

# A Web-based Learning Module for the Design and Construction of Industrial Pavements

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**Abstract:** The “ Industrial Ground Slabs “ topic was selected for development into an interactive computer module. The web based tutorial exercises comprise multiple- choice questions with multiple answers and visual image questions. Appropriate questions covering all of the structural design issues as well as construction detailing and methods of construction, are based on the lectures, digital video presentations and the site visit. The package encompassed structural design principles, pouring sequences, joint types and layouts, formwork and joint detailing, pouring methods, trowelling methods, surface finishes and tolerances, curing and sealants. 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 tutorial program developed has direct access to a database of construction images. The students have the ability to access and review all the lecture images and can view the full database of images in their own time, thereby strengthening the contextual links.

**Key Words:** Structural design principles, contextual links, virtual design management and construction studio.

## Introduction

The web based package was developed as part of a Virtual Design Management and Construction Studio (VDMCS) suite of projects. This paper overviews and highlights the key features of a web based interactive program / learning tool, developed for a third year “ Structures and Construction 3A” subject. The paper discusses some educational theory surrounding the advantages and limitations of computer-based courseware as a learning model, and the development of a set of interactive web-based tutorial exercises and assessments.

The course’s ultimate aim is to produce graduates that can become effective construction and project managers. There are a number of subsidiary objectives that can also be articulated which include:

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

## Teaching Environment

The University of Melbourne offers undergraduate courses in Property and Construction as a single undergraduate degree and also as compulsory core 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.

According to Seracino, Daniell, Webster and Doherty (2001), “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.

The digital videos and images taken over many years can provide a viable learning alternative to site visits and comparisons from various sites can be made, thus providing a distinct advantage over a single site visit.

There are many difficulties in arranging site visits for students. For example, Kajewski (1999) 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. These restrictions necessitate alternative solutions and brought about the development of this package.

Ramsden (1988) contended that a contextual understanding of the problem is an important step in the learning process. However, teachers in construction management courses are increasingly having little ability to provide the students with an effective contextual experience in construction.

According to Beacham, Bouchlaghem, Seden and Sher (2000), 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. With very specific and precise questions in the tutorial system, and backing up with appropriate images, current design theory and construction practice can be placed in context.

Atkinson and Shrifffen (1968) 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 web-based package allows students to work through the entire topic and repeat sections if necessary, all at their own pace in their own time.

The need to encompass a variety of teaching methods and adapt to cover differing learning modes is further evidenced by Walker and Vines (1997), 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. The package caters to the needs of varying student cohorts.

## **Background to Computer-assisted models and learning**

Previous research has shown that computer-assisted models can provide a worthwhile addition to the teaching aids used in the undergraduate subjects, as indicated by Menser (2001). As an example, computer courseware provides many advantages over traditional teaching approaches, including, the ability to undertake the exercises at times 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 and may provide a better learning experience.

In computer-based tutorial exercises, Menser (2001) showed that many factors impacted on the ability of the courseware's effectiveness. The adoption 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".

Given these research findings, the web-based tutorials adopted a self-paced, convenient time approach utilizing the students' own computers. Interaction was incorporated through immediate feedback with scores and reasons for the correct answers.

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

### **Selections**

The first VDMCS screen 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, requires the student to have developed a reasonable level of understanding in most 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 in developing an reasonable understanding of this topic. This was as indicated by way of improved student results and responses to a similar hard copy written test and at the end of semester exam questions.

### **Sample questions from the 8 tutorial exercises**

With 83 questions in total, covering 8 areas of design and construction, followed by the image questions; the tutorial package is quite comprehensive. A considerable amount of time was spent developing the 8 sections and the range of questions within each exercise to extract the important concepts and contextually place these concepts into real construction issues. The selection of corresponding answers was methodologically developed to require some in depth thinking and comparisons to be made between alternative answers. There are subtle and discrete differences between the alternative answers provided and the correct selection does take a considerable amount of time to correctly evaluate. To give the reader some indication of the typical questions and answers, a selected few have been provided below to give an indication of the question styles developed.

