Computer aided learning (CAL) and computer aided assessment (CAA) in civil engineering

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Abstract

Commercial CAL packages have been introduced to supplement traditional lecture material and encourage Civil Engineering students to take more responsibility for their own learning. Initial experiences were disappointing but when CAL was supported by formative and summative CAA, students engaged with CAL material and examination performance was significantly improved. Development of CAA is ongoing, with implementation of new European design codes.

Keywords: computer-aided, learning, assessment, concrete, design.

Introduction

Teaching of design of reinforced concrete structures has traditionally been a topic which many students fail to engage with effectively. The subject matter is very practical but students often do not cope well with visualisation of the real implications of their calculations, the requirement for practical detail and the necessity of designing in compliance with an engineering Code of Practice. In their second year of study, civil engineering students are taught the design principles of common structural reinforced concrete elements, such as beams, slabs, bases and columns. Assessment is by coursework (20%) and examination (80%). Marks for coursework are usually acceptable, yet examination results are often poor, Figure 1. This shows a wide range of marks for students attempting a question on simple bending design. 50% of the students avoided doing this question altogether. It was deduced that a significant number of students were either copying coursework or colluding with other students. Discussions with colleagues at other UK institutions suggest that this is a common problem and not unique to Liverpool. Much of the learning, as a result, appears to be 'replicative' rather than 'transformative'. To tackle these teaching and learning difficulties, it was decided that the introduction of computer teaching software could be helpful.

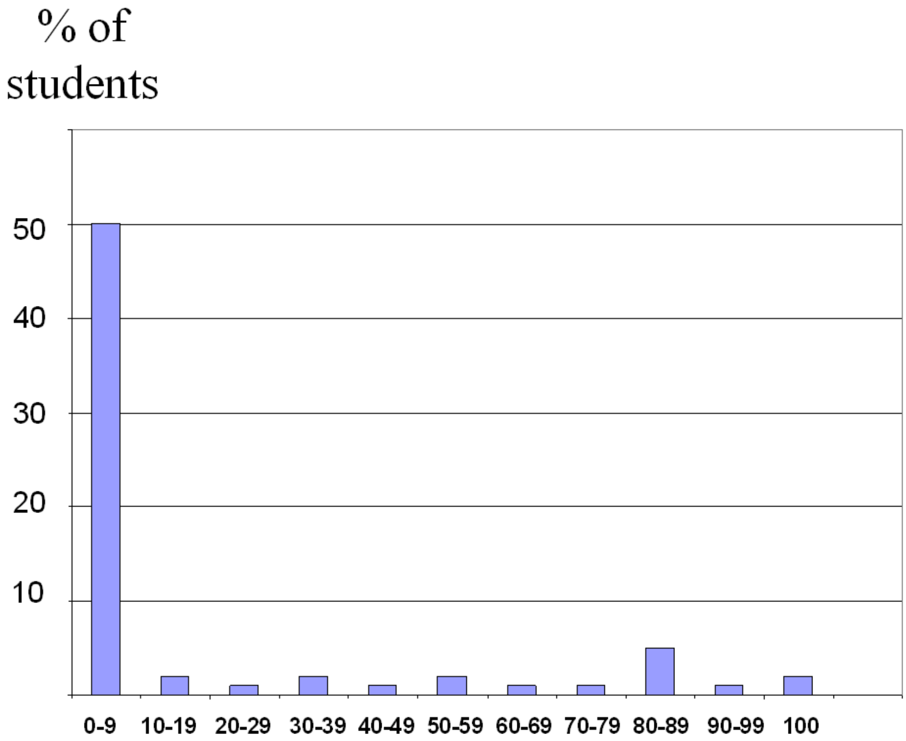

Figure 1. Examination performance on simple bending design, pre-CAL/CAA

Computer-Aided Learning

The introduction of commercially available Computer-Aided Learning (CAL) packages to augment the conventional teaching of reinforced concrete structural design was initiated in the year 2000 at the University of Liverpool. Over the past few years the UK has been in a transition from using British Standards for structural concrete design, i.e. BS 8110, to the adoption of new Eurocodes, i.e. EC 2. Although based on the same principles of limit state design, Eurocodes provide a harmonised standard right across Europe that remove national barriers caused by each country insisting on the use their own national standard.
Initially there were two separate CAL packages are available to support the teaching of reinforced concrete design:

- **RC-CAL** [1] (BS 8110: 1987 *Structural use of concrete*)
- **COMPACT** [2] (Eurocode 2)

RC-CAL was first adopted as the more suitable software to support teaching which at that time was in line with BS 8110. However a third CAL package then became available:

- **CALcrete** [3] (BS 8110 and Eurocode 2),

which provided the flexibility of working with either design Code of Practice. In subsequent years CALcrete was the CAL software used to augment all concrete design teaching.

