Reinforcing the Learning of Reinforced Concrete Design Online

Chiew Fei Ha[1], Ong Mooi Lian[1] and Lee Beng Yong[2]
[1]Faculty of Civil Engineering, Universiti Teknologi MARA
[2]Faculty of Computer Science and Mathematics, Universiti Teknologi MARA
[1]chiewfa@sarawak.uitm.edu.my

***Abstract*—Reinforced concrete design is a core subject in the civil engineering programme. Students are taught calculations for a safe design of reinforced concrete elements in accordance to the code of practice. The long and tedious calculations often restrict the number of examples that can be demonstrated in the limited classroom time. When practicing on their own, students do not have the means to verify their work in order to identify their mistakes. As such, exploiting the flexibility and convenience of the Internet, a web-based reinforced concrete design system is developed. It aims to provide students the opportunity to go through the design procedure at their own pace and convenience, and verifying worked solutions when doing practice questions. The web-based system is able to perform design calculations and display worked solution for beams, slabs, columns and footings. This system also generates proposed reinforcement for the elements, interwoven with explanation on the design procedure. A hands-on session has been carried out in order to seek feedback on the usability of the system from a group of students.**

***Keywords*—web-based system, reinforced concrete design, learning tool**

INTRODUCTION

Information Technology has made progress in leaps and bounds over the past decade. With the advancement in the Internet and communication technology, the World Wide Web has been increasingly used as an additional platform to aid students' learning process in higher education. These tools are not meant to discard the traditional face-to-face classroom meetings, but to aid teachers to enhance students' understanding and performance (Calixto *et al*., 2004).

Universiti Teknologi MARA encourages its lecturers to adopt the blended learning approach in running their courses. The establishment of iLearn Centre, a centre managing the e-learning portal of the university has supported the drive by providing a platform for lecturers to upload teaching materials and communicate with their students. A mix of traditional instructor-led training coupled with synchronous online forums and asynchronous self-paced study would make a simple model of blended learning. The self paced asynchronous self-paced learning can be achieved in many ways. Self-paced learning implies solitary, on-demand learning at a pace that is managed or controlled by the learner (Singh, 2003). The most common form of self-paced e-learning approach comprises of organizing the course contents in a premeditated, structured, or formal learning program with organized content in specific sequence like chapters in a textbook (Singh, 2003). The main attraction of such an approach is in the flexibility it gives to the students as to when and where learning will take place. With blended learning, students can get the best out of both classroom learning and asynchronous learning (Starenko, 2008).

Reinforced concrete design is a core course in the Diploma of Civil Engineering program. In this course, students are taught the design of reinforced concrete members including beam, slab, column and pad footing. The teaching methodology for this course includes face-to-face classroom lectures, tutorials and e-learning. As this course involves long and tedious design calculations, limited number of examples can be demonstrated during lectures and tutorials. To overcome this problem, one of the solutions is to make use of the Internet and computer, and let students engage in additional problem solving outside classroom (Das, 2004).

Various web-based systems have been developed in higher education institutions to assist students in familiarizing with the subject content in civil engineering (Haque, 2001; Chou & Hsieh, 2002; Calixto *et al*., 2004; Haque & Aluminiumwalla, 2004). In the Sarawak branch campus of Universiti Teknologi MARA, a similar approach has been adopted to create a web-based reinforced concrete design system to supplement students' learning in the course of reinforced concrete design.

WEB-BASED REINFORCED CONCRETE DESIGN SYSTEM

An interactive web-based system, named WebCED has been created for the learning of reinforced concrete design. WebCED allows multiple users to run the program at the same time and it is created with the main objective for students' self-paced learning outside the classroom. The system is written using Active Server Pages (ASP) with Visual Basic Scripting Edition (VBScript). The code of practice for the design standards used is based on British Standards Codes of Design BS8110-1:1997 (BSI 1997) and BS8110:Part 2:1985 (BSI 1985).

