# Creation of a construction practice laboratory

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***Abstract****: A Construction Practice Laboratory was set up to give students a better understanding of some of the processes carried out on a construction site. These processes involve construction of a scaffold, assembly of formwork for a concrete slab, and demonstration of a climbing safety screen. In addition to knowledge of the physical aspects of these processes the students also gain insight into other aspects, such as teamwork and OHS. The Construction Practice Laboratory is unique. Students do not just plan the activities, but actually carry them out using full size industrial equipment*

## Introduction

This paper describes the creation and use of a construction practice laboratory. The laboratory has equipment for two exercises: assembling a section of slab formwork and assembling a section of scaffolding for a stairwell. It currently has one additional display: a climbing safety screen.

Most of the Civil Engineering curriculum focuses on the design of engineering systems and the science needed to analyse these designs. The amount of time available to teach the students about the construction operations and processes that are used to construct these systems is limited. However, the range of construction operations and processes is very diverse. Therefore the number of these operations and processes that can be covered and the depth of coverage is quite limited. The limited amount of time devoted to the processes that are covered can make it difficult for students to fully understand each process.

In teaching this class it was found that there was a big difference between students who had had an opportunity to work on construction sites and those who didn't. The students who had this experience were able to grasp the descriptions of the construction operations considerably better than those who hadn't. Having previously seen the operations and processes that occur on construction sites made it much easier for them to understand the theory behind them. The Construction Practice Laboratory solves this problem by giving a more concrete and practical understanding of a couple of processes so that students will be able to extrapolate to the other processes that they learn about.

To give students a proper understanding of construction processes they not only need to grasp the physical process and how the steps involved fit together but also they need to get a feeling for the teamwork involved. In fact in construction processes organising the team is usually the difficult part. It is easy to grasp the physical interrelation between the steps. Commonly the physicals steps can be understood as a straightforward sequence. However, in execution it is much more difficult because the workers who carry out the steps need to be organized. This may seem simple but not only does each person need to know their own role, but they need to know the other roles. These roles are not necessarily cleanly packaged. The team itself needs to work out exactly how the tasks are going to be divided up between its members. This requires lots of communication. Thus one of the main benefits is the students get a chance in the laboratory to experience this teamwork and get a taste for dividing up a complex manual work task amongst themselves simultaneously as they solve the problem of how to carry out the work process.

Another issue that is important in Construction Engineering is spatial reasoning and visualisation (Hsi et al, 1997). In the Construction Practice Laboratory is students need to think in three dimensions to work out how the pieces need to be placed and also how to manipulate the pieces to get them there.

A further benefit of the construction practice laboratory is that it can help students who have different learning styles to learn. Felder and Silverman (1988) show that students may have any of a variety of learning styles. Students who have difficulty assimilating information in lectures and text books may find the practical hands on activities more useful. Students also have different motivations (Felder and Brent, 2005). Using a variety of teaching techniques is more engaging for students and caters for a wider range of student interests. With greater interest comes greater learning (Ainley et al, 2002).

Commonly when construction engineering activities are described as “hands on” it refers to planning exercises or computer simulations (eg Alamad and Tills, 2010). There is a large literature on using virtual reality to help train workers in assembly tasks (eg Brough et al, 2007 and Sawhney and Mund, 1998). There is also a growing literature on using teleoperation of equipment for training purposes (eg Bernold et al, 2002).

One way that large scale construction operations can be experienced by students is through construction camps. A recent example of this is the Constructionarium (Ahearn, 2005) begun by Imperial College London where a construction site is prepared with, for example, an artificial river and then students are given construction tasks such as building a large scale model of a real bridge over that river during a weeklong exercise. A similar activity to this previously occurring in Australia was the CONCAMP run by The University of New South Wales (Fraser, 1990 and Fraser, 1992) where students, for example, moved and restored historical bridges to preserve them as a historical monument. In all of these activities students are not only required to solve the technical problems of the construction project, but also the management problems such as scheduling, budgeting and procurement. The Construction Practice Laboratory differs from these week long construction camps in that it occurs on campus in the laboratory and the activities take 2-3 hours rather than a whole week.

