

Spreadsheet as a Tool in Teaching of Buckling Fundamentals

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ABSTRACT: *The paper presents an Excel® spreadsheet for the buckling analysis of elastic struts. The spreadsheet has been prepared as a tool for use in the second year course on Strength of Materials in the Faculty of Engineering and Technology at the University of Botswana. It calculates the elastic critical load and the ultimate stress for any of five typical cross-sections, the dimensions of which are given by the user. The user has also a possibility of choosing the modulus of elasticity from the table containing different materials and their elastic properties.*

1 INTRODUCTION

The buckling principles, as studied in a general Strength of Materials course, have been a struggle for generations of engineering students. Even the calculation of critical loads for different boundary conditions presents a challenge for the majority of students when they study the buckling principles for the first time. In the current semesterized curriculum of the Bachelor of Engineering programmes at the Faculty of Engineering and Technology of the University of Botswana, buckling is a part of the core course on Strength of Materials. The course is taken by engineering students of civil, electrical and mechanical disciplines during their Year 2 of the 5-year degree programmes. Year 2 under the new semesterized system introduced in 2001/02 academic year is a common year for all engineering students. The new programmes have been designed to give students a greater freedom as to the selection of subjects from a wider range of courses, and permit them to broaden their studies by taking courses offered by other faculties. The B.Eng. programmes extend over ten semesters after entry at the GCSE level, or eight semesters for those with A-level or Ordinary Diploma qualifications. Course credits over ten semesters are required to total 150, at approximately 15 per semester, of which 28 will be gained from general education or elective courses. Choices within the home faculty courses permit students to select options for approximately 25% of the 122 credits allocated to these courses. The new semesterized curriculum is oriented more towards the concepts of computer-assisted teaching and computer-aided learning. The former requires a wider involvement of the lecturer while the latter is focused on the student self-learning activities. The buckling spreadsheet tool presented hereafter falls in the second category of concepts.

2 COMPUTERS IN ENGINEERING EDUCATION

The use of the computers in enhancing the teaching of engineering courses is not a new concept. This approach can help students not only to understand the particular topic but also to check his/her calculations instantaneously without being referred to a lecturer or an instructor. It also gives the freedom to the student of studying the problem at any time. Since computers play a significant role in the daily live of engineers, their use in engineering education helps students to develop the attitude towards creativity in future work in design offices. Present informative societies are assumed to be computer literate where everybody has close contact with a computer at schools and the majority of school children have them also at home. However, the situation in Botswana has some special factors, not unusual in developing

countries, that even those few school leavers that select engineering as their career of first-choice have rarely been exposed to modern technology or the work of engineers. Generally, only urban middle-income households have electricity, television, telephone or home computer.

3 SOFTWARE DEVELOPMENT FOR ENGINEERING EDUCATION

One of the major goals in teaching contemporary mechanics of materials and structures is to assist students in grasping fundamental principles with help of computer assisted techniques. This goal necessitates that students be introduced to computer-assisted techniques at the very beginning of their engineering education. Different approaches can be used in educational practice to reach that goal. They include:

- providing the students with simple software based on applications of the commercial Microsoft Office package,
- using special interpretive software,
- using the MATLAB package supplemented by calculation routines, and
- confronting students with an existing commercial software, typically in an educational versions.

The first approach is most likely to be based on the spreadsheet Excel® software (Microsoft EXCEL®, 2000) that is the most suitable for teaching mechanics fundamentals. In the course of building up the student engineering knowledge, when fundamental principles need to be used in courses on engineering design, more advanced approaches, listed above as the second and the third, are used. Appropriate software has become a must-have tool for the analysis and synthesis of engineering systems. Analysis is often performed using dedicated engineering software, and one of the most used teaching and research simulation software packages in universities and research institutions is MATLAB® (MATLAB®, 2001). As an example the computer code CALFEM (CALFEM, 2000) may be referred to. In the final years of study engineering students are exposed to commercial specific design oriented like SOLIDWORK (SOLIDWORKS, 2003) or general research oriented packages like ABAQUS (ABACUS, 1998).

