

## AN INTERACTIVE WEB-BASED PACKAGE LINKING STRUCTURES WITH CONSTRUCTION TECHNOLOGY

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***Abstract**-Construction technology is an intrinsically visual discipline and structural design theory and principles must be contextually linked to construction practice. Slides, digital images and digital video from past and current construction sites are used during lectures to provide these links. The web based learning tool developed is also linked to a database of construction images. The students then have the ability to access and review all the lecture images and can view the full database of images in their own time, further providing and reinforcing the contextual links. The web based tutorial exercises include appropriate questions based on the case study project images. The “ Industrial Ground Slabs “ topic was selected for web-based development. The package covered structural design principles, pouring sequences, joint types and layouts, formwork and joint detailing, pouring methods, trowelling methods, surface finishes and tolerances, curing and sealants.*

*Index Terms*-Construction technology, contextual links, construction image database, industrial ground slabs.

### Introduction

This paper overviews and highlights the key features of a web based interactive program / learning tool, developed for a third year “ Structures and Construction” subject. The web based package was developed as part of a Virtual Design Management and Construction Studio ( VDMCS ) suite of projects. The paper discusses some educational theory surrounding the advantages and limitations of computer-based courseware as a learning model, and development of interactive web based tutorial exercises and assessments.

The ultimate aim of the course is to produce graduates that can become effective construction and project managers. There are however, a number of subsidiary objectives that can be articulated, these include:

- To engage the students as active learners
- To link structural design principles with current construction practice
- To provide contextual information and links with real world concepts and examples
- Encourage the acquisition of the skills necessary to undertake construction projects

### Teaching Environment

The University of Melbourne offers undergraduate courses in Property and Construction as a single undergraduate degree and also as compulsory subjects within a number of double undergraduate degrees including architecture, geomatics, commerce and law. The subjects offered must accommodate several discrete cohorts of students that may have different perceptions of the value of the subject to their needs.

Many authors have stated that a contextual understanding of the problem is an important step in the learning process, [1]. However, teachers in construction management courses are increasingly having little ability to provide the students with an effective contextual experience in construction.

There are many difficulties in arranging site visits for students. For example, [2] suggested that large class sizes, tight time tables, busy site management, distant sites and site safety concerns have drastically curtailed such useful opportunities for a close-up appreciation of some construction processes.

According to [3], “One of the greatest shortcomings in the training of civil and environmental engineers is the lack of real life practical experience upon graduation. The experience gained by visiting construction sites first-hand cannot be conveyed through lectures alone. Unfortunately, site visits amount to only a few hours in the academic career of a student and only a “snapshot” of an entire project is ever experienced.

[4], claim that an additional advantage of a self-paced learning approach is that it allows the learners to rehearse lessons learned which allows information that would normally slip from short term memory and be lost, to instead reside in long term memory.

The need to encompass a variety of teaching methods and adapt to cover differing learning modes is further evidenced by [5], who state that large group teaching presents difficulties when dealing with students from diverse backgrounds with varying levels English language comprehension as it tends to inhibit asking questions to clarify technical points or the nomenclature of building components.

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Construction is an intrinsically visual discipline. Many construction processes are underpinned by an understanding of how structures are constructed and how constituent components fit together. [6].

### Background to Computer-assisted models and learning

Past research has shown that computer-assisted models can provide a worthwhile addition to the teaching aids used in the undergraduate subjects, [7]. For instance, computer courseware provides many advantages over traditional teaching approaches, including, the ability to undertake the exercises at time convenient to the student, the opportunity to repeat the exercise a number of times, the ability to interact with the computer model, and the capacity to be used with large class sizes. Thus computer assisted learning approaches have a much greater flexibility which may provide a better learning experience.

In computer based tutorial exercises, [7] showed that many factors impacted on the ability of the courseware's effectiveness. The use of computer-based tutorials can only be used for the practice of low-level skills, this is because although there are some standard feedback dialogues, lecturers bring an insight into how the student is approaching the problem. The face-to-face approach allows the personal intuition of the teaching to guide the student down the correct path. For instance, the authors said, "when students enter a wrong answer, it is usually wrong in a reasonable way.... Students found that they need to talk to lecturers about questions arising from the computer-based problem. Teaching needs enthusiasm and its effectiveness is dependant upon creating that environment".

