Learning Tool for Reinforced Concrete Design

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Abstract: *Reinforced concrete design is considered as a vitally important discipline in the field of civil engineering. The design of reinforced concrete is done to various standards and well established code of practices. The British standard, BS 8110, has been followed for the design of reinforced concrete structures in Sri Lanka for almost three decades now. However, with the withdrawal of BS8110 by the United Kingdom to pave the way for European common standards, Sri Lanka has been compelled to use Euro standards or adopt other international standard for the design of reinforced concrete. American Concrete Institute ACI 318(2008), European Standard EC2 (BS EN 1992-1-2), Japan Concrete Institute JCI standards and model codes like CEB FIP Model Code 90 are the commonly used international standards for reinforced concrete design. It is also known that Sri Lanka are gearing to embrace the EC2 (BS EN 1992-1-2) in place of the withdrawn BS8110.The design approaches and design provisions of various standards are different form one another and results of various design approaches and their structural implications are continuously being debated in various forums. It is considered that the knowledge of different design approaches is essential for the better understanding of the behaviour of reinforced concrete. In addition, there is an especial requirement to train structural engineers in Sri Lanka to adopt Euro standards. Both of the above objectives can be achieved by a well design learning tool. Leaning tool allows the users to learn on their own phase. It is in this back ground that interactive learning tool "Recode" is formulated. This paper presents various features of Recode, the learning tool developed to teach beginners how to do design under different standards and the experienced, how to adopt to changing scenarios to which their designs have to be confirmed.*

Keywords: *Reinforced concrete, Design, Standards, Learning tool, Engineering education.*

1. INTRODUCTION

With the popularization of computer applications and internet applications, development of learning tools for various application and illustrations is getting popular by the day. There are few such attempts to use such applications for teaching reinforced concrete design as well. One such notable attempt is the development of "COMPACT" for EC 2(EC2, 2008). The main emphasis on such tools is normally to teach an establish code approach for the design of reinforced concrete and rarely have attempted to introduce different code approaches together. Therefore they have limitations to be used to compare result from different code approach and moreover to provide the advance learners the option to compare results under different code approaches.

It is in this background that "Recode", a learning tool that teach different codes and compare design philosophies of different code approaches has begun. In term of structural action Recode provide a platform to learn and compare major code approaches BS 8110(BSI, 1997), EC 2(EC2, 2008), ACI 318(ACI, 2008), JSCE (JCI, 1996), and the CEB-FIP Model code (CEB-FIP, 1993). In terms of element design, the Recode compares BS 8110(BSI, 1997) and EC 2(EC2, 2008) approaches.

2. SIGNIFICANCE OF THE STUDY

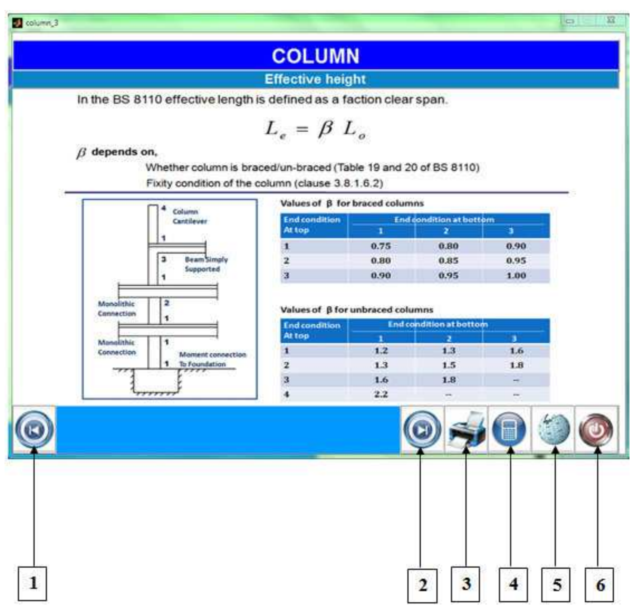
With the withdrawn of BS 8110, Sri Lanka is compelled to change for a code where latest developments and technological advances are continuously being upgraded. This learning tool provide a platform to teach design approaches for some of the notable codes namely ACI, BS 8110, EC 2, JCI, and the CEB

FIP in terms of major structural actions; bending and shear in the ultimate limit state and deflection and crack width in the serviceability limit state. Tool also offers provisions to element design. In terms of element design, the tool intends to cover BS 8110, EC 2 and ACI method and have so far covered column and beam design under the BS8110 and EC2.