The processes selected to be part of phase one the construction practice laboratory were erection of a section of scaffolding, erection of a section of a proprietary system of formwork, and demonstration of a climbing safety screen that is used to protect construction workers from falling or dropping objects from the top levels of a high rise building under construction.

## Scaffolding

In the scaffolding activity the students have to erect a section of scaffolding that includes one flight of stairs.

The students begin by laying out sole boards, small wooden planks that in an actual construction site would serve the purpose of spreading the load over the soil foundation. Next the base plates are placed on these planks. The base plates have built in screws that allow for vertical adjustment. The standards are placed on the base plates (the standards are vertical poles). The standards need to be supported by students until they are firmly connected together by the horizontal ledgers and transoms. Ledgers are the short horizontal members, transoms are the long horizontal members. To do this the students have to work out how to use the scaffolding connections.

**Figure 1: Adjusting vertical screws to ensure ledger is horizontal**

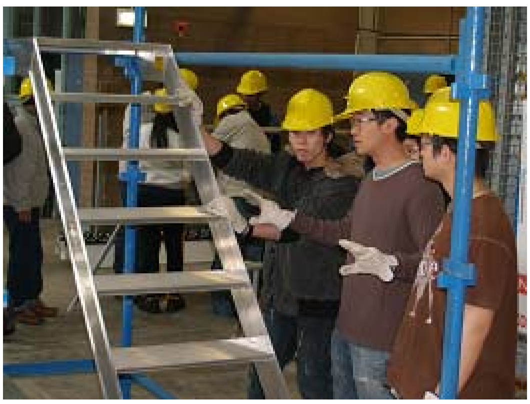

**Figure 2: A tutor giving an explanation to some students**

**Figure 3: The upper handrail is installed from a lower level protected by the lower handrail**

**Figure 4: A proud group of students showing off their scaffold**

At this stage the scaffold is self supporting and the students are given a level and are expected to adjust the vertical screws on the base plates and to ensure that the ledgers and transoms actually are horizontal, see Figure 1.

Boards are then placed spanning between the lower ledgers for half the width of the bay. This gives students a working platform to place some intermediate transoms to give protection from falling and the ledger that will support the top end of the flight of stairs which is then installed. The stairs give access to place the top transoms and ledgers and the students also install an handrail and a gate for the upper end of the stairs. Cross braces are then installed to secure the whole structure.

A major focus of the upper section of the scaffold is the safety aspect of working at heights. The scaffolding system has been designed around these OHS constraints. In order to make the students aware of these OHS constraints the tutors running the activity will restrict the students from working higher than a level for which height protection has already been installed, see Figure 3. This reinforces one of the learning objectives of the engineering construction subject, which is that students recognise the importance of OHS in designing their own construction operations.

Another important safety aspect of the activity is related to the number of students involved. Normally on a construction site this job would be performed by two workers. However with the construction practice laboratory students work in teams of up to eight students. Furthermore the students are inexperienced and are less likely to realize what other members of the team are doing. This means that there is a much higher chance that students will knock over one of the standards before they are supported by the ledgers and transoms. This problem is increased during the dismantling phase when students think that they know what they are doing and attempt to move faster in order to finish the job more quickly.

To deal with this major safety problem one tutor is allocated to each team working on the scaffolding activity. The tutor is instructed that their most important responsibility is to ensure that each of the standards is supported by a student and to ensure this they interrupt the students at the appropriate points both during the assembly and dismantling phases to draw the students attention to this. This is a high ratio of tutors to students, but it is believed that the risk that one group of students will have such an accident while the tutor is with another group is too great.

## Formwork Deck

In the second activity the students need to assemble two bays of a proprietary formwork deck system. The system used is the SKYDECK Aluminium Panel Slab Formwork System made by PERI. This system is designed to be easy to assemble and disassemble with all pieces being easily carried by a single worker.