### Features of the Structures and Construction 3 Web Package



Virtual Design Management & Construction screen

### Selections

The VDMCS screen then directs the students to select one of four packages:

- Construction Methods and Equipment
- Structures and Construction
- Construction Cost Planning
- Management of Construction 3

Students at this stage may also select to go directly to the:

- Construction Image Database (details later provided)

### Access

Having selected "Structures and Construction", the students Login name ( their name from their student email address and their Password are required to be keyed in. Only students currently enrolled in the subject can gain access to the web-based exercises under the University of Melbourne's "webraft" system. A matrix of questions in all sections allows the questions to be rotated for 6 years, without repeats. Students can practice in one section and be tested in another. (refer to delivery strategy below).

### Assignment problems index

The lecture series on industrial ground slabs covered 4 x 2hour lectures, tutorials and a site visit. The tutorial questions followed the lecture content / series and students could then select from eight different exercises: The number of questions in each section are shown in brackets.

- Exercise 1 Design Principles (14)
- Exercise 2 Pouring Sequences (7)
- Exercise 3 Joint Types and Details (20)
- Exercise 4 Formwork and Joint Detailing (7)
- Exercise 5 Pouring Methods (10)
- Exercise 6 Trowelling Methods (9)
- Exercise 7 Surface Finishes & Tolerances (9)
- Exercise 8 Curing and Sealants (7)
- Total 83 questions

A series of multiple choice questions of varying difficulty under each of these exercises and areas, provides and requires from the student, an in depth analysis and understanding of all aspects of industrial ground slabs from design and detailing through to construction.

The number of responses to correctly answer each question is indicated. If a student answers correctly on their first attempt, a mark for that question is given together with an explanation for the correct answer. If a student answers incorrectly on their first attempt, an "incorrect" response is indicated. The student is then permitted a second attempt. A second incorrect answer produces a zero mark, followed by the correct answer with an appropriate explanation.

This immediate feedback builds up their level of understanding as they progress through the exercises. The ability to complete these tutorial questions in their own time and at their own pace has proved to be quite successful.

### Sample questions from the 8 tutorial exercises

**Design Principles:** What does the Californian Bearing Ratio measure?

- (a) The ratio of the subbase to the subgrade bearing capacity
- (b) Modulus of subgrade reaction
- (c) Bearing capacity of the slab
- (d) The bearing capacity of the concrete at the surface
- (b) *By definition the CBR is a measure of the subgrade reaction*

**Pouring Sequences:** In the “Long strip” method of construction, what are the maximum dimensions of the strip that the engineers endeavour to keep within?

- (a) 40m x 8m
- (b) 40m x 6m
- (c) 50m x 6m
- (d) 60m x 5m
- (c) *Approximately 300 sq.m of area can be poured and trowelled by most industrial concrete slab gangs. With saw cuts at 7-8m centers, the 6m width is preferred.*

**Joint Types and Details:** What is the main purpose of a sleeved dowelled joint?

- (a) Allows lateral movement to occur
- (b) Allows differential vertical movement to occur
- (c) Allows longitudinal movement to occur
- (c) *The duct allows sideways movement by providing a gap either side of the dowell bar.*

**Formwork:** What is the minimum time after a slab is poured, that you would be allowed to strip the edge formwork?

- (a) 12 hours
- (b) the next day
- (c) 24 hours
- (d) Depends on whether the joint is dowelled (12hours) or keyed (24hours)
- (e) When the concrete obtains 25% of its 28 day strength.
- (c) *Removal of key formwork needs careful stripping to avoid hairline cracking in the fresh green concrete. Dowell formwork is straight edged without the key.*

**Pouring Methods:** If a truss type vibrating screed is used during construction of a slab, do you need to use immersion / poker vibrators as well? ( 3 answers req'd)

- (a) Only if the slab is post-tensioned
- (b) Only close to the edges
- (c) Only if the slab is steel fibre reinforced
- (d) Only if the slab has steel reinforcing bars or fabric
- (e) Only if there is a keyed construction joint.
- (a,b&e) *Vibrators required in post-tensioned slabs to make sure concrete completely encloses the ducts (underside). Edges of slab need to be smooth finished / free of voids to avoid bonding. Key joints ditto.*

**Trowelling Methods:** Pizza pan trays are often used and are locked under the 4 blades of ride on helicopters. What is the purpose of these pizza pans? (2 answers req'd)

- (a) So that trowelling can commence earlier and hence finish earlier
- (b) To compact the top surface of the concrete
- (c) To flatten the concrete off prior to the normal 4 blade trowelling
- (d) None of the above
- (a&b) *The weight of the ride on helicopter is spread out over a larger area when pizza pans are used, so trowelling can commence earlier. Early trowelling also helps in compacting the surface to improve abrasion resistance.*