There was a period when plenty of new texts on almost any engineering subject have appeared, each with accompanying software written in every scientific programming language (Goodfellow, 1990). Not surprisingly, by natural selection, MATLAB have become the most popular and widely used package. Its performance and presentation is so impressive that it is possible to overlook the fact that the computation process is now no longer really under the control of the student, and that the code is invisible. It has been considered too expensive in some places (Sebusang et al., 1999), thus prompting the search for less expensive software packages that can equally do the task.

4 THE USE OF A SPREADSHEET

Electronic spreadsheets, originally developed by automating accounting analysis, have always been recognized as particularly useful in engineering education (Doak et al., 1996, Finnemore et al., 1997, Moheimer & Antar, 2000, Reed & Sass, 1997). Being universally available and affordable, spreadsheets may be used in engineering laboratories and lecture halls as alternatives for the simulation and optimisation of engineering systems. Modern spreadsheets that are now supplied as standard with multipurpose software offer a very wide range of scientific functions. They will evaluate formulae at high speed on large quantities of data, and they are provided with tools to generate graphs and charts that are ideal for most student work. Import and export of data to other programs is simply achieved, which makes spreadsheets useful as a stage in the production of laboratory reports, published papers and web pages.

The authors of this paper have used spreadsheets in setting student assignments and laboratory work for several years. The work reported in this paper forms the part of a much larger collection of simple software tools that has been developed in the Faculty of Engineering and Technology at the University of Botswana (Foster et al., 1999, Sebusang et al., 1999).

5 ADVANTAGES OF USING SPREADSHEET

- The spreadsheet offers several advantages as a tool for the learning process as well as in terms of the learning resources that the institution must provide.

- As there are no special commands, structures of input and output data or procedures as it is normally in the programming language, there is no extra learning required, since the student already knows how to use a spreadsheet. Even if the student is not familiar with the spreadsheet, the time needed to introduce spreadsheet techniques to students and then to get meaningful results is relatively short.
- The calculation process is based on formulae that the student can see, inspect and modify at any time without going into the invisible code, as it is the case of programming languages. The computation process is always under the control of the student.
- Since syntax or data errors will be obvious and visible as they are entered, the “debugging” is minimal.
- There is a huge advantage in the ability of a spreadsheet to represent the outputs of engineering systems in a graphical form that is of a great help in the interpretation of trends, correlations and other phenomena that ordinary tabulated data may not reveal.
- The use of a spreadsheet reinforces techniques that the student meets in other parts of the curriculum, and provides practice in generating the student’s own skills highly required in professional work later.
- Spreadsheets are now supplied as standard with multipurpose software program that is usually acquired together with the purchase of computer. Hence, there is no extra cost on the purchase of specialized software.
- Software can be made available at unlimited number of individual computers used by staff and students, as access is not restricted by license agreements.

6 BUCKLING FUNDAMENTALS SPREADSHEET ACTION

The authors have favoured the concept of a tool that can be easily used by the students themselves to compare their results obtained by conventional calculations with the correct answers produced by the spreadsheet.

The buckling fundamentals spreadsheet has been prepared as a tool for use in the second year course on Strength of Materials in the Faculty of Engineering and Technology at the University of Botswana. It calculates the elastic critical load and the ultimate stress for any of five typical cross-sections, the dimensions of which are given by the user. It gives also the possibility of choosing the modulus of elasticity from the table containing different materials and their elastic properties. There is also a choice of different end-fixing conditions, which change the effective length of the strut and thus affect the critical load. The spreadsheet works as a menu driven program and is designed to be user-friendly. The choice between the sections, materials and boundary conditions is done by a click of the mouse at the appropriate inserted figures. It visualizes different conditions. The spreadsheet has hyperlinks to text files with theoretical information on the buckling theory. These files can be also reached by clicking on a button. Students may also investigate relationships between different cross-sections and material properties on the strength of the strut. The tool mentioned above should be ‘open’ to the students so they can see how the calculations are done and they may modify them.

The consecutive steps in the calculation process are shown in Figs. 1 - 7.