Between 2000-2006 the teaching of structural concrete has been broadly in accordance with BS 8110 but with increasing reference to the new Eurocodes which were soon due to be launched. In 2007 the Department made the decision to embrace the full suite of Eurocodes for both steel design and structural concrete design. Next year the Eurocodes will also be used for the teaching of design in structural masonry and in timber.

Why CAL?

From a student perspective, CAL provides:

- An alternative perspective to lectures
- Student-Paced learning
- Additional material not covered in lectures
- Simple feedback tests
- Photographs and animations
- A sense of fun, often absent from formal lectures.

The modules available within CALcrete are shown in Figure 2. Once the student has entered a module, a list of available topics is given (see Figure 3). From the lecturer's viewpoint, CAL can release time in lectures to focus on specific aspects, in the knowledge that material not covered in detail on other topics is readily available to students.

Initial Problems

Once the first CAL package was made available to students, it became apparent that the more receptive students were making some limited access to CAL in their spare time, but the majority of students did not. However, no record was made to establish whether students were making use of the system.

A more direct approach was required to:

- Encourage students to use CAL
- Establish that the material on the system was being accessed
- Verify that the material was understood and could be applied.

It was also necessary to:

- Reduce the level of collusion and copying of course work
- Improve the examination results at the end of the course.

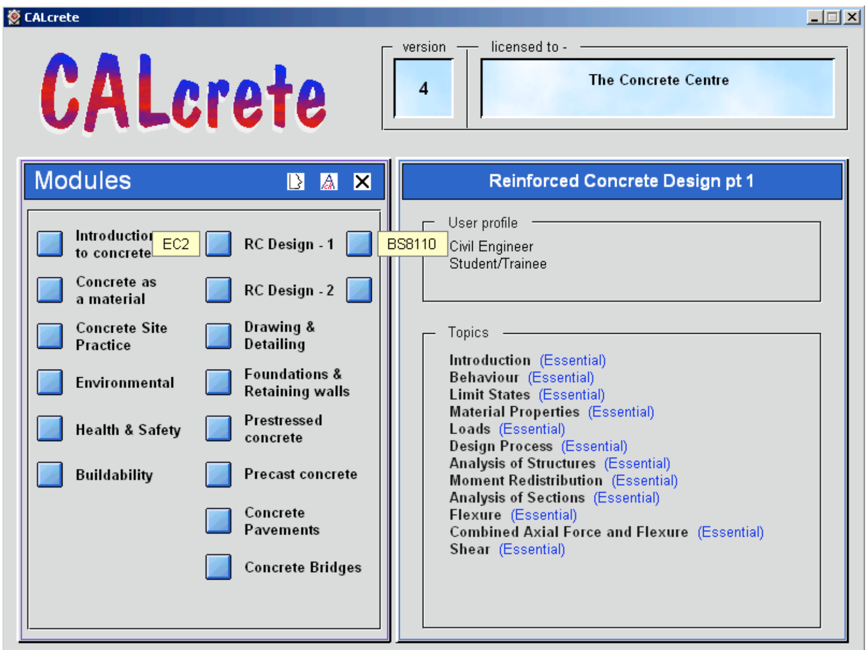

Figure 2: Modules available in CALcrete.