**Surface Finishes and Tolerances:** For high performance industrial floor slabs, the specifications on floor tolerances should include which of the following? ( 3 answers req'd)

- (a) The floor should be within + or – 5mm in 3.0m
- (b) The floor should be within + or – 3mm in 3.0m
- (c) Deviation from RL should not exceed 5mm
- (d) Deviation from RL should not exceed 3mm
- (e) Differential vertical movement across joints should not exceed 3mm
- (f) Differential vertical movement across joints should not exceed 1mm
- (b,c&f) *This provides a reasonable degree of flatness and levelness, overall control of levels and minimal joint displacement*

**Curing and Joint Sealants:** Adequate curing of the slab will? ( 2 answers req'd)

- (a) Improve the flexural tensile strength
- (b) Improve the abrasion resistance
- (c) Reduce long term shrinkage cracking
- (d) Reduce plastic shrinkage cracking
- (e) None of the above
- (c&d) *Overall crack control is the major benefit of curing slabs*

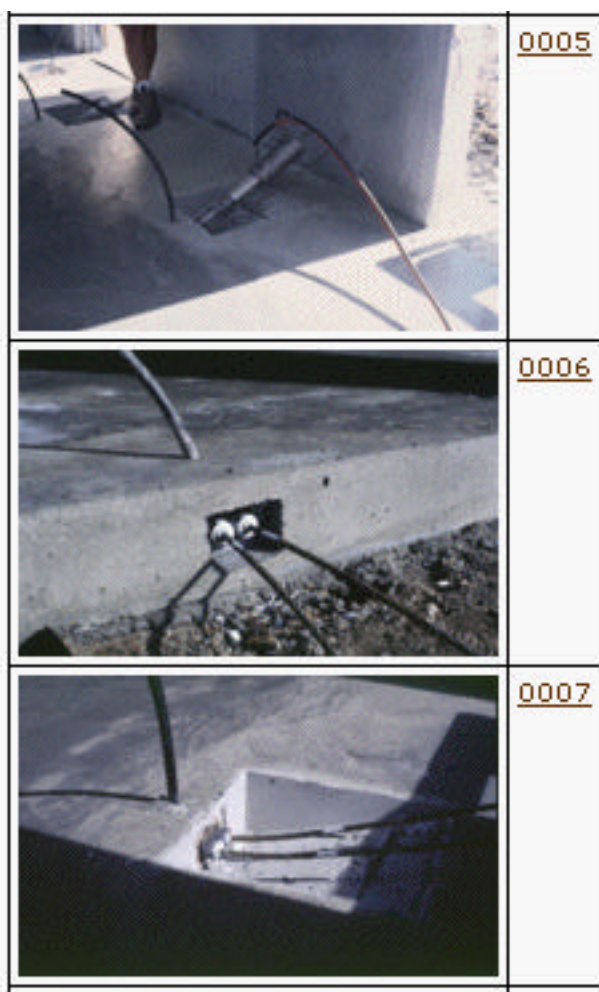
At the completion of their session, the students can receive their final score. Not all questions need be completed in any of the categories nor in any one sitting.

## Construction Image Questions

In addition to the tutorial questions, there is a bank of questions / exercises related to the digital construction images for the students to review and answer. The purpose of this section is to ensure that all the students review the lecture images shown, reinforcing the contextual relationship between theory and practice, and to provide the visual links so essential in the understanding of construction technology.

Having practiced on the construction image questions, the students can then proceed to the "On-line Test" of images from the construction image database. Students are asked questions on individual images or a series of images. Clicking on the "View Images" icon generates a vertical row of thumbnail images on the screen. Each image has its own number. Double clicking on any thumbnail produces a full screen image.

Review images 1 - 12 Post tensioned ground slabs, Ingles Street, Port Melbourne



Sample of digital construction images

Q1. Which image indicates that the final post tensioning load has been applied?

7 Full tendon extension (approx 170mm) indicated by white paint mark on strand



Q2. On image 10, the stressing procedure is underway and the operator is checking the dial. What does the dial / reading display?

(d) The pressure can then be converted / tabled to the applied tension load.

Immediate feedback is provided with a response as to whether the answer is correct or not, followed by an explanation for the correct answer. On completion of the on-line test, the total score is shown and the tally recorded on the coordinator's spreadsheet.



## Delivery Strategy & Coordinator's Index Page

All the multiple choice and digital image questions are set up on a matrix grid which can be altered / updated by the lecturer / coordinator. The questions that are currently online are divided into three categories:

1. Online examples that serve as practice questions for the tests.
2. Questions used for testing.
3. Questions stored in a separate bank for use in future years.

