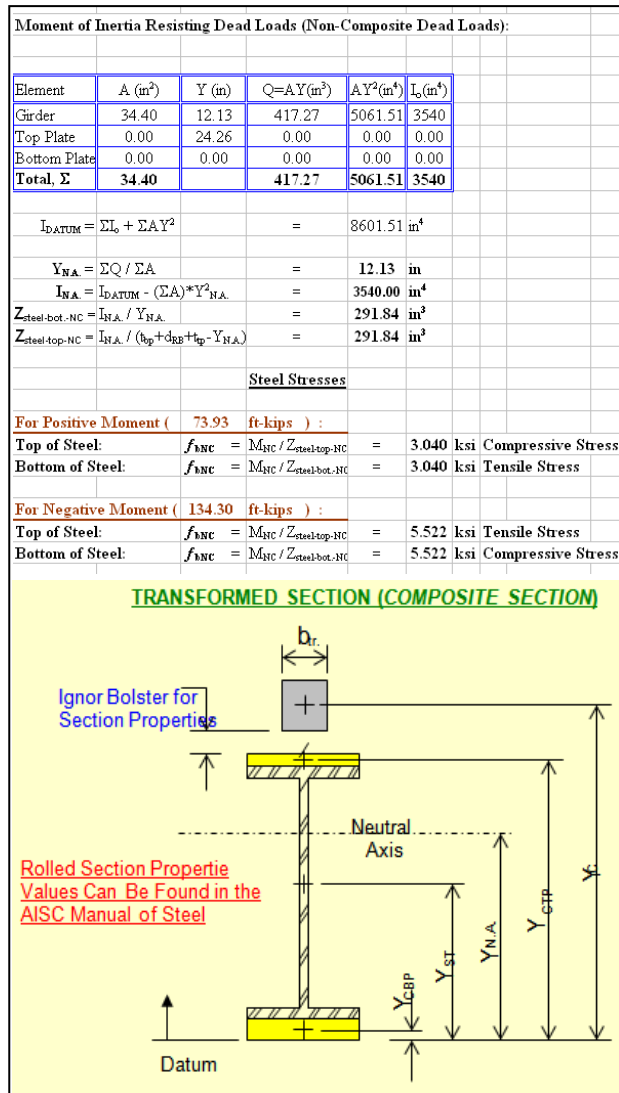


Figure 6: Section Properties and Stress Calculations.

4. CONCLUSIONS

Spreadsheets are becoming increasingly popular for use as a powerful tool and are considered among the earliest software innovations that had a profound effect on the widespread use of personal computers. Among the strong features of spreadsheets are their intuitive cell-based structure and the simple interface that is easy in education. This is in addition to its powerful programming capabilities. Underneath the structure and the

interface is a host of powerful and versatile features that can be utilized in teaching, from data entry and manipulation to a large number of powerful functions. In this paper, several spreadsheet applications are developed for use in teaching civil engineering concepts. For the purpose of illustration, seven of these spreadsheet applications are then presented. The examples demonstrate the simple and powerful features of spreadsheets and its capability in solving complex construction management and structural engineering problems. These examples can be used by civil engineering students as templates for solving similar problems or for developing models to solve other problems. In addition, the developed spreadsheets, as such, represent a transparent methodology that allows for quick what-if analysis in cost estimation, optimum markup estimation, risk analysis, and structural members optimization. Finally, the availability of Excel and its VBA programming capabilities makes it a powerful tool in developing applications for teaching civil engineering concepts and concepts related to other engineering disciplines.

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