Integrated Approach for Teaching Laboratory Courses and Basic Properties of Construction Materials

By

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ABSTRACT

A common course in the curriculum of civil engineering programs is on the "Properties of Construction Materials". The majority of text books for this subject focus on the use, selection, and specifications of common construction materials; such as aggregate, concrete, asphalt, wood and masonry. Courses of this nature often centered around laboratory sessions focused on test procedures designed to measure the properties that are typically used in specifications of these materials. There is a desire to include more scientific concepts and improve the linkage between the fundamental material properties and the behavior of construction materials under different loading and environmental conditions. Available textbooks vary widely in their treatment of fundamental concepts. Although standard ASTM test procedures for related material tests are often referenced and re-stated for the convenience of the student, little guidance is suggested as to the conduct of the laboratory exercises relative to the information presented beyond the knowledge and comprehension levels of learning. Consequently, an integrated approach has been developed in which the basics of mechanics are introduced within the context of the different construction materials covered in this course and within a learning cycle that addresses all the styles learning within an experiential learning cycle. The learning cycles are designed to achieve the cognitive levels *analysis*, *synthesis*, and *evaluation* in order for the student to fully appreciate the relationship between engineering materials, mechanics, and behavior and that control and design of engineering infrastructure can be understood from a systems perspective. In the opinion of the authors this approach provides students with a better understanding of the fundamentals of mechanics that govern the behavior of different materials, and the underlying mechanisms that cause certain material response.

INTRODUCTION

There two undergraduate courses in the Civil Engineering Department at Texas A&M University on Materials Engineering. One of these courses is taught at the sophomore level and is required for all engineering students. It is taught mainly at the knowledge and comprehension level and is partially focused on the relationships between macroscopic properties (including mechanical, rheological, optical, thermal, and magnetic properties) and microscopic causes in terms of fundamental principles (including chemical bonding, crystal structure, and microstructure). The content of the second course, which is titled Materials of Construction, has been mainly oriented on the practical applications of common construction materials such as aggregates, asphalt, concrete, masonry, and wood. This course covers basic properties of these materials, the tests used to measure them, and their use in engineering applications at the higher cognitive levels of analysis, synthesis, and evaluation. Nonetheless, the link between the two courses may be better established if the content of the course on Construction of Materials was revised to address all the styles of learning and bridge the ‘gap’ across the cognitive levels in order to better establish this link. This paper discusses the course revision and the basis for them in terms of the course lectures as well as the laboratory activities and homework assignments.

REVISIONS OF COURSE CONTENTS

Seven conditions of learning identified by Knowles[1] are deemed by the authors to be applicable to the Construction of Materials course:

1. Students recognize the *need* to learn
2. Physical *comfort*, mutual *trust*, *respect*, and *helpfulness,* freedom of *expression*, and *acceptance* of differences characterize the learning environment
3. Students *perceive* the goals of a learning experience
4. Students accept a *share* of the responsibility for planning and operating a learning experience, and therefore share a commitment to it
5. Students actively *participate* in the learning process
6. The learning process is related to the *experience* of others
7. Students *sense* the progress towards their educational goals

It is clear that learning is an active process that is positively enhanced by doing and experiencing type activities as would be carried out in a laboratory course. To this end, the authors have found it convenient to apply the theory espoused by Kolb[2] describing four modes of learning as:

- Concrete experience
- Reflective observation
- Abstract conceptualization, and
- Active experimentation

Every student possesses portions of each learning mode but actually has a preferred or a dominant learning style and typically consists of 2 modes of learning. However, Kolb states that the most effective learning takes place when the student learns from each mode of learning.

Concrete experience can provide the student a personnel perspective of learning where the student learns by feeling rather than thinking which is not in the cognitive domain. Ideally, in a concrete experience the student realizes the complexity associated with reality while involving the student in a new situation. This complexity is elaborated in the course by the use of invited outside speakers who represent certain industries or material suppliers. *Reflective observation* allows the student to learn for observation rather than action. Here the students see key implications and relationships. *Abstract conceptualization* falls within the cognitive domain where the student acts on intellectual understanding of their observations from a quantitative analysis perspective by which they can theorize the manner to configure their design-engineering related decisions. *Active experimentation* is most interesting because it involves more than simply learning by doing. In the context of a laboratory course, the students learn by trying out a new concept or a skill in the laboratory environment. This is often a perfect opportunity for the students to use a concept or a theory to solve a problem which inherently involve the students in assuming some risk in the process.

The Experiential Learning Model

The experiential learning model (ELM) is a framework for providing a learning experience that takes the student through each of the modes of learning described above. The model is particularly useful in designing lectures that are associated with laboratory programs since they tend to be interactive and experiential in nature while allowing development of *critical thinking* skills. The first component is provision of a concrete experience that is in effect designed in the affective domain since it relates to an experience the student is or has been personally involved. A *concrete experience* should be interactive as possible, involve the entire class, and related to the learning objective. This has been done in a rather broad manner in this course by relating throughout the course the use of the five materials as it would pertain to residential building construction since one time or another, most everyone has had some practical experience living in a home that uses all the materials that are discussed in the class. Consequently, the residential construction example is used throughout the course in projecting how the students think about each material type, it use, and its specification for construction.

Figure 1 Example of Residential Construction.

From each of these references, it is possible to easily use the second step in the ELM of *publish and process* (P&P). In these instances, and some may be very short, the instructor guides the students with leading, opened-ended questions regarding a concrete experience:

- What happened?
- What did you see?
- What did you learn?

The P&P sessions can be a time of discovery for the students and in a laboratory course the questioning can go further as to "Why were there differences?" During these sessions the student move into the analysis and synthesis cognitive levels and prepared to receive for new information. It is also interesting to note, that the study of one material may extend over several weeks where difference aspects of the material are introduced sequentially both in lecture and in laboratory sessions. As a consequent, the laboratory sessions become the concrete experiences for the students and provide the basis for the P&P. For instance, this is done in the asphalt concrete labs, the students are introduced to mix design first and testing for the material as a composite and then on the binder as a separate topic. This process leads to providing learning sessions of *new information* which is the third step of the ELM. This is the classic style of lecture which mainly focuses at the knowledge and comprehensive cognitive levels.

In this step, we have identified the mechanics concepts and pared them with selected materials that best facilitate learning of these concepts as shown in Table 1. The mechanics of composites are introduced within the context of four materials. Simple composite models such as the parallel model, series model, and Hirsch's model are introduced to calculate the coefficient of thermal expansion based on the coefficients of the minerals included in the aggregates. Students are presented with experimental measurements of the coefficient of different rocks and composite model predictions as shown in Figure 2. The same models are used to predict the modulus of a mixture of asphalt and aggregates and a mixture of cement and aggregates mixed at different proportions given the moduli of the binder and aggregates. In masonry, the models are used to predict the strength of masonry units with mortar in between knowing the compressive strength of the mortar and masonry units. Introducing the mechanics concepts in different applications would allow the students to clearly see that the same

Table 1: The Mechanics Concepts and the Materials within which these Concepts are Introduced.

	Aggregates	Asphalt Concrete	Asphalt	Concrete	Wood	Masonary
Mechanics of Composites	•	•		•		•
Anisotropy	•				•	
Fracture				•		
Rheology of Liquids and Solids		•	•	•	•	

concepts can be used for different materials and to predict important properties.

Creep has great practical significance and it is the result of the viscoelastic behavior of materials[3]. Although similar models can be used to describe creep in different materials, the underlying mechanisms for creep in engineering materials are different. It is important for students to understand the link between the model and the mechanism it represents. The Burger model is introduced to students. Then, application of this model to the creep of binder and asphalt concrete is discussed with emphasis that the binder flow is the main mechanism for creep in asphalt concrete. The same Burger model is also introduced when the creep in concrete and wood is discussed. However, it is pointed out that creep in these materials is governed by the movement of moisture under stress. It is believed that this approach allow the students to better understand that the same model or mathematical expression can be used in different materials, but the parameters of this model represent different phenomena depending on the material under consideration.

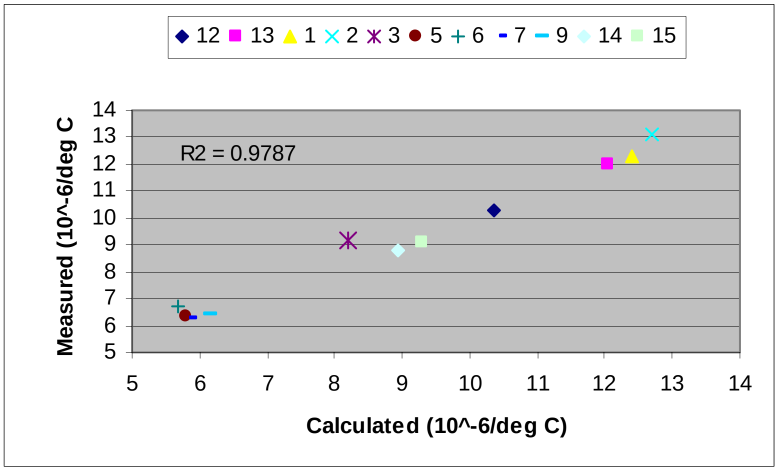

Figure 1 The Relationship between measured and calculated coefficient of thermal expansion of concrete.

Anisotropy is another important property that is emphasized in this course. The course content discusses anisotropy in pavement layers due to the shape of aggregates, and anisotropy in wood due to the preferred directional distribution of wood fibers. The influence of anisotropy on the tensile strength, compressive strength, flexural strength, shear strength and modulus of elasticity of wood is discussed. A simple finite element simulation of the stress distribution in anisotropic wood material is presented to students.

The laboratory activities are used to apply the fourth and fifth steps of the ELM which are *develop new courses of action* and to *apply courses of action*. Here the students go from abstract theory to application of the theory. To some extent, the students are allowed to plan their laboratories prior to each laboratory experience but this is where they decide how to apply their learning. This is where the students can be somewhat creative but the labs have also been configured to better link with mechanics concepts introduced in the lectures to the test programs and test results obtained in the lab. This opportunity is provided in competitions setup in the masonry laboratory sessions where the students are