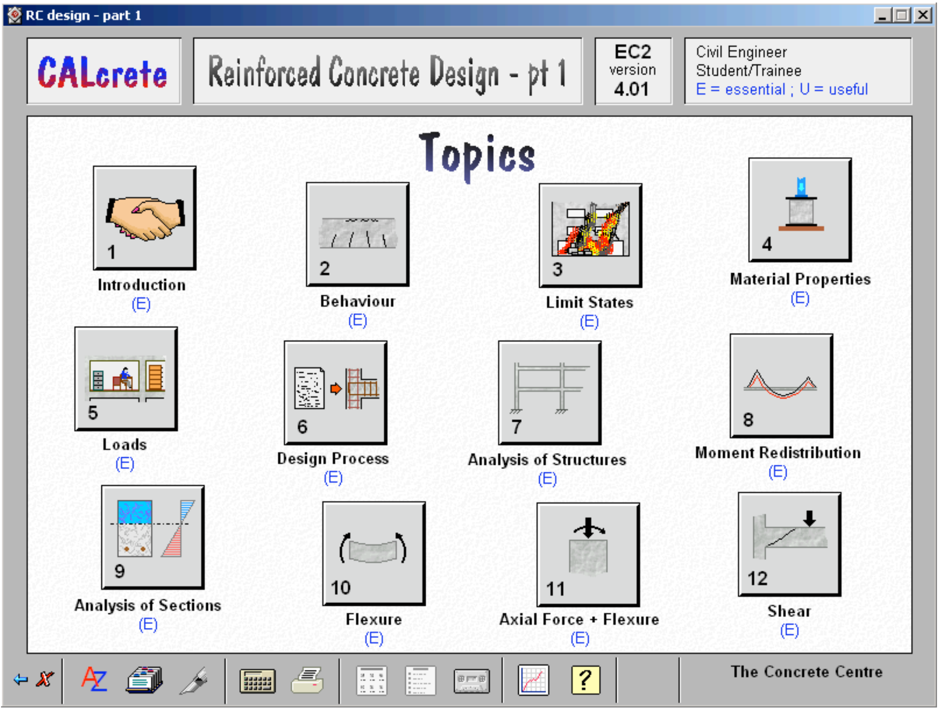

Figure 3: Topics available within a module.

Use of Computer-Aided Assessment

To address some of the above issues a decision was made to link the student use of CALcrete to an automated Computer-Aided Assessment (CAA) package which could provide both the student and the lecturer with feedback on access and learning of material presented in CALcrete. A proprietary package TRIADS was introduced. In the UK there are two principal CAA packages, 'TRIADS' and 'Questionmark Perception' who are the market leaders and could be suitable for the feedback required. Questionmark Perception (4) is a sophisticated commercial package that enables the lecturer to set a series of questions using multiple-choice solutions, "hot-spot" selection, priority ranking and other responses. While it is both well supported and easy to use, it required the solution to every question to be input by the lecturer in setting up the test. While this was seen to be quite suitable for assessing the access and retention of information from the students using CALcrete, it did not provide the flexibility of a programmed solution which was required for later CAA tests

TRIADS (5) offered a number of significant advantages over Questionmark Perception, as numerical questions can be set using randomised variables. Each time a question is set, it incorporates different numbers. The response is then compared with a solution calculated by TRIADS using the randomised values selected. There is no need for the lecturer to calculate the solution to every possible question before the test is set. TRIADS has been developed by a consortium of three UK universities (Liverpool, Derby and the Open University) and was initially available at no cost to other contributing partners. It has now been further developed and sold as a commercial product. While having a much steeper learning curve for the lecturer to gain familiarity and effective usage, it provides a high degree of flexibility in the way probing questions may be set. Once set up, running the assessment and marking the results using either software packages is fully automated.

Using TRIADS with CALcrete

CAA was initially used to encourage all students to access the package by testing the replication of information displayed in CALcrete. Figure 4 shows a multiple choice question that asks for a dialect repeat of information found in CALcrete (see Figure 5). Each question has three different versions, randomly selected so that no student receives exactly the same test. Immediately after inputting a response the student is given feedback regarding the correct answer, before moving onto the next question.

There were two tests set on different sections of CALcrete, coinciding with coverage of material in the lectures. The objective of setting these two tests was to stimulate exposure to CALcrete, in the hope that students might be encouraged to use it to expand their learning. The CAA test was also simultaneously used to present a questionnaire to all students to determine their views on both CAL and CAA.

The results of these two tests appeared to be generally successful:

- Students said they enjoyed using CALcrete
- CAA encouraged students to explore the CAL package
- All students accessed CALcrete.

However it was understood that each test was not probing the students' retention or understanding of the subject material, nor was the ability to use this material in subsequent reinforced concrete design being tested. It was also clear that some students were more motivated by collecting marks rather than knowledge. They simply repeated the test enough times, there was no limit set, and guessed their way to a high mark. Using the feedback from TRIADS, it is easy to detect these strategies. For example, one student had initially taken three genuine attempts to complete the test, achieving a score of 80%. The remainder of the attempts had been undertaken so quickly that a guessing strategy must have been used to score the final 20%. One student accessed a test 27 times in order to find out the correct reply to each question and gain full marks. Nevertheless, these students were allowed the 100% score.

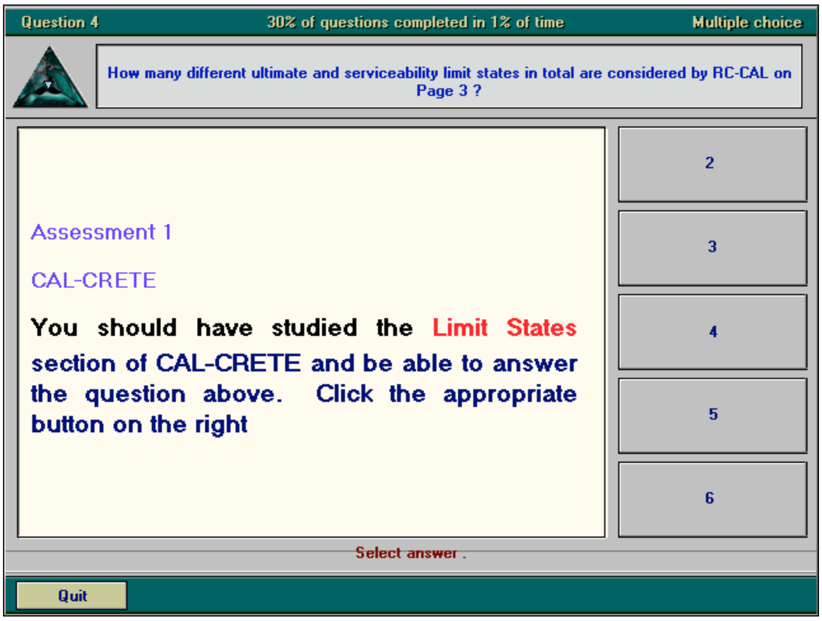

Figure 4: Using TRIADS multiple-choice questions.

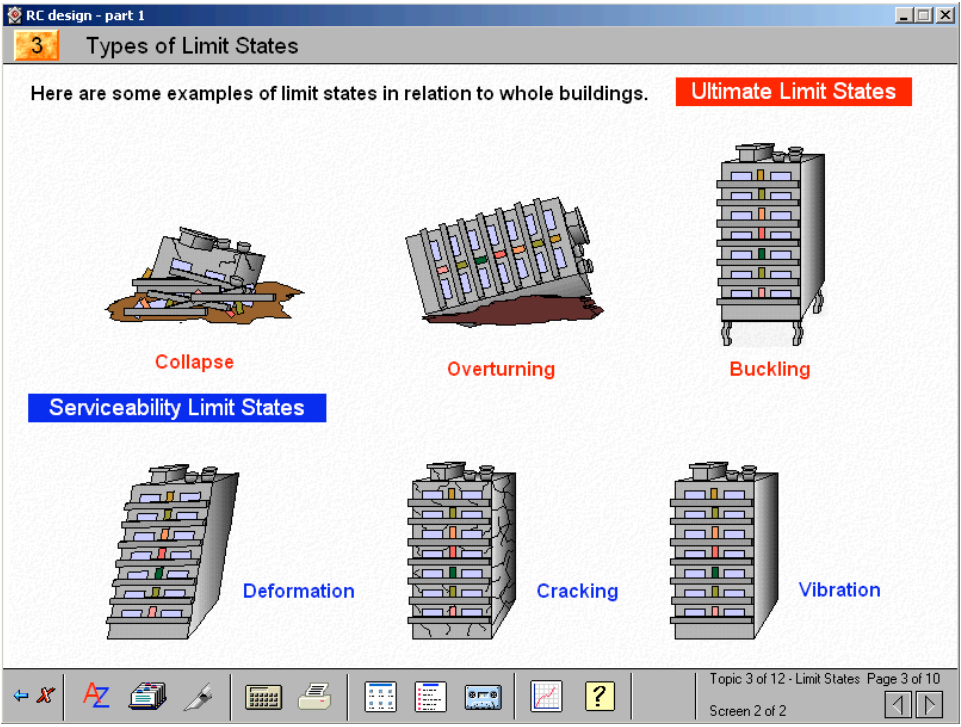

Figure 5: The CALcrete page used for the question in Figure 4.

Testing understanding

Following the two CALcrete tests, TRIADS was then used to assess the students' analytical and design problem-solving abilities. Two further tests were developed to probe understanding of bending and shear of a reinforced concrete beam to BS 8110. For example, a test relating to the bending moment capacity of a rectangular RC beam with randomised variables was used (circled in Figure 5). The problem was separated into small parts and immediate feedback of errors was again provided. Students have to calculate the solution to a different question if they restart the test. The results appear to be successful and students learned to solve the problem over a (sometimes large) number of attempts. The average mark for the class was exceptionally high, typically about 90%. The randomisation of each test removed the likelihood of copying from another student. Some students chose to solve the test in groups, and this was considered quite acceptable as the test is considered more formative (i.e. a learning experience) than summative (i.e. an examination).

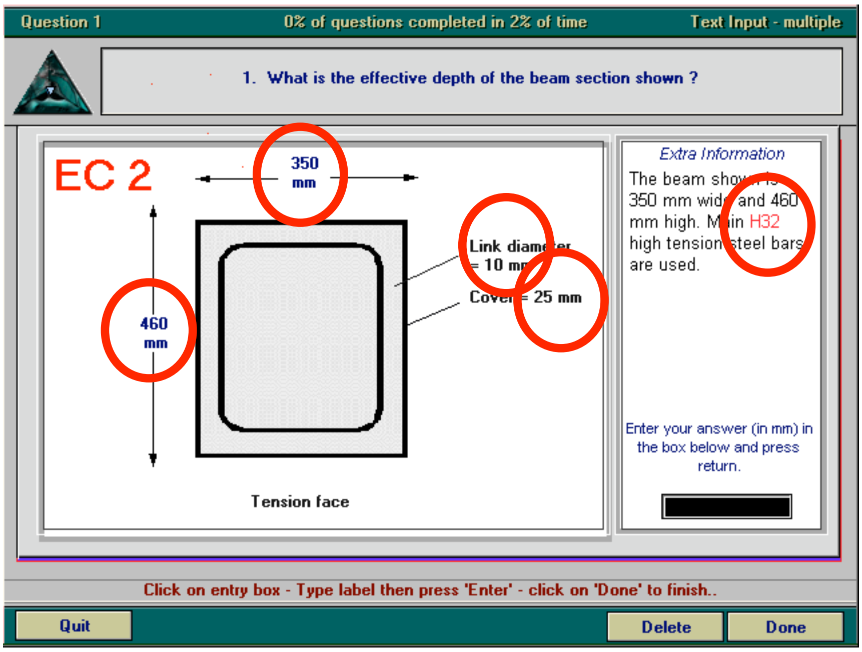

Figure 6: TRIADS beam question.

Did it work ?

In the first year of implementation, despite the efforts in setting up the CAL/CAA systems, when presented with a similar question under examination conditions, most students either avoided it or scored very badly. This caused the lecturer son consolation. Either the students had a very short-term memory or they were comfortable going through a design question when given guidance step-by-step and given feedback at each stage of the correctness of their answer. However when presented with the whole question and a blank sheet of paper. However when presented with the whole question and a blank sheet of paper most simply gave up. The following year, the test was modified so students could achieve 50% by solving each part of the bending moment question but were then required to solve the whole question without interim feedback to gain the other half. The mean score dropped from 92% to 83% with a larger spread of marks. It should be noted that any mark between 0 and 39% was automatically rejected. Students were not allowed to marginally fail (<40%). Because each student is allowed to carry out the test as often as they like and are given direct supported feedback, failure is not accepted. A failing market is reset to zero and the student is asked to try again.

The modified TRIADS test proved more difficult for the students, but their performance was nevertheless still very successful. However, subsequent examination performance on the bending moment question was a considerable improvement on the previous year, Figure 7. The large numbers of students in the 0–9% band were principally those who chose not to answer this question rather than those who tried it and failed.

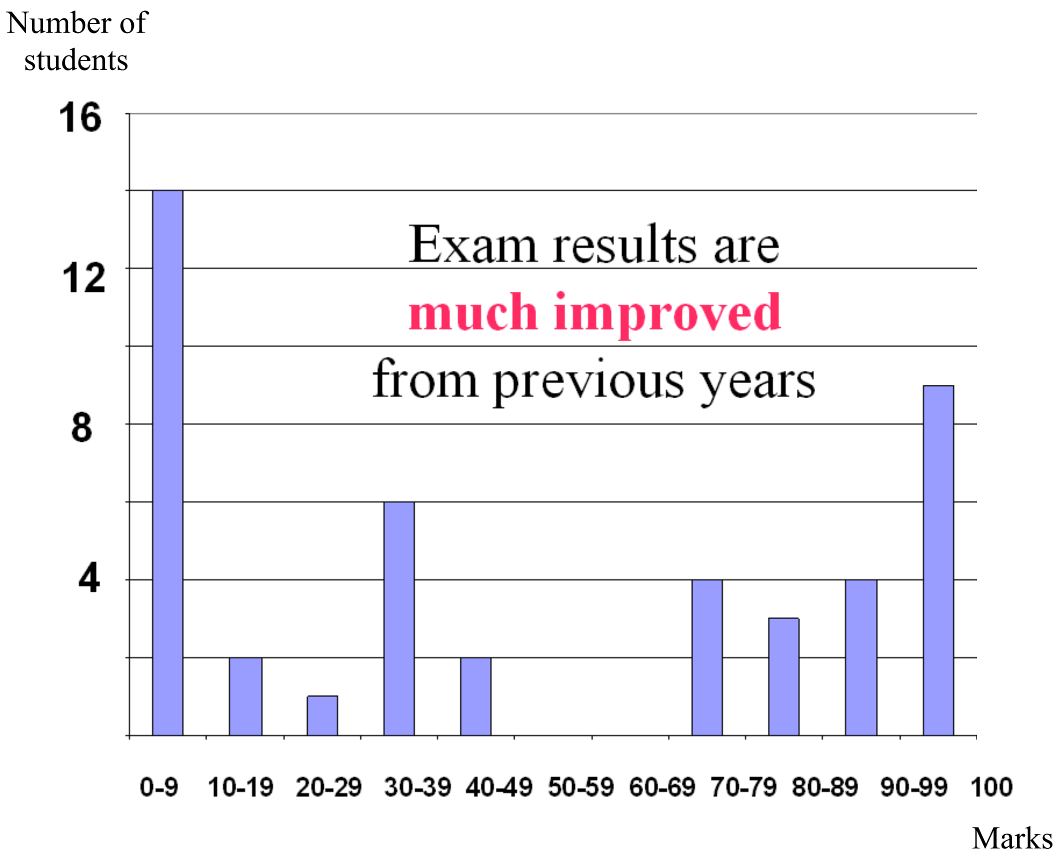

Figure 7. Examination performance on simple bending design, post-CAL/CAA

With the adoption of Eurocode 2 as the design Code of Practice in 2007, the tests have been revised and updated. The presentation and format of Eurocodes is quite different to the national British Standards and has provided some challenges in teaching delivery and assessment. This has been compounded by the lack of availability of a suitable student textbook which has led to a much greater student dependence on CALcrete as a source for information. Notwithstanding these changes the level of student performance in the CAA tests has remained high.

Typically a student would log on and look at the test for the first time but not make a serious attempt at answering questions, resulting in a score of say 5-15%. Two to four further attempts would then be made at the test, with an increasing score which levelled out at a maximum of say 75%. In 2007 an overall average for the two tests were 63% (bending test) and 71% (shear test).

Conclusions

Although there were a few pitfalls, the combination of CAL and CAA has proven to be an effective learning resource for students. Examination performances were greatly improved and the opportunity for cheating/copying of coursework has been minimised. The CALcrete CAL package and TRIADS CAA system has also proved very popular with students. Feedback questionnaires have been very positive. The CAL/CAA approach has been further developed to incorporate structural design in timber. An in-house Timber-CAL package has been developed by the students themselves through a series of final year projects. A series of TRIADS CAA timber tests has also been developed by an MSc student and is now used to develop the learning of final year undergraduate students. It is planned that both Timber-CAL and the TRIADS timber tests will be updated to be compatible with the Eurocode 5 Code of Practice for timber which will be incorporated into undergraduate teaching in 2008.

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