Improvement of students' engineering skills in numerical modelling of the structural systems

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Abstract—**The software solution, that allowing users, students and engineers, to easily determine the values of the soil reaction coefficient (the coefficient of subgrade reaction) and buckling coefficient, has been developed. These are four modules within SE_Calc software, two have been implemented in the object–oriented programming language C#, within Microsoft Visual Studio 2015 software package, and another two have been implemented as Flash solutions. The aim of this paper is to determine the significance of the influence of the use of SE_Calc software on acquiring students' knowledge of soil reaction and buckling, as well as their reactions to learning by the use of computer teaching methods. It has been intended to obtain a clear insight of the benefits of computer–aided teaching in a specific area of engineering education.**

Keywords-computer–aided teaching; engineering education; buckling coefficient; soil reaction coefficient; students' learning

I. Introduction

A large number of research and studies in the field of engineering education, as well as in general education, have shown significant advantages of computer aided–teaching methods over the traditional techniques, i.e. that technology has an important educational potential to improve learning efficiency. Moreover, in the last twenty-five years, it has undoubtedly proved that computers are a valuable part of the overall teaching strategy, or that teaching and learning based on digital technology contributes to a higher level of understanding of material/subject, motivation and engagement of students, as well as to a better transfer of knowledge and better achievements. In comparison to traditional learning mode (classroom learning), those approaches enable the pace, sequence, content and method of instruction to better fit each students' learning style, objectives and goals, but at the same time depends much on their ability to tailor instruction to the needs of individuals [1]–[14].

Undergraduate and graduate students of civil engineering at the University of Mostar, but also at other Technical Universities throughout the world, during their study having very often a need for numerical modelling of the constructive or structural systems. In many of those calculations, they will have to determine the values of several coefficients, such are the soil reaction coefficient (the coefficient of subgrade reaction) or buckling coefficient. For example, students may have a task to examine the influence of soil reaction coefficient on 2D steel frame behavior, or on the simple 3D frame. Unfortunately for students, in the literature there is a large number of authors with different approaches/expressions for obtaining unique solutions for the soil reaction coefficient, so they may remain in a dilemma over which solution to choose, and what consequences that solution will have on the behavior of the static system. These questions and the lack of software solutions that will assist students, but engineers too, or in other words that will facilitate the calculations of these coefficients, but also their average value, or give the relationship between the dimension of the square foundations and the value of soil reaction coefficient, motivated the authors to develop SE_Calc software [15]–[20]. Moreover, we wanted to investigate students' opinions on a new learning approach.

II. Sowtware solution

Our core idea was to create an efficient engineering tool, but also an effective teaching tool, i.e. to develop a software solution by which students and engineers may be assisted in their numerical modelling tasks. In order to achieve such goal, the authors decided that the SE_Calc software should meet a number of generally acceptable design criteria, but also to meet the most important aspect of teaching and learning based on digital technology. These include [1], [10], [14], [21]–[23]:

- The software should meet the ability to customize learning approaches to match students' learning styles – that is, pacing the learning approach, speed, and depth to reflect students' prior knowledge, level of comprehension, and areas of interest.
- The software should be easy to use, should engage students' attention and motivate them, and should be user–friendly – that is, sympathetic to the student's inexperience with regard to engineering parameters.
- The software should be user interactive – that is, the student should be encouraged to participate in the solution process and to develop their problem–solving strategies, or to improve their engineering skills, rather than simply watching the computer solve a problem.

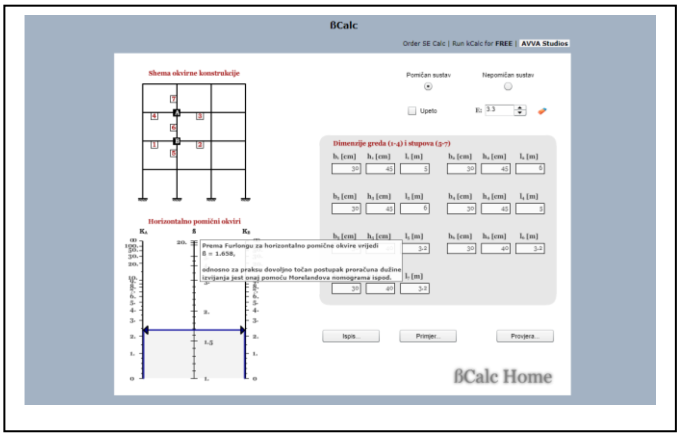

Figure 1. The module for determining the buckling coefficient.