The students begin by using support stands to hold the first two props upright. Spacing trusses are then used to connect these two props with the next two props. This ensures that the props are in the correct position, see Figure 5. Dropheads are placed on top of each prop in the raised position and beams suspended between the drop heads. Next the Formwork panels are placed on top. The students then assemble a second bay adjacent to the first bay, although this does not require spacing trusses as the dimensions are controlled by the first bay.

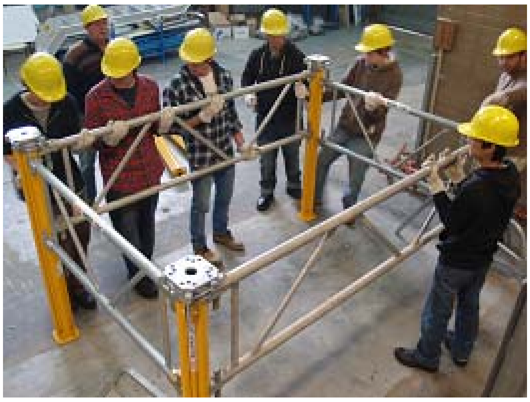

**Figure 5: Using trusses to position the formwork props correctly**

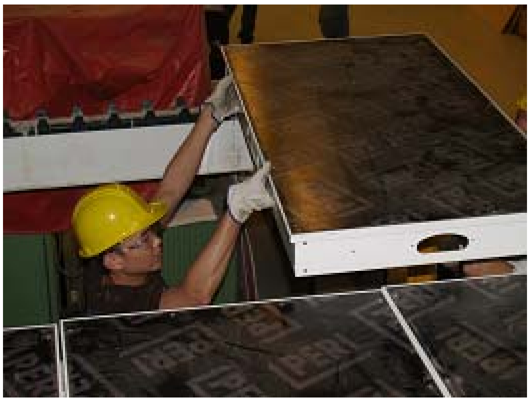

**Figure 6: Placing the deck**

After both bays are completed the tutor demonstrates how the beams and slabs are lowered by hammering the release catch on the dropheads, see Figure 7. The students can then see how the slabs and beams could be removed without interference from the (imaginary) concrete slab above while the props continue to support the concrete until it is strong enough to be fully self supporting. This enables the tutor to talk about time and cost and the reduced amount of formwork components required for a repetitive job. (At this stage the students all want a turn at hammering one of the release catches).

The safety aspect of this task is not as critical as for the scaffolding. The props in this exercise are much shorter that the standards in the scaffolding exercise. Indeed the props are shorter than most of the students. They are also thicker so they are more stable.

## Climbing Safety Screens

The third activity in the construction laboratory is a demonstration / display of a fall protection safety screen for use on high rise buildings.

Modern high rise buildings typically use a curtain wall facade. One of the benefits of this system is that it provides edge protection to each floor of the building not long after each floor is constructed. However, at the very top of the building, where the structure is being advanced, other arrangements are necessary. A common method of dealing with this is to use safety screens. These screens are attached to the concrete slabs of the building one after the other. As the building advances the screens are lifted by crane from floor to floor.