WebCED comprises of four modules, namely reinforced concrete beam, slab, column and footing design modules. Each module comes with an introduction page and a design input page. The introduction page gives a brief explanation of governing formulae and rules from the code of practice, as well as the design procedure required for the reinforced concrete element concerned. The design input page is the page where users input the values of the design parameters for the system to carry out the corresponding design calculations. All the modules in WebCED are written to work in three stages: data input, analysis and output. In the data input stage, the system receives input from users and stores them in the memory. Subsequently, the system runs design analysis based on the formulae and rules in the code of practice, and stores the results in the memory. In the last stage, the system displays the results from the analysis on the screen as output.

The beam design module is able to carry out limit state design calculations of moment reinforcement, shear reinforcement, torsion reinforcement and deflection. The beam design introduction page for this module gives a brief explanation on the procedures involved in designing moment reinforcement, shear reinforcement, torsion reinforcement and performing deflection check. For each of the moment, shear and torsion reinforcement designs respectively, the system displays the full results of all the calculations involved, and gives suggestions of suitable reinforcements for the users to choose from. This allows users the freedom to choose the combination of reinforcements they want to adopt for the problem.

The slab design module is designed to carry out limit state design calculations of moment reinforcement, shear and deflection. Similar to the beam design module, this module has a slab design introduction page which gives a brief explanation on the procedures in designing moment reinforcement and checking for compliance in the shear and deflection requirements. This module also displays the full results of the design calculations offering its users with choices of suitable reinforcements to be used.

The column design module includes axially loaded rectangular and circular column design. Column coupled with moments is not included in this module as the design for that type of column involved a different procedure using design charts of BS 8110:Part3:1985 (BSI 1985). There is also a column design introduction page, which displays the procedure involved to find vertical reinforcements and links for an axially loaded column. A few choices of vertical reinforcements are suggested to be displayed alongside the full design calculations in the output page for the users to choose from.

The footing design module only covers axially pad footing, as this is the only type of footing required in the course syllabus. This module is designed to carry out calculations of moment reinforcements, vertical shear, punching shear and maximum shear checks. In the similar manner as the other modules, there is a pad footing design introduction page, which displays the procedures involved in finding moment reinforcements, and the system carries out checking to make sure that all requirements of vertical shear, punching shear and maximum shear are made accordingly.

All the modules will notify users whether the requirements listed in the code of practice are being fulfilled in the output page. If the system finds that there is any requirements in the code of practice which is not being fulfilled, the system will inform users about this and display a note 'Use a bigger section' at the output page. Otherwise, it will display a note 'Ok'.

Figure 1 shows the layout of beam design input page for beam design module. When all required data are entered in the form, the system will start to execute calculations involved in finding moment reinforcements and displays the results in the web page, as shown in Figure 2. When a user selects the preferred moment reinforcement from moment reinforcement output page, the system will use the selected moment reinforcement to calculate for shear reinforcements for the beam. The display of shear reinforcement output page is shown in Figure 3. When a user selects the preferred shear reinforcement, the system will proceed to execute calculations to check whether the deflection requirements are satisfied. The display of deflection output page is shown in Figure 4.