Three sets of questions (set A, set B, set C) can therefore be cycled through the examples-bank-test cycle over a three year period:

TABLE I

	2001/4	2002/5	2003/6
<b>Examples</b>	A	C	B
<b>Bank</b>	B	A	C
<b>Test</b>	C	B	A

The following table starts with the non-image questions that are currently online and divides them into those that will remain online as practice examples (set A), those that will be used in a hard-copy test this year (set C), and those that will be stored away for use as test questions next year (set B). The image questions are treated in the same way except the test was administered online.

TABLE II

	Online Examples	Hard-copy Test	Bank
<b>Design Principles</b>	1-4	5-9	10-14
<b>Pouring sequences</b>	1-2	3-5	6-7
<b>Joint types and Details</b>	1-6	7-13	14-20
<b>Formwork and joint detailing</b>	1-2	3-5	6-7
<b>Pouring methods</b>	1-3	4-7	8-10
<b>Trowelling methods</b>	1-3	4-6	7-9
<b>Surface finishes and tolerances</b>	1-3	4-6	7-9
<b>Curing and sealants</b>	1-2	3-5	6-7
	Online Examples	Online Test	Bank
<b>Image Questions</b>	1-4	5-26	27-34

As indicated above, the students have practice questions and test questions to complete. All test questions are automatically recorded and can be viewed by the lecturer. It is very easy for the lecturer to overview the results and check those students who are falling behind or those who have not completed parts or all of the tests. Marking and assessment time is drastically reduced in contrast to conventional tutorial programs.

#### Assessment Modes and Weighting

A hard copy test of the multiple-choice questions was the preferred test mode as there were insufficient computer terminals within the faculty for all students to complete the test at one time. The test could have been turned on and made available online for students to complete within a specified time period (at the university or at home), but this could easily lead to group sittings and collusion by students. The test carried a weighting of 10% of the total assessment.

The on-line visual test can be turned off or on by the lecturer so that a specific time frame can be given for the students to complete the visual test which carried a weighting of 5% of the total assessment.

There was some 25% difference in the average scores between the two test modes, suggesting that:

- there was some group sittings and collusion between students
- the visual image test was far easier than the multiple-choice test
- students perform better in a relaxed and less time restrained environment than in the traditional test / exam mode

#### Construction Image Database

A digital image database with over 2,500 images from past and current construction sites has been developed. This allows the students to view any images shown during lectures (or a multitude of other images not shown during lectures) in their own time. The images have been taken from numerous sites over many years and indicate a variety of construction methods for each topic covered in the lecture programs. These images are proving to be a valuable additional resource as they indicate the key issues of:

- Construction methods and alternatives
- Design methods
- Construction detailing
- Construction sequence

- Ability to compare and contrast different site methods
- Buildability issues
- Equipment
- Site Tolerances
- 

The database searches by keywords (any field) for:

- Description
- Topic
- Construction system / method
- Image number or sequence
- Site address or location
- Proprietary name
- Building name
- Australian Standard Method of Measurement reference
- Element code

New images are continually being added whilst data entry for each image continues.

The database contains over 250 images related to industrial ground slab construction.

### Discussion & Conclusions

If web-based activities form part of a student's assessment and the activity is outside of tutorial sessions times, collusion between students needs to be addressed or the tutorial percentage reduced accordingly.

The automatic marking of student's answers and spreadsheets of the exercises results, dramatically reduces the lecturer's marking time when compared to the more traditional tutorial or assignment submissions. In addition the spreadsheet can provide useful feedback to the lecturer on individual student progress.

The web package accommodates the self-paced learning styles as discussed by [4], with the students able work through practice questions and receive immediate feedback, prior to attempting the test questions.

Whilst the construction images cannot replace actual site visits, they do provide overall construction sequencing, detailing and site to site comparisons. In addition to lecturer's explanations of the images, the database does provide a

second look at the links between design theory and construction practice, reinforcing the student's contextual understanding. These are key issues as shown by [1] and [3].

The web-based package developed and the construction image database provide additional and alternative teaching tools encompassing different student learning modes. To generate interest amongst the students in the highly complex and ever changing field of construction technology, face-to-face contact is essential. The teaching needs enthusiasm and a multi-disciplinary approach as outlined by [5] and [7]. The overall effectiveness is dependent upon creating that environment through teacher commitment.

### Future Developments

- Inclusion of digital video clips into the construction image database
- Development of a freestanding CD rom

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