3. METHODOLOGY

To achieve desirable outcomes as a leaning tool and comparison tool of different code approaches, “Recode” is design as an interactive program that allows user to familiarise with various design code approaches using interactive sessions, followed by guided examples and general examples. Guided examples provide user the ability to test their knowledge, while the general example provide user with the ability to define their own problems and find solutions for them. The user is also provided the ability to produce a report for the user defined example. Finally to assist the comparison, user is provided a comparative tool where solution can be found for user defined problems according to different code approaches. Notable variations of different code approaches are also highlighted in the tool to make the user aware of specific and generic variations of the different code approaches.

Given the complexity of mathematical manipulation required for putting all code approaches and design equation into a programmable platform graphical user interface provided in MATLAB 2010a was preferred for the programming. Main advantage of the use of MATLAB 2010a is its ability to tackle symbolic operations. Furthermore, the graphical interface allows the program develop as a a Windows application, which can be conveniently incorporated. Learning tool was also made available with inbuilt calculator, printing option and command buttons to easily navigate through tool. Fig. 1 explains the basic outlook of a tool window under general explanation illustrating how to find the effective length for columns according to BS 8110. Advance users are provided with the ability to navigate directly into the area they want to by providing a content page at the beginning of the module.



Numbers given to push buttons indicate the following,

1 – Navigate to previous window
2 - Navigate to next window
3 – Printer window
4 - Calculator
5 - Navigate to content page (home page)
6 – Discontinue a learning tool session

Figure 1: Overview of the typical arrangement of a window in the general explanation

4. COMMON FEATURES OF THE LEARNING TOOL

Arrangement of different modules of the learning tool can be summarised as follows,

1. Each module of the design tool will start with the contents page followed by the generic explanation on the basic philosophies for the design and other more specific design considerations, if any, required by the standard.

2. General explanation will always contain number of interactive sessions and a flow chart towards the end of the explanation to summarise how said code provision work in a given module to complete a given design aspect. This flow chart also outlines the way the learning tool will make its calculations for a particular aspect of design – Figure 2 shows the flow chart of the design of flange section according to the BS8110 as an example.

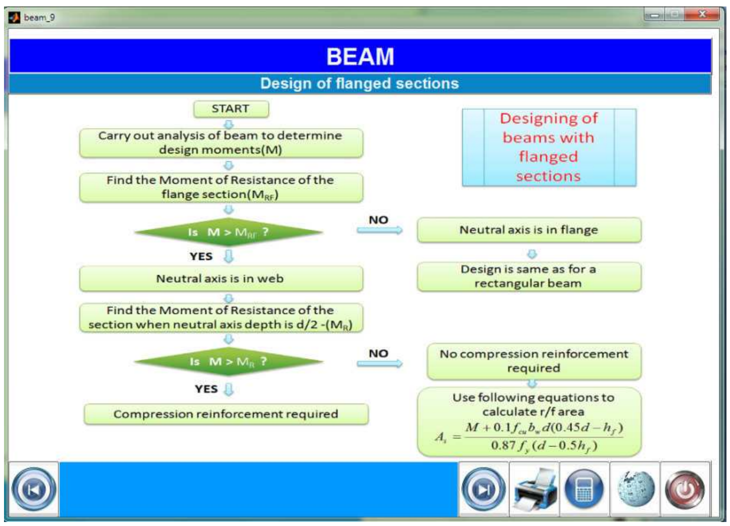


Figure 2: Flow chart used in the general explanation summarising the design of flanged beam

3. General explanation is followed by a guided example that will provide the learner with ability to check his understanding in the subject matter learned. At first the user will be able to work out the problem for which the results can be checked. Use of a guided example in the learning tool is illustrated in Figure 3.1 with Figure 3.2 showing the results at the end of the user interaction.