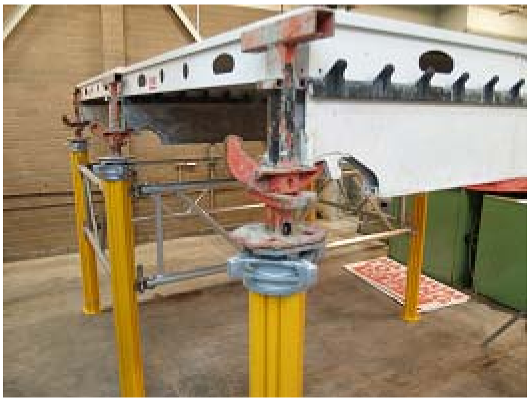

**Figure 7: Formwork complete. A drophead is in the foreground ready to be released**

**Figure 8: Equipment packs away neatly and compactly**

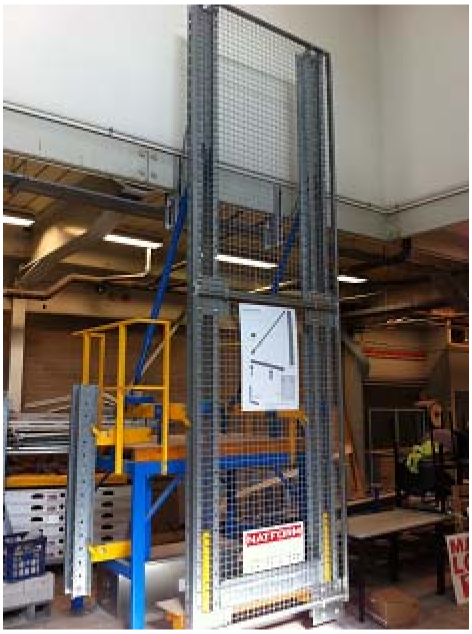

**Figure 9: Climbing screen display**

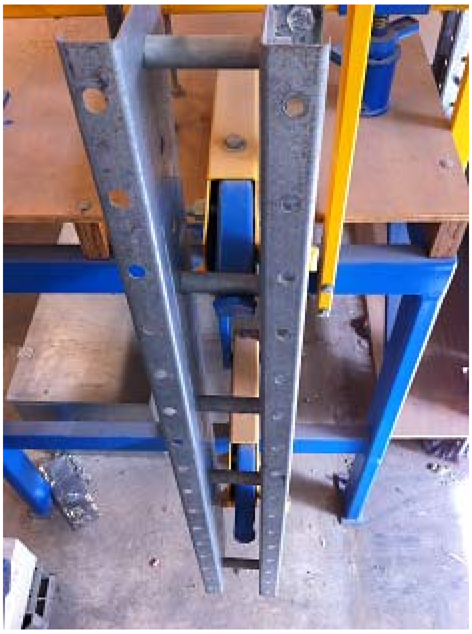

**Figure 10: Detail of the climbing ratchet that a tutor will raise during the demonstration**

For the display a wooden platform was constructed to simulate the concrete slab that the screen is suspended from. A climbing safety screen was attached to the platform in the same way that it would normally be attached to a concrete slab. During the demonstration to the students the tutor can show the degrees of freedom that the supports have to allow the screen to be slightly raised or lowered, and tilted in/out or left/right for proper alignment.

An extra part of the display was added to show students the functioning of the ratchet that allows a crane to raise (“climb”) the screen from one floor to the next, see Figure 10.

## Personal Protective Equipment

Students were issued with hard hats, safety glasses and gloves for the laboratory exercises. They were required to arrive at the laboratory wearing safety boots.

## Student Response

Before any students had attended the laboratory they complained about being required to obtain their own safety boots. This problem was eliminated by making the students who turned up without them perform the exercise on a subsequent occasion after they had obtained safety boots.

Similarly to what was found with the Constructionarium (Ahearn and Holdsworth, 2007) students related that they enjoyed dealing with a real, physical challenge. They don’t just achieve a greater understanding of some engineering processes, but also a feeling of accomplishment. This is quite clear from their mood when they finish their constructions.

Students are very engaged in the activity and once they know what they are doing will start to self organise themselves into a production team. One of the benefits of performing the exercise in the laboratory instead of, for example, watching a video is that students can be given the information they need “just in time”. For example the tutor will explain how to install the handrail when the students are ready to install it. At this time everyone is focused on the handrail as being the next part of the activity, rather than just being one item in a long list.

## Future Plans

Future plans for the laboratory include displays of other formwork elements and a cutaway section of a concrete slab showing placement of reinforcement and prestressing.

## Conclusion

The construction Practice Laboratory described in this paper addresses the problems associated with attempting to teach students the wide range of construction processes in a limited time. Bringing the students in contact with the construction materials gives those who have not had construction site experience some familiarity with the processes in a more concrete rather than just theoretical manner. An example of this is that experiencing the OHS constraints restricting their own actions makes these constraints become much more real to them. Similarly, having the students actually carry out work enables them to see the issues of teamwork and communication involved rather than just view the process a series of physical actions that somehow happen automatically.

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