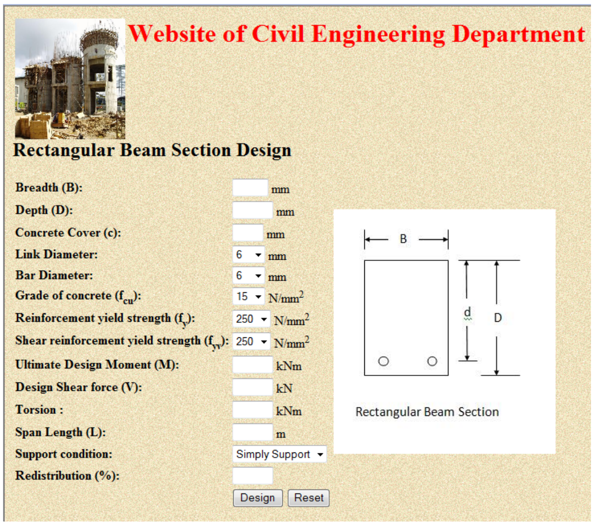
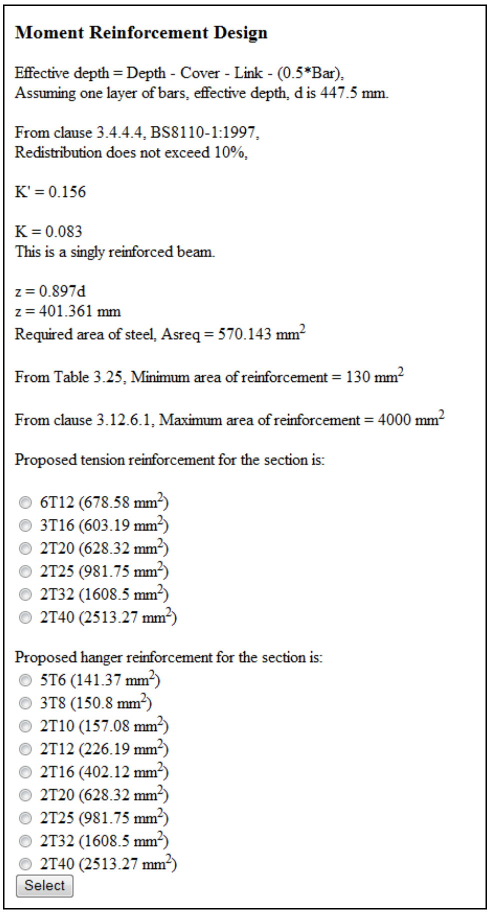


Figure 1. Input page for beam design module



Moment Reinforcement Design

Effective depth = Depth - Cover - Link - (0.5*Bar),
Assuming one layer of bars, effective depth, d is 447.5 mm.

From clause 3.4.4.4, BS8110-1:1997,
Redistribution does not exceed 10%,

K' = 0.156

K = 0.083
This is a singly reinforced beam.

z = 0.897d
z = 401.361 mm
Required area of steel, Asreq = 570.143 mm^2

From Table 3.25, Minimum area of reinforcement = 130 mm^2

From clause 3.12.6.1, Maximum area of reinforcement = 4000 mm^2

Proposed tension reinforcement for the section is:

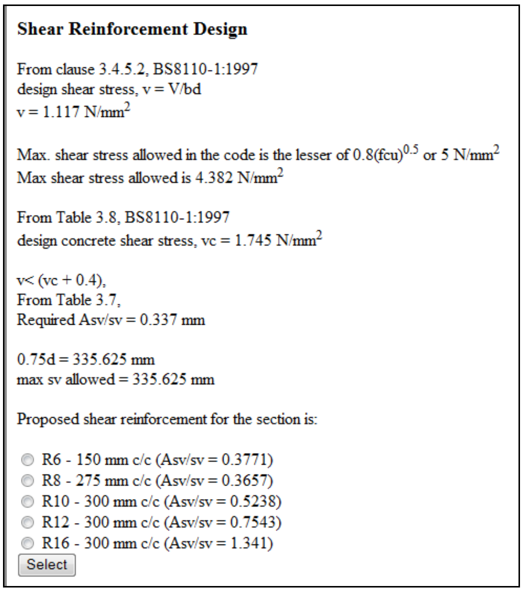
- 6T12 (678.58 mm^2)
- 3T16 (603.19 mm^2)
- 2T20 (628.32 mm^2)
- 2T25 (981.75 mm^2)
- 2T32 (1608.5 mm^2)
- 2T40 (2513.27 mm^2)

Proposed hanger reinforcement for the section is:

- 5T6 (141.37 mm^2)
- 3T8 (150.8 mm^2)
- 2T10 (157.08 mm^2)
- 2T12 (226.19 mm^2)
- 2T16 (402.12 mm^2)
- 2T20 (628.32 mm^2)
- 2T25 (981.75 mm^2)
- 2T32 (1608.5 mm^2)
- 2T40 (2513.27 mm^2)