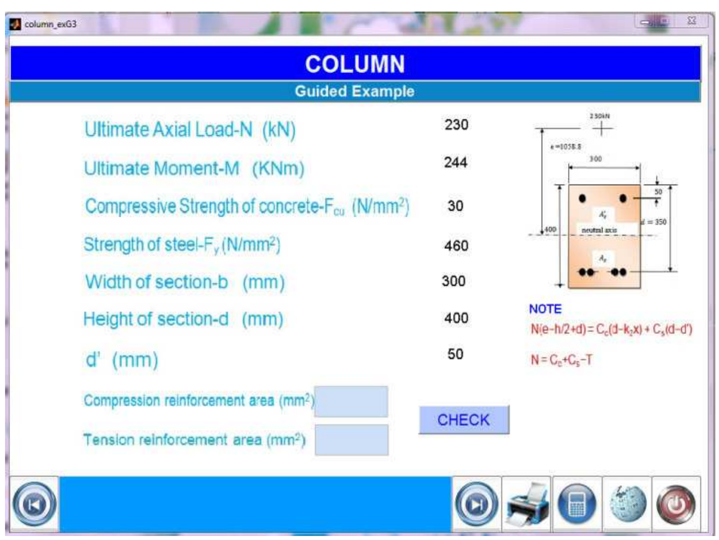


Figure 3.1: Guided example prompting the user to work out a question

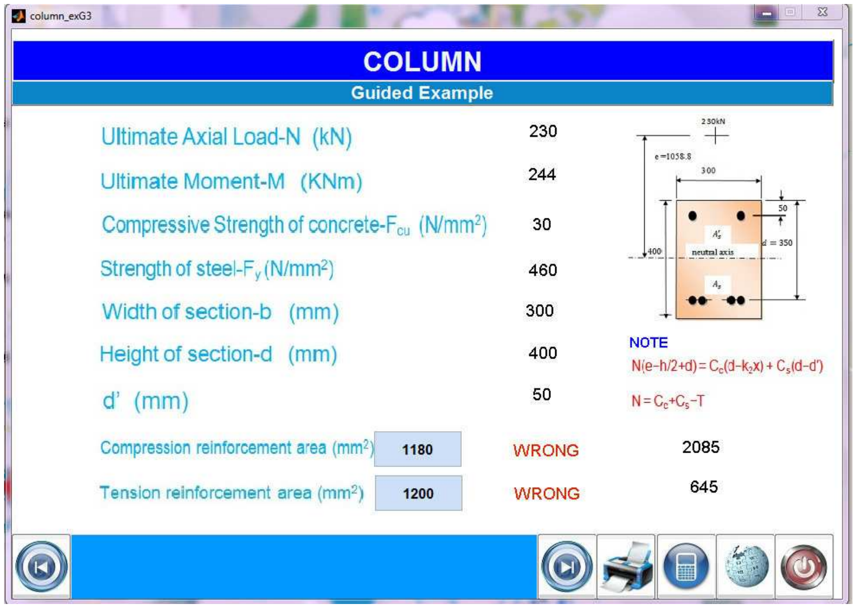


Figure 3.2: Results of the guided example after the user interaction.

4. Learning tool is also programmed to find the solution for user defined examples. Figure 4.1 and 4.2 show screenshots of a general example –Design of short column subjected to bending moment. Figure 4.1 is a screen shot that allows the user to define their own problem while the solution for the question formulated is shown in the Figure 4.2.