Next, according to an IMHE (Institutional Management in Higher Education) guide for higher education institutions, policies and practices to foster quality teaching in higher education should be guided by ultimate goal – that is, to improve the quality of the learning experiences of students and – through this – the outcomes of learning [23]. Such a goal can be achieved by using several actions (levers). For example, the actions in regard to constant staff–oriented support, focused mainly on staff's endeavors to develop their ICT skills and prompts on them to update their knowledge and digital capability as well as on informing them on the opportunities that ICT can provide for enhancing teaching and learning. Also, this guide is recommending an intensive explore on how learning environments can be made more conductive to exchange of knowledge, information and ideas between teachers and students, and encourage them to interact within and across engineering disciplines. Each of the SE_Calc modules strives to satisfy all these demands: generally acceptable design criteria, the most important aspect of teaching and learning based on digital technology and ultimate goal – and they are described briefly below.

SE_Calc software consists of four modules: βCalc, kCalc kComp and k–B Graph.

The first module, or module for determining the buckling coefficient, and the second module, or module for determining the coefficient of subgrade reaction, have been implemented as a Flash solution. The reasons for using this tool are multiple. For example, for more than two decades, its potential of creating rich media or multimedia for the World Wide Web and standalone applications with a user-friendly interface is well known, and in particular its ability to combine drawing and programming tools at the same time, or its availability and compatibility. These features make contents (problems) more accessible and more attractive for almost all users, and this is especially important for engineers in practice. The βCalc application has an intuitive interface, which provides the input of all necessary data for determining the buckling coefficient, and next by which the frame system is selected, and at the end, a recommendation for it use is checked. Moreover, the application enables printing of the results, i.e. documenting of a specific calculation for the needs of technical documentation. The βCalc module is shown in Fig. 1.

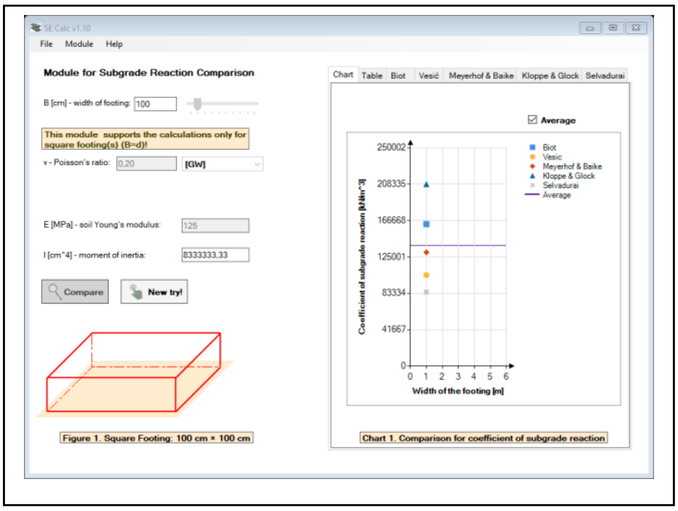

Figure 2. The module for subgrade reaction comparison – graphical form.

Third module, or module for subgrade reaction comparison, and fourth module, or module for drawing k–B graphs (where k is the coefficient of subgrade reaction and B is the width of footing) have been implemented in the object–oriented programming language C#, within Microsoft Visual Studio software package, and can be run on Microsoft Windows operating systems. The kComp application also has an intuitive interface, allowing the user to easily specify the parameters for the width of footing and the soil characteristics, as well as to select the soil type in a separate drop–down menu. After specifying the parameters, it is possible for the user to compare the values of coefficient of subgrade reaction according to several different authors in separate windows/tabs, and in tabular and graphical form. In addition to the standard option of printing the comparison results, it is possible at any time to export/save the graphically presented values of subgrade reaction coefficients to special image files (.png files) on the local hard disk and/or a flash disk, as well as to export a snapshot of the entire module, all in order to more completely document a particular calculation [15]. The kComp module is shown in Fig. 2 and 3.