Buckling					
1	Reset the sheet by clicking on the red button in the next cell or Ctrl-b (you can always reset the sheet by clicking the red button or Ctrl-b)				
2	Enter data for the column				
Select the type of cross section by clicking on the appropriate cell, when you are OK with the section click NEXT					
	Angle	"Tee"	"I"	Tube	Rectangular Tube
					

Figure 1 – The selection of the cross section

Enter dimensions for the "Tee" section

"Tee" SECTION		
Width of flange:	100	0.1
Height of flange:	10	0.01
Length of web:	120	0.12
Width of web:	10	0.01

Second Moment of Area about the Axis through the Centroid:

Horizontal Axis I_{xx}	3.753E-06	m ⁴
Vertical Axis I_{yy}	8.433E-07	m ⁴
Least Second Moment	8.433E-07	m ⁴
Least Radius of Gyration	0.0195789	m

That concludes the calculations for the section, in order to go back to the Main sheet click the green button in the next cell

Figure 2 – The process of entering the dimensions for a particular cross-section

3 The calculations for the selected section has brought the following results:

Type of section:	"Tee" SECTION
The least second moment of area (I):	8.43333E-07 m ⁴
The least radius of gyration (k):	0.0195789 m

[NEXT](#)

Figure 3 – The confirmation of the geometrical properties of the selected cross-section

4 Select the material for the column by clicking the appropriate cell, when you are OK with the section click NEXT

Material	Elasticity GPa	Compressive Yield Stress MPa	c constant
Mild Steel	200	300	7500
Wrought Iron	190	250	8000
Cast Iron	140	560	1800
Aluminium	70		1000
Timber	12	35	1000

The selected properties are:

Material	Elasticity	Compressive Stress	c constant
Mild Steel	200	300	7500

[NEXT](#)

Figure 4 – The selection of the material

5 Select end-fixing conditions by clicking the appropriate drawing, when you are OK with the section click NEXT

Depending on the end conditions of the column, the effective length will be different.

Pinned or Hinged on Both Ends	Rigidly Built-In at Each End	Built-In at One End and Free at Other	Built-In at One End and Pinned at Other
Pin	Clamped	Free	Pin
Pin	Clamped	Clamped	Clamped
Effective Lengths Factor			
1	0.5	2	0.7

The selected end conditions and effective length are:

End Conditions	Pin-Pin
Effective Length	1

[NEXT](#)

Figure 5 – The selection of the end-fixing conditions

6) The formula below is for the critical loading. The constants and variables are explained below.			
$P_{cr} = \frac{\pi EI}{L_e^2}$			
E - elastic modulus (elasticity) [GPa]			
I - the least second moment of area of the constant cross-sectional area of the column [m ⁴]			
L _e - effective length of the column (a product of the effective length factor and the theoretical length of the column)			
Critical load:	529.8819609	MPa	
7) In order to get a get a printout, click NEXT which will take you to the next step.			

Figure 6 – The final step showing the formula used and the result obtained

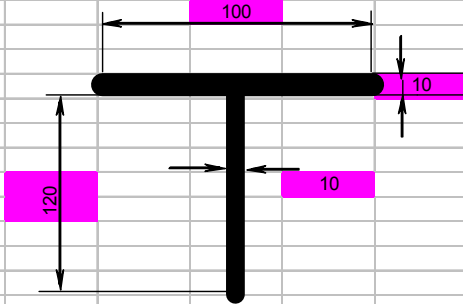
Type of Section	"Tee" SECTION		
Width of flange:	100		
Height of flange:	10		
Length of web:	120		
Width of web:	10		
The least second moment	8.4333E-07 m ⁴		
Material	Mild Steel		
Elasticity	200 GPa		
End Conditions	Pin-Pin		
Effective Length	1		
Critical load:	529.881961 MPa		

Figure 7 – The printout from the spreadsheet can be obtained as a separate worksheet or a hard print copy

7 CONCLUSIONS

The work reported here is based on well-known solutions of buckling problems of a straight and prismatic strut. The aim was to create a tool that might be used as a learning aid for students when they study buckling phenomenon. There was a need for a user-friendly instrument, which will not be viewed by students as a “black-box” that they cannot explore. The transparency of a spreadsheet tool helps to avoid any student perception that the work is something beyond his or her reach. The Excel[®] spreadsheet gives the student the ability to manipulate the problem for various conditions of elastic buckling, and also to see how the calculations are done. It shows how effectively a spreadsheet can be used in introducing to students the concept of buckling. It also allows the students to introduce variations in the input data and then observe how changes in data affect the response. All this demonstrates that spreadsheets are useful and readily available computational tools. They also teach how to exploit the in-built functionality of spreadsheets to solve everyday engineering problems without resorting to expensive and specialised software packages.

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