An Alternate Learning Approach for Destructive Testing in Civil Engineering

Benefits from Remote Laboratory Experimentation

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Abstract: An alternative learning approach for destructive testing of structural specimens in civil engineering is explored by using a remote laboratory experimentation method. The remote laboratory approach focuses on overcoming the constraints in the hands-on experimentation without compromising the understanding of the students on the concepts and mechanics of reinforced concrete structures. The goal of this study is to evaluate whether or not the remote laboratory experimentation approach can become a standard in civil engineering teaching. The teaching activity using remote-laboratory experimentation is presented here and the outcomes of this activity are outlined. The experience and feedback gathered from this study are used to improve the remote-laboratory experimentation approach in future years to other aspects of civil engineering where destructive testing is essential.

1 INTRODUCTION

Civil engineering is a practical discipline which applies scientific and mathematical principles in a socially responsible manner to design, construct, and operate infrastructures and building systems. The overall goal of the civil engineering education is to prepare students for the profession to get solutions for the practical problems. To do this successfully, civil engineers must have the knowledge that is traditionally gained in the educational laboratories (Feisel and Rosa, 2005).

Laboratory based courses play a critical role in engineering education. Nersessian (1991) claims that "hands-on experience is at the heart of science learning" and Clough (2002) declares that laboratory experiences "make science come alive". Lab courses have a strong impact on students' learning outcomes, according to Magin et al., (1986). Instructional laboratories have been implemented for engineering education from the early days. The traditional one is known as hands-on laboratory with real instruments. Feisel and Rosa (2005) summarised the fundamental objectives of the engineering teaching laboratories, which can be used as a guide for engineering educators to develop and improve the effectiveness of laboratory learning experiences. There are three types of educational laboratories in engineering education (Ma and Nickerson, 2006). These include hands-on laboratory, simulated or virtual laboratory, and remote or distributed learning laboratory (Krivickas and Krivickas, 2007).

Remote/ virtual laboratories are currently being developed and used in many places around the world in areas that do not require destructive testing. There have been debates over the introduction of remote/ virtual versus hands-on laboratories in engineering education. Hands-on laboratory allows students to directly see, hear, touch, and feel the devices and the experimental specimens. Whilst in the virtual laboratory students learn engineering principles through simulation running on computers without any real element of equipment or specimens. In the remote laboratory, students interact with the real devices/ equipment/ specimens remotely through a computer user interface. Therefore, the remote laboratories are called as the "Second Best of Being There" by Aktan (1996). However, with the rapid advancement in technologies, even hands-on laboratory utilises more and more computers and technical devices and controllers which blurs the

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hands-on and the remote laboratory learning experiences.

There is still a shortage of data on whether new technologies such as remote laboratory experimentation are as effective as hands-on laboratory when it comes to teaching design skills involving destructive testing of materials/ structural members. The effectiveness of the remote-laboratory compared with traditional hands-on laboratory practice is seldom explored. Therefore, this paper will discuss the effectiveness of the remote laboratory experimentation for civil engineering undergraduates through an analysis of the students' feedback based on a remote-laboratory project. The main target is to promote an effective use of alternative learning approach for undergraduate learning civil engineering.

2 REMOTE LABORATORY EXPERIMENTATION

An year 2 undergraduate subject, ENB 276 Structural Engineering-I, that aims at introducing the analysis of simple statically indeterminate structures, pattern loadings in structural design and the behaviour and design of reinforced concrete beams, slabs, and columns is used for the introduction of remote lab testing. Laboratory practice is an important element for this unit. Historically hands-on laboratory practices were implemented for students to design and construct reinforced concrete beams and test them to failure within the on-campus laboratory. In those days, the student number was around 90. With the relocation of the on-campus laboratory to a new campus in a remote suburb, the hands-on laboratory practices become less efficient for a cohort with a large number of students (398 enrolments). In order to enable the students to experience what they would do for the hands-on experiment in the laboratory, a remote laboratory project was developed as explained in this paper.

2.1 Background

The idea was that the students design their own beams in a team of 4-5 members of their choice. The criteria (capacity of the testing machine and space allowance) of the design were explicitly stated in the design brief. Basically, one beam was designed for bending failure and the other for shear failure. Two beams among all the designed beams were then selected as the test specimens for the remote laboratory experimentation.

The reinforced concrete beams were prepared by tutors and technicians. The whole preparation process from formwork preparation, steel bar bending, placement and positioning, concrete materials proportioning, mixing, and lastly the casting of concrete beams were all video recorded and played in the lecture theatre before the remote laboratory testing. At the time of testing, the students sitting inside the lecture room could remotely control the testing machine through an internet protocol (IP) and observe the whole testing procedure through the live streaming of an IP camera, while technicians in the laboratory are supervising the whole testing process in case of hazard events happening and having real-time communication with the students remotely through another camera. The detailed test setup is narrated in the following section.