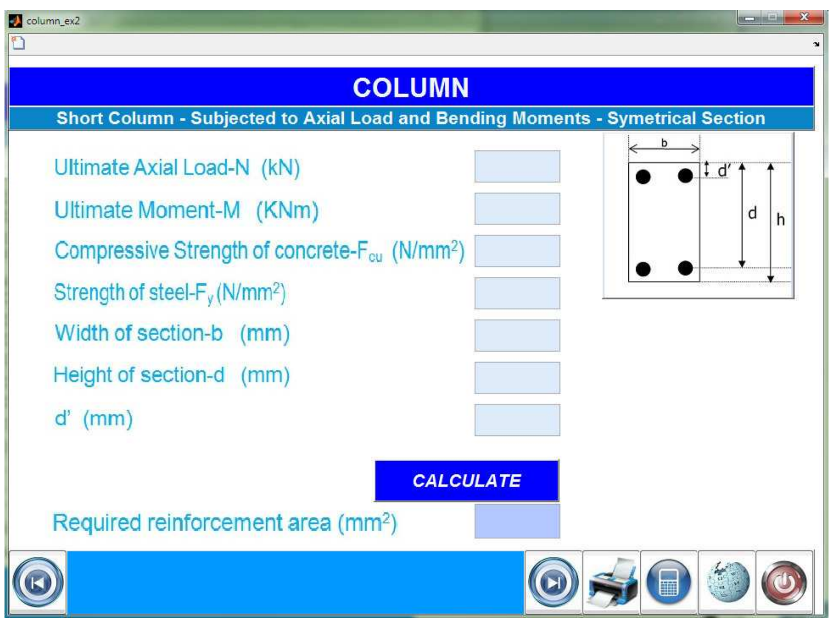


Figure 4.1: General example included in the learning tool (Before the results were obtained)

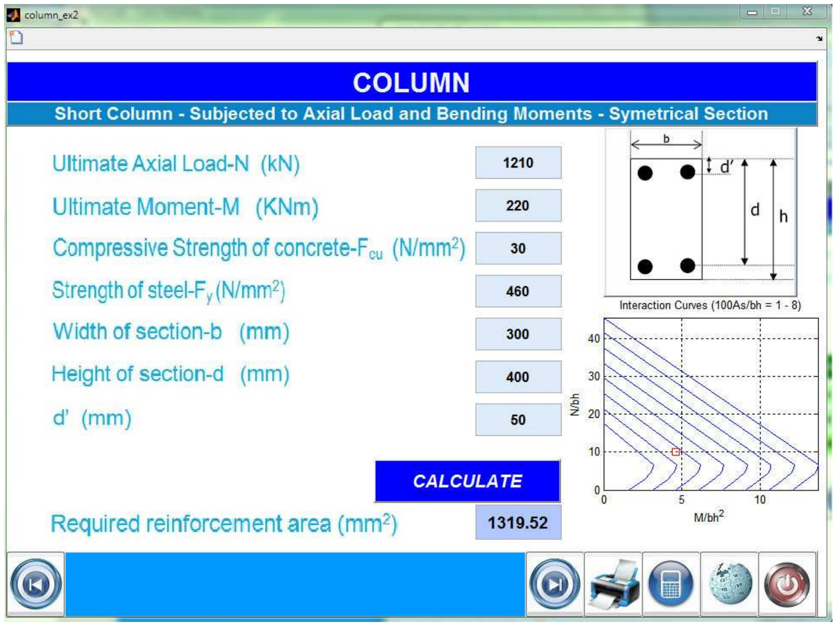


Figure 4.2: General example included in the learning tool (After the results were obtained)

5. Learning tool facilitate the advanced learners allowing them to compare the results of the user defined problem under different standards for the reinforced concrete design. Figure 5.1 and 5.2 shows the comparison tool for column design (Short column subjected to bending), checked under the design provision of BS 8110 and EC2. Figure. 5.1 prompt the user to defined the column while Figure 5.2 show the results under the different code approaches. Different reinforcement area resulted by the different standards highlight the different code provision and philosophies employed by the two standards for the design of reinforced concrete and in particular for the column design (Short column subjected to axial and bending deformations-asymmetric reinforcement arrangement).

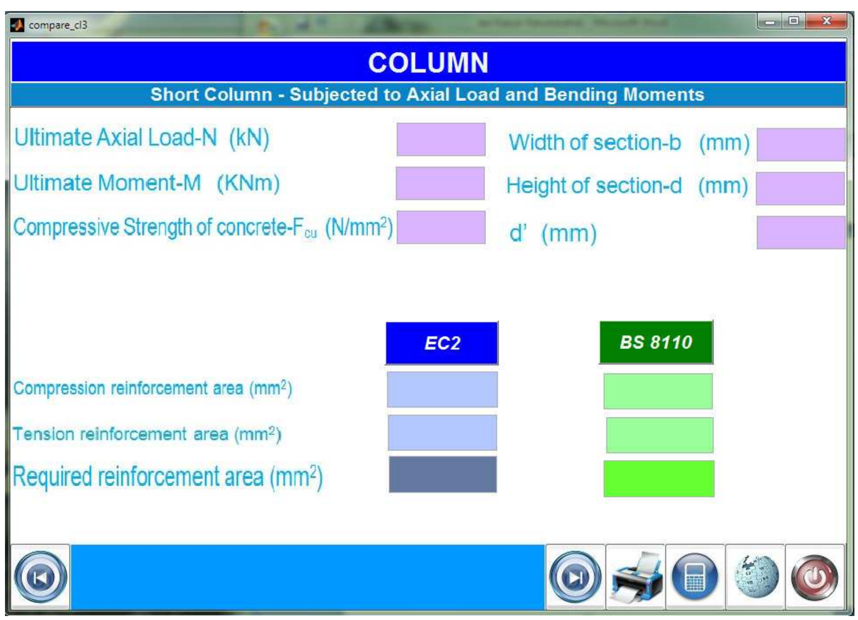


Figure 5.1: Comparison tool included in the program (Before the results obtained)

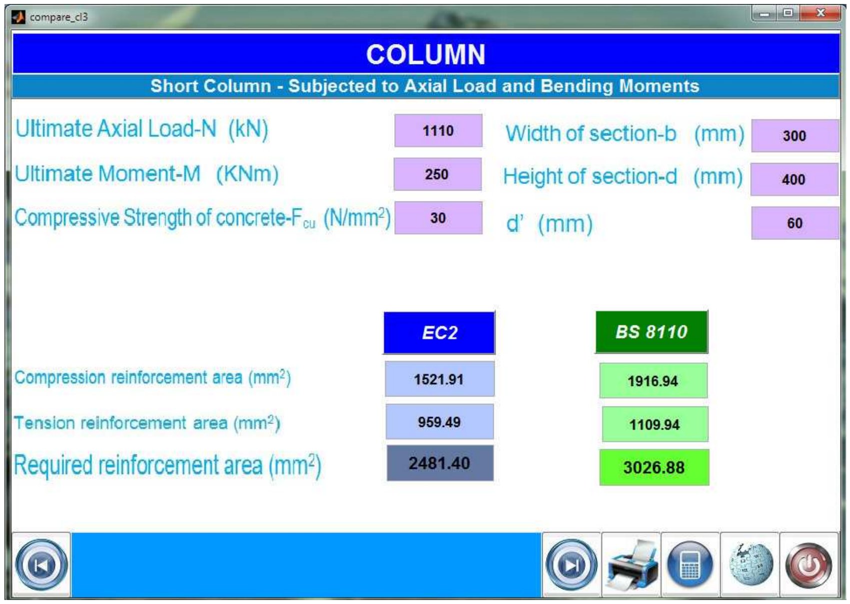


Figure 5.2: Comparison tool included in the program (After the results obtained)

5. DISCUSSION

The paper summarises learning tool devised to teach different code approaches for the design of reinforced concrete. Apart from the teaching the established design philosophies, the tool can be used in comparing results of various design standards among each other and against the actual experimental evidence to evaluate the relative merits and demerits of the different design approaches. At the moment the tool is limited for the structural actions bending, shear, deflection and crack width calculation for prominent code of practices namely BS 8110(BSI, 1997), EC 2(EC2, 2008), ACI 318(ACI, 2008), JSCE (The Japanese code)(JCI, 1996), and the CEB-FIP Model code (CEB-FIP, 1993) and element design for beam and column elements under BS 8110 and EC2 methods.

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