Select

Figure 2. Display of moment reinforcement output page for beam design module



Shear Reinforcement Design

From clause 3.4.5.2, BS8110-1:1997
design shear stress, v = V/bd
v = 1.117 N/mm^2

Max. shear stress allowed in the code is the lesser of $0.8(fcu)^{0.5}$ or 5 N/mm^2
Max shear stress allowed is 4.382 N/mm^2

From Table 3.8, BS8110-1:1997
design concrete shear stress, vc = 1.745 N/mm^2

v< (vc + 0.4),
From Table 3.7,
Required Asv/sv = 0.337 mm

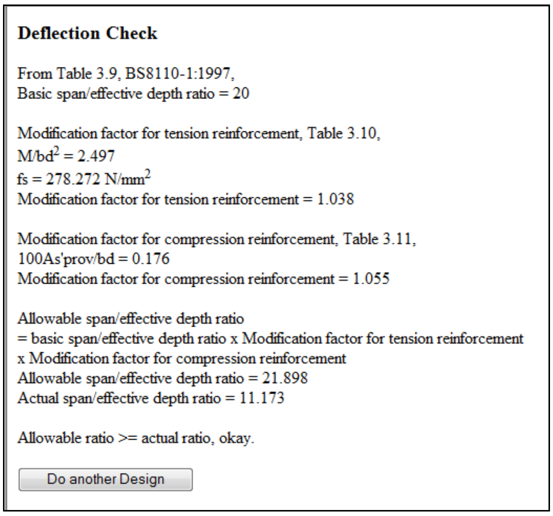
0.75d = 335.625 mm
max sv allowed = 335.625 mm

Proposed shear reinforcement for the section is:

- R6 - 150 mm c/c (Asv/sv = 0.3771)
- R8 - 275 mm c/c (Asv/sv = 0.3657)
- R10 - 300 mm c/c (Asv/sv = 0.5238)
- R12 - 300 mm c/c (Asv/sv = 0.7543)
- R16 - 300 mm c/c (Asv/sv = 1.341)

Select

Figure 3. Display of shear reinforcement output page for beam design module



Deflection Check

From Table 3.9, BS8110-1:1997,
Basic span/effective depth ratio = 20

Modification factor for tension reinforcement, Table 3.10,
M/bd^2 = 2.497
fs = 278.272 N/mm^2
Modification factor for tension reinforcement = 1.038

Modification factor for compression reinforcement, Table 3.11,
100As'prov/bd = 0.176
Modification factor for compression reinforcement = 1.055

Allowable span/effective depth ratio
= basic span/effective depth ratio x Modification factor for tension reinforcement
x Modification factor for compression reinforcement
Allowable span/effective depth ratio = 21.898
Actual span/effective depth ratio = 11.173

Allowable ratio >= actual ratio, okay.

Do another Design

Figure 4. Display of deflection output page for beam design module

PROBLEM AREAS IN LEARNING REINFORCED CONCRETE DESIGN

A questionnaire survey was conducted among the final semester students who have taken reinforced concrete design in the previous semester. The results show that the most common problem students faced in this course is the difficulty to remember all the steps involved in designing a reinforced concrete element. Most students (79.49% of the respondents) claimed that they had difficulty in remembering the steps required to carry out section design calculations of reinforced concrete elements. The second most common problem is that the students were not familiar with the code of practice, as they needed to refer to different sections of the code of practice in order to find the respective clause or formula that they needed to use in answering a question. In this survey, 30.77% of the respondents claimed that they had difficulty remembering the clauses that they needed to refer when they attempted practice questions on their own.

When the students were asked what they would do when they encounter problems in learning reinforced concrete design, the most common path they chose is to refer to their friends. The second most common solution is to refer to the lecturer, followed by referring to reference books. However, when the students were introduced to WebCED, they wished that they had been introduced to the system earlier as the online system is the probably the preferred alternative as they can use it to learn reinforced concrete design anytime and anywhere convenient to them. All the students expressed enthusiasm in using WebCED to check their design calculations that they need to perform in the final semester reinforced concrete design project.