#### **Design Principles:**

Subgrade drag can be reduced by? (2 answers req'd)

- (a) Providing one layer of polythene membrane under the slab
  - (b) Providing two layers of polythene membrane under the slab
  - (c) Not having thickenings in the slab
  - (d) Providing a thicker sand bed
- (b & c) *Two layers of polythene allows slab to slide easier. The sloping edges of thickenings restrict the sideways shrinkage movement of the slab, increasing drag*

**Pouring Sequences:**

What are the disadvantages of large area continuous pours? (1 answer req'd)

- (a) Shrinkage / crack control
- (b) Need very long screeds to level the surface
- (c) Difficulty to obtain surface tolerances
- (d) Takes too long to pour the concrete
- (b) *Unless vibrating laser screeds are used, surface tolerances for large areas can be difficult to achieve using spot levels.*

**Joint Types and Details:**

What are the critical items to look for when dowels are used in a joint? (4 answers req'd)

- (a) They are accurately spaced
  - (b) They are set up level
  - (c) They are aligned parallel with the long direction of the strip
  - (d) They are coated with grease / bitumen each end
  - (e) They are clean cut at the ends and not guillotine cut
  - (f) They must have transverse bars tied to them to hold the dowel bars in place during the concrete pour
- (b,c,d & e) Dowels must be at right angles on plan and sections to allow free movement to occur. Coating the bars allows slippage. If ends are not clean cut, burrs on end of dowel can bind the joint together.

**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:**

Several passes of the helicopters are required to obtain a smooth hard surface. Each pass is different to the previous pass. Which of the following is incorrect? (2 answers req'd)

- (a) Passes overlap one another by 25%
  - (b) Passes overlap one another by 50%
  - (c) Once a series of passes is completed in one direction, the next series of passes is at right angles to the first.
  - (d) Once a series of passes is completed in one direction, the next series of passes is in the opposite direction to the first
- (a&c) To improve the flatness, laps are 25%. To improve surface levelness, alternate passes are at right angles to one another.

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. The student's final score is recorded on the coordinators "student exercise marks" page for portion of the student's overall assessment in the subject.

### **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 during lectures, thus reinforcing the contextual relationship between theory and practice, and to provide the visual links so essential in the understanding of construction technology.

Having completed the practice 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.

The typical set of questions below, relate to a series of thumbnail images (also listed below).

#### **Review the images 144 – 150 (QP2 warehouse facility at Broadmeadows)**

1. What is the method of construction?
  - (a) Long strip method
  - (b) Double strip pour method
  - (c) Wide / large area pour method
  - (b) *Rail shown on images 144 / 149*
  
2. Which image best depicts a uniform head of concrete at the vibrating screed?  
*145*
  
3. Which image best indicates that the vibrating screed is supported on an intermediate rail?  
*148*
  
4. On image 146 & 150, what do the 2 bottles on the ride on helicopter contain?
  - (a) water
  - (b) Set accelerator
  - (c) Set retarder
  - (c) *Retarder used to slow date rate of set if concrete is harder on the surface in some areas compared with other areas*

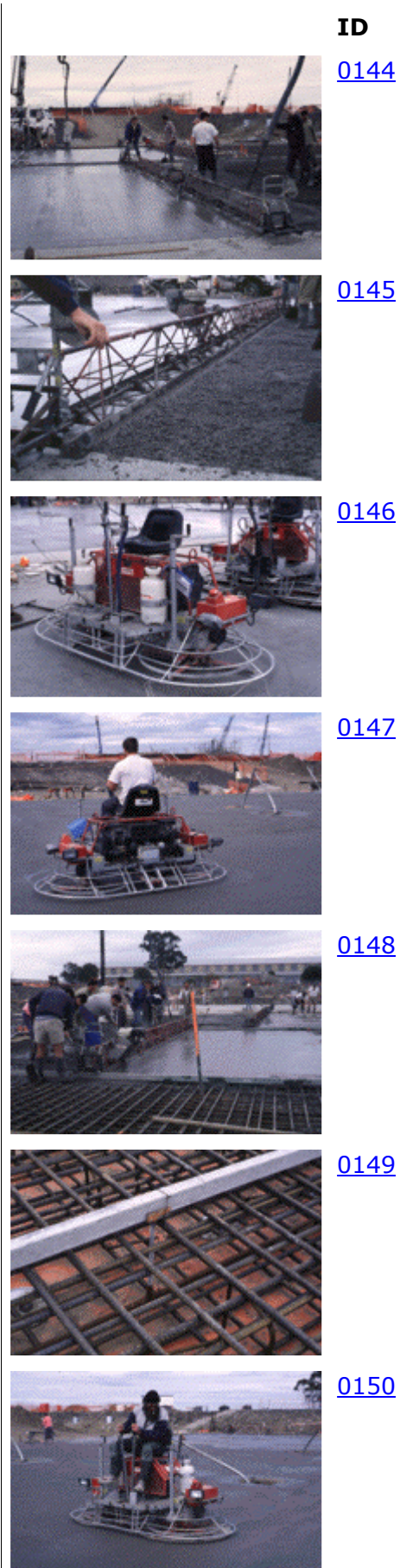


Figure 1. Example digital image set

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. The role of the marking is firstly to provide the student with a self-assessment score and secondly to give some indication through the spreadsheet, of areas where the students have not grasped the concepts; enabling the lecturer to review and cover these issues in other tutorial sessions. The marking also provides some degree of assurance that the students will actually complete the exercises as they form part of the overall assessment.

### **Delivery Strategy & Coordinator's Index Page**

The VDMCS coordinator's page provides and allows the lecturer to:

- View the students' Exercise marks
- Update the question set
- Turn access to the web based package "off" or "on"

### **View the student's exercise marks**

Each student's progress can be ascertained and checked with their scores monitored for each topic, including the image questions. Poor aggregate scores within one topic are easily identified and further explanation if required can be given to the students in the tutorial sessions. This provides useful immediate feedback to the lecturer on student progress.

### **Update the question set**

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: Refer table 1 below.

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

**Table 1**

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.

	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
	<b>Online Examples</b>	<b>Online Test</b>	<b>Bank</b>
<b>Image Questions</b>	1-4	5-26	27-34

**Table 2**

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. This hopefully prevents collusion between students in giving answers to one another.

The 25% difference in the average scores between the two test modes, suggests 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 3,000 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

Anecdotal evidence from students suggests that they are realizing the advantages of reviewing images shown in lectures as a revision process and for use in assignments both in this subject and others.

**The database searches by keywords (any field) for:**

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

New images are continually being added whilst data entry for each image continues. The database contains over 350 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 session 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 Atkinson and Shriften (1968), with the students able to 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 the lecturer's explanations of the images, the database can 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 Ramsden (1988) and Seracino et al (2001). Some further development is required to make reviewing the construction image database a component of the package, perhaps as an extension of the image questions. The construction image database does however cover many other topics within this and other subjects within the overall program, not just the industrial ground slabs component.

The web-based package developed and the construction image database can provide additional and alternative teaching tools encompassing different student learning modes. Construction technology is an intrinsically visual discipline and both the image questions and database have purposely been incorporated into the package to provide visual and contextual links between theory and practice. Self-paced learning and immediate feedback with scores and reasons for correct answers are other features that help enhance the student experience and understanding. 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 Walker and Vines (1997) and Menser (2001). The overall effectiveness is dependent upon creating that environment through teacher commitment.

This module of “Industrial Ground Slab Design and Construction”, forms one topic only out of a total of 6 for the subject. On completion of the module, the students should be confident in addressing the rationale engineering design concepts, subbase preparation requirements, construction sequences and coordination, pouring methods, joints layouts and detailing, trowelling methods and means of achieving floor tolerance specifications. These are the basic concepts and knowledge base required of site managers. Other topics within this subject aim to provide the students with similar skills.

### Future Developments

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

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