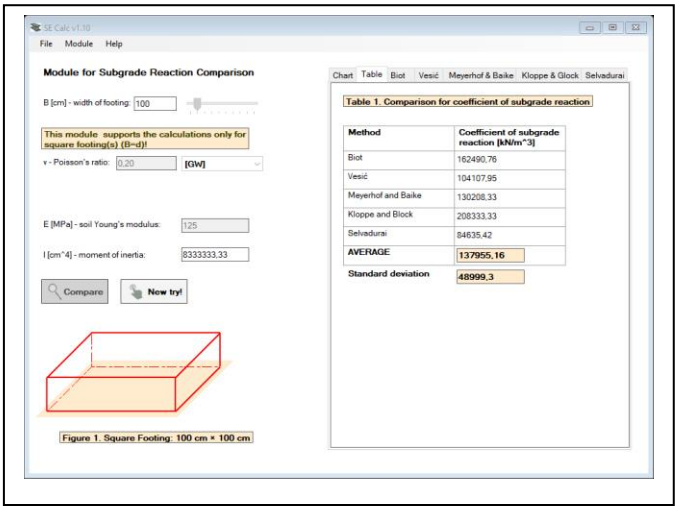

Figure 3. The module for subgrade reaction comparison – tabular form.

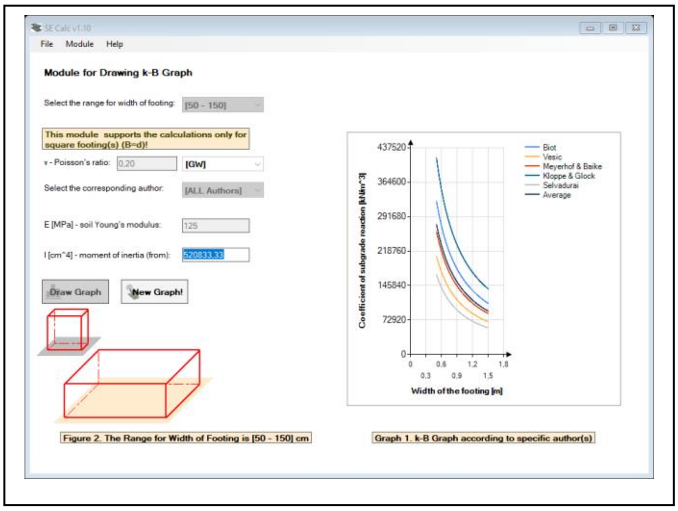

Figure 4. The module for drawing k–B graph.

The k–B graph application requires from the user three simple actions: to select the range for the width of footing, to specify the soil characteristics, and finally to choose the corresponding author. Upon completing all these actions the graph with a curve, which shows the relationship between the dimension of the square foundations and the reaction coefficient, will be displayed. The user is able to choose only one specific author or all authors. In another case, the graph will contain the curve families for each author, as well as the average curve, which will be of great help to user for predicting the behavior of 3D frame structure in more easily way [20]. The k–B graph module is shown in Fig. 4.

III. Research Results

The ability to develop a numerical model of the specific constructive or structural systems, for example, to determine a values of the soil reaction coefficient and buckling coefficient, in an engineering–based modelling environments is of special interest in the present engineers' curricula, but also will remain in permanent interest. Hence, the constant need for suitable learning tools for that purpose in the specific area of engineering education is reasonable and current.