STUDENTS' SATISFACTION SURVEY

A hands-on session was conducted in order to seek students' feedback on the usability of WebCED system. The participants were 39 students from the final semester of the Diploma in Civil Engineering program. During the session, students were asked to perform section design calculations for beam, slab, column and pad footing problems. They found that the system is easy to use and helps them to remember the long and tedious steps involved in solving the reinforced concrete problems. All the students recommended the use of the web-based system in the learning of reinforced concrete design.

A questionnaire was given at the end of the session. The questionnaire was adopted based on the learning satisfaction questionnaire of Wei *et al.* (2009) and Ling *et al.* (2009). A five-point likert scale was used ranging from "1 = strongly disagree" to "5 = strongly agree". Results from the analysis are shown in Tables 1, 2, 3 and 4. Table 1 shows students' satisfaction ratings on the user interface. Table 2 shows the students' satisfaction ratings on the content of WebCED system, while Table 3 shows the students' satisfaction ratings on enhancing students' learning. The students' satisfaction ratings on the overall performance of WebCED are given in Table 4.

When the students were asked what they like most about WebCED, most of them mentioned that the system is easy to use, and the display of design calculations at the output page is easy to understand. They find that the display of worked solutions generated by WebCED helps them to check their design calculations and give them a better understanding of the procedures of design.

Table 1.
Students' satisfaction ratings on the user interface

Item	Mean score	Standard deviation
WebCED is easy to use.	4.74	0.442
The WebCED system is stable.	4.49	0.556

Table 2.
Students' satisfaction ratings on the content of WebCED system

Item	Mean score	Standard deviation
WebCED has sufficient modules in reinforced concrete design.	4.36	0.5843
The results shown in WebCED are easy to understand.	4.39	0.7114
The introduction pages of each module give clear explanation of the rules and procedures of design.	4.33	0.7375

Table 3.
Students' satisfaction ratings on the enhancing students' learning

Item	Mean score	Standard deviation
WebCED is able to help me learn at my own pace.	4.31	0.6551
WebCED helps me learn and remember the design procedures.	4.41	0.5946
I can use WebCED to check the answers of my design calculations.	4.72	0.4559
WebCED helps me identify my problem areas in reinforced concrete design.	4.31	0.6551
WebCED can help me in learning reinforced concrete design.	4.54	0.5547
I can have more fun learning reinforced concrete design by using WebCED.	4.56	0.5024

Table 4.
Students' satisfaction ratings on the overall performance of WebCED

Item	Mean score	Standard deviation
I feel that WebCED can help me in learning reinforced concrete design.	4.641	0.5374
I am keen to use WebCED to design reinforced concrete elements.	4.513	0.6437
I recommend the use of WebCED in the learning of reinforced concrete design.	4.692	0.4676

INTEGRATING WEB-BASED SYSTEM IN CLASSROOM TEACHING

The traditional teaching method is normally conducted in a way where lecturers spend most of the classroom time explaining and writing long solutions on the board, while students rush to copy the solutions onto their notepads. Limited lecture hours limit the number of examples that can be discussed in the classroom. This kind of teaching can discourage critical thinking among students, as they are too busy copying the solutions, rather than understanding the solutions on the board (Al-ansari & Senouci, 1999). Therefore, efforts are taken to incorporate WebCED in the teaching methodology of reinforced concrete design, in order to enhance the learning of the subject.

Lecturers can use WebCED during lecture to solve design problems and display the generated solutions to the students using projectors. As the solutions are generated right away, there will be considerable time saving, thus enabling more examples to be shown. During tutorial sessions, lecturers can use the system to demonstrate the effects of changing various parameters or intermediate variables. Although students are also taught how to use the system, they are still required to solve problems manually during tests and examinations. WebCED should be used solely in the learning process by the students to provide immediate feedback and verifications to their design calculations. WebCED also makes it possible for lecturers to set individualised questions for assignments and tests as the respective solutions can be generated within seconds. This would help curb students plagiarising homework and assignments.