At the end of the semester, after the final examination and declaration of result, the students were surveyed on different aspects of the influence of the remote laboratory experimentation on their learning experience and outcomes through a voluntary online questionnaire system. The feedbacks based on a respondent number of 53 (out of 398, or 13.3%) are used in the analysis of the effectiveness in the learning experience and learning outcomes by using remote laboratory experimentation in civil engineering education. The low response rate is typical at Queensland University of Technology as the students are surveyed (response is voluntary) for each subject in each semester by a university wide system known as "Reframe". Further the questionnaire from this unit was personally carried out using blackboard system.

2.2 Remote Laboratory Setup

The overall remote laboratory setup is presented in Figure 1 schematically. The students sitting inside the lecture room remotely operated the controller of the actuator that applied loading on the test specimen in the laboratory. The remotely controled panel image was projected onto Projector 1 in the lecture theatre. Meanwhile, performed testing was captured by an IP camera, the live streaming images were used to feedback to the lecture theatre (PC3), and projected onto Projector 2. In addition, the mutual communication was established in parallel between the students in the lecture theatre and the staffs in the laboratory through the use of Skype for cost-effectiveness. This is to make sure the information from both sides can be instantly exchanged and the whole process can be conducted

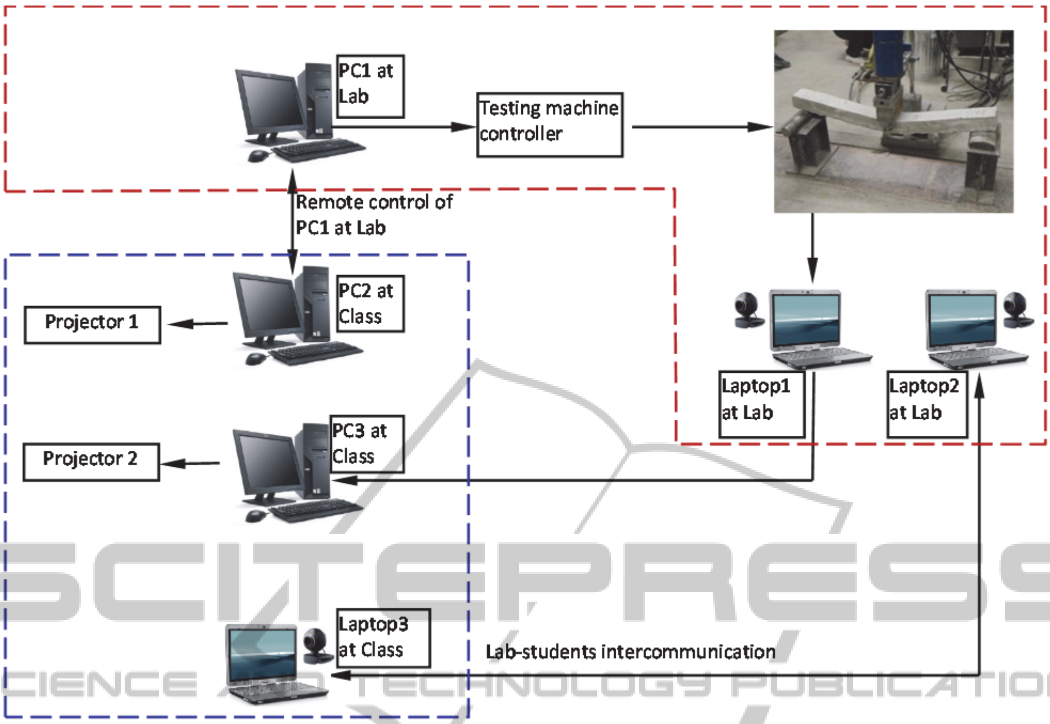

Figure 1: Schematic setup of the remote laboratory experimentation.

seamlessly and safely.

The lecture theatre was quite full on the day of remote testing with approximately 90% attendance and keen participation; in contrast during theory lectures attendance varied between just 60% - 75%.

2.3 The Benefits of Remote Laboratory

2.3.1 The Effectiveness of Video Casting in Learning Outcomes

The first part of the remote laboratory project involved the learning experience using webcast video. The video directly presents proportioning of materials for concrete, mixing and construction of beams. The benefits of the project in mix proportioning and mixing concrete by using the webcast video is shown in Table 1.

Table 1: The benefits of remote laboratory in mix proportioning and mixing concrete.

Benefits	Response
I know how to do mix proportioning	13%
I know how to mix concrete	4%
I know both	79%
None	4%

In the result, not surprisingly, the students benefitted a lot from the webcast video in extending their understanding of the mix proportioning and mixing of concrete. 79% of students responded that they have now known both mix proportioning and the mixing process of concrete. While 13% of them only knew how to do the mix proportioning and 4% of them only knew the mix procedure of concrete mixing. Although 4% of the students still admitted that they knew nothing about the mix proportioning and mix procedure of concrete, the benefits of the video cast are imminent for improvement of student learning outcomes.

2.3.2 The Outcomes of Remote Laboratory Learning

The benefits of designing reinforced concrete members as part of the remote laboratory experimentation for the students are summarised in Table 2 based on the feedback. It should be reminded that the remote laboratory only involved the design and testing of reinforced concrete beams. In the feedback, 88% of the students admitted that they have benefited from this project in designing the reinforced concrete beams in comparison to other reinforced concrete members (such as slabs) columns and slabs which were not covered in the remote laboratory project. This could therefore be inferred that the remote project greatly and directly has strengthend students' understanding and impression of designing concrete beams. As other structural elements have not been tested, students found the behaviour of those elements more challenging. The results could be improved if the students not only design their specimen but also make the specimens by themselves, unfortunately it was difficult to involve students in preparing specimens due to time and space constraints. Negative data from 4% of them came with explicit statement of them not getting benefits in either designing or testing of any of the reinforced concrete members, namely, beams, slabs, or even columns as presented in Table 2.

Table 2: The benefits in designing reinforced concrete members.

Benefits	Response
Beams	88%
Slabs	6%
Columns	2%
None	4%

The two reinforced concrete beams with different reinforcement arrangement providing two different failure modes – bending and shear - were purposely planned to help students understand the differences between these two failure modes of reinforced concrete beams. 87% of the students strongly agreed that they have clearly understood these two different failure modes. About 12% students got some benefits in understanding of the failure modes of the reinforced concrete beams. While only 2% thought that they did not get any benefits regarding the failure modes of the reinforced concrete beams from the remote laboratory experimentation. As shear failure is more brittle, it is good to know a high majority of students could differentiate the two (flexure and shear) failure modes.

Table 3: The benefits in clearly understanding the different failure modes of the reinforced concrete beams.

Benefits	Response
Yes, absolutely.	87%
A bit	12%
Not at all	2%

2.3.3 The Benefits of Remote Laboratory in Comparison to Hands-on Experiment

Regarding to the general benefits from the remote laboratory experimentation to the students learning experiences, they gave different opinions. About 65% of the students agreed that the remote laboratory experimentation improved the learning outcomes of the engineering study. 50% of them thought that the remote laboratory experimentation will benefit them in implementing new technologies into their study and work. 44% of the students believed that this project benefited them in working as a team. About a quarter of them (29%) believed that this remote laboratory experimentation project improved their skills in organising reports. The results are shown in Table 4.

Table 4: The benefits of remote laboratory experimentation for engineering education.

Benefits	Response
Working as a team	44%
Organizing reports	29%
Implementing new technology into study and work	50%
Improving learning outcomes of engineering study	65%

3 CONCLUSIONS

The remote laboratory experimentation has not been often utilised for education in civil engineering design units involving destructive testing of material and structural specimens. Although the most desirable option is “hands-on” experimentation, with relocation of heavy structural labs away from city campus into suburbs and with very large cohorts, it becomes not possible to offer the hands-on approach; therefore, remote-lab is the most feasible option. There is no evidence of utilising this approach for experiments involving destruction of material and structural specimens. The information provided in the paper can therefore be considered as first of its kind for destructive testing of RC beams.

A case study for teaching structural engineering (Reinforced concrete design) that involved both video casting and remote laboratory experimentations is presented. The remote laboratory experimentation involved team-based design of reinforced concrete beams subjected to different failure modes, construction of the beams, and testing by using the remote-laboratory setup. The feedback on the understanding and the learning experience and learning outcomes are also presented. This feedback allowed to assess how well students benefitted and made use of the project, the video casting, and the remote laboratory experimentation.

It is concluded that the remote laboratory experimentation is an effective method for teaching and learning of subjects involving reinforced concrete design, where destruction of concrete cylinders and reinforced concrete beams are unavoidable. It creates an alternative learning approach for the students by implementing new technologies. The use of webcast video and remote laboratory experimentation allows comprehensive learning of the structural engineering basics, construction of reinforced concrete beams and understanding of the failure modes (bending or shear). The effectiveness of the remote laboratory experimentation was confirmed by the students' positive feedback from the case study described in this paper.

In addition, the students' feedback will help us to shape the future teaching to further improve the teaching and learning experience of civil engineering education.

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