Today's students, and especially students of technical universities, are accustomed to managing digital technologies in everyday activities at the university, or home or in general [3]. Asking such students to perform classical paper–and–pencil exercises can be counterproductive – particularly if we want to offer voluntary remedial courses to improve their engineering skills and knowledge in numerical modelling of the structural systems. It is more than obvious that it's difficult to maintain students' attention in such a course, and that they will often abandon it before it ends. In order to respond to this, we have strived to develop an efficient engineering–based modelling tool, and which will be at the same time an effective teaching/learning tool. This software tool has been introduced to the graduate students at our Faculty of Civil Engineering during the intensive course regarding numerical modelling in November 2018. Our students have the ability to attend such courses on a voluntary base twice a year. For the affirmation of our thesis regarding the improvement of students' engineering skills in numerical modelling of structural systems by use of SE_Calc software, we have been conducted basic research. Another important point of this research was the determining of the students' reactions to learning by the use of computer teaching methods. In brief, the total course duration was 20 hours, and during the course, students have to combine our software solution with Tower program – a high–performance professional tool for static and dynamic structural analysis. They had several numerical modelling tasks regarding foundations on the elastic ground, as well as regarding the structural stability calculations. Upon the completion of the course, students have been requested to fill up a short survey. The survey was mandatory for all students who have been participated in an intensive course, and the results of this basic research distinctly affirmed our thesis.

When asked if they could easily learn, understand, and solve engineering task, for example, to examine the influence of soil reaction coefficient on 2D steel frame behavior, by using SE_Calc application during lectures and individual work, students gave the following answers shown in Table I and Fig. 5. Students gave almost identical answers on other similar questions, but with different engineering tasks. Due to the tendency for a concise form of this article, we will not present these answers either with new tables or charts.

TABLE I. A Sample of Students' Answers

	Answers		
	Rather disagree	***Rather agree***	***Strongly agree***
I have easily learned, understood and solved engineering task by using SE_Calc application during lectures	3[a]	10	12
I have easily learned, understood and solved engineering task by using SE_Calc application during individual work	4	5	16

a. Task was to examine the influence of soil reaction coefficient on 2D steel frame behavior.

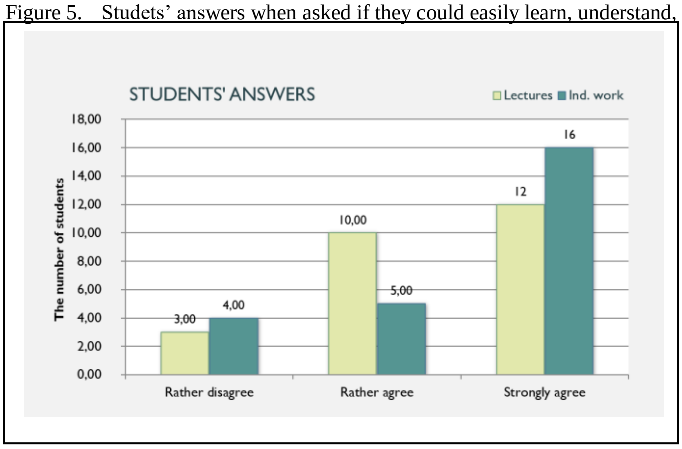

Figure 5. Studets' answers when asked if they could easily learn, understand, and solve engineering tasks by using SE_Calc application during lectures and individual work.

IV. CONCLUSION

To create a numerical models regarding foundations on elastic ground, or structural stability, readily useable for teaching students about the influence of soil reaction coefficient on 2D steel frame behavior or on the simple 3D frame, a software program SE_Calc that allows students and engineers to easily determine the values of the soil reaction coefficient and buckling coefficient has been developed [15]. The software solution was practically applied during the intensive course regarding numerical modelling in November 2018 at the Faculty of Civil Engineering University of Mostar. A short survey at the end of the course revealed that the majority of the participants rather agree or strongly agree about the significant influence of the use of the SE_Calc application on acquiring their knowledge, as well as on improving their engineering skills in numerical modelling of structural systems. Such students' answers (research results) are good enough to conclude that developed software solution can provide an effective means by which students may be assisted in their comprehension of fundamental engineering principles, or to conclude that teaching and learning based on the use of SE_Calc software can contribute to a higher level of understanding of engineering materials/subjects, motivation and engagement of students, as well as to a better transfer of knowledge. Moreover, the obtained results are the best proof of the need for the development of such software solution. We are aware that the work on our tool is still a long way off from the end, but also that our basic research may serve as a guide for a more methodological, forthcoming studies [3], [14], [24]. The future development of SE_Calc tool will have a focus on the other factors that are essential for the successful development of computer–aided learning/teaching software, and were not investigated nor implemented in the current solution. We will strive to listen all users who will be able to reveal the areas that require some improvement.

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