For students in their final semester taking reinforced concrete design project of a building, they have to carry out design for all the structural members in the whole building. They often spend many hours doing it and yet are still unsure whether their design calculations are correct before proceeding to the subsequent structural members. In this situation, WebCED can be used to verify their design at each stage to prevent sequential errors from building up.

With the help of WebCED, students will be able to identify where they go wrong and the immediate feedback from the system will help to improve students' ability to retain knowledge significantly (Howard, *et al.*, 2006). The development of self-learning skills will enable students a better control over the learning process and the assurance from WebCED will rid the students of the apprehension which very often arise when they do not get immediate feedback.

CONCLUSION AND RECOMMENDATION

WebCED is a web-based system that can be used to enhance students' learning in reinforced concrete design. It can be used by lecturers to supplement classroom teaching and by students as an additional tool in learning the subject. Formal investigation has yet to be carried out to assess WebCED on its effectiveness on helping students in learning reinforced concrete design. However, students who have already learned the subject the traditional synchronous way found the system very helpful in providing immediate feedback in problem areas.

As the new era of teaching and learning is moving away from pencil and paper, integrating asynchronous web-based tools into the learning process would help sustain the interest of students in subjects which involve tedious calculations in contents. Interactive web-based systems have opened up a new platform for teaching and learning. Further studies are planned to evaluate the effectiveness of using web-based system in enhancing the teaching-learning process in reinforced concrete design.

REFERENCES

Al-ansari, M.S. & Senouci, A.B. (1999). MATHCAD: Teaching and Learning Tool for Reinforced Concrete Design. *International Journal of Engineering Education*, 15(1), 64-71.
BSI (1985). *BS8110:Part 2:1985, Structural Use of Concrete, Part 2: Code of Practice for Special Circumstance*, London: British Standards Institution.
BSI (1985). *BS8110:Part3:1985, Structural Use of Concrete, Part 3: Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns.* London: British Standards Institution.

BSI (1997). *BS8110-1:1997, Structural Use of Concrete, Part 1: Code of Practice for Design and Construction*, 2nd Ed. London: British Standards Institution.

Calixto, J.M., Almeida, G.N., Maia, E.V. & Rodrigues, F. (2004). A Web Oriented Reinforced Concrete Design Course. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition.*

Chou, Y.H. & Hsieh, S.H. (2002). AWRC: A Web-Based Reinforced Concrete Design Adaptive Testing System. *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*, Montreal, Canada.

Das, N.K. (2004). A Computer- Based Problem-Solving Courseware for Reinforced Concrete Design. *Proceedings of 34th ASEE/IEEE Frontiers in Education Conference.*

Haque, M.E. (2001a). Web-based Visualization Techniques for Structural Design Education. *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*.

Haque, M.E. & Aluminiumwalla, M. (2004). A Virtual Tour of a Reinforced Concrete Building Construction. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*.

Howard, L., Remenyi, Z. & Pap, G. (2006) Adaptive Blended Learning Environments. *Proceedings of the 9th International Conference on Engineering Education*, San Juan, Puerto Rico.

Ling, S.E, Lee, E.A.L., Goh, K.T.H. & Lee, B.Y. (2009). Teaching Mathematics Using Blended Learning Model: A Case Study in UiTM Sarawak Campus. *Proceedings of Conference On Scientific & Social Research 08'09*.

Singh, H. (2003). Building Effective Blended Learning Programs. *Journal of Educational Technology, 43* (6), 51-54

Starenko, M., (2008). *Reflections on Blended Learning: Rethinking the Classroom*, Rochester, NY. 1-5

Wei, C.K., Chen, N.S., Kinshuk & Hsu, F.H. (2009). Effects of Goal Setting Strategy on Web-Based Learning Performance. *International Journal on Digital Learning Technology*, 1(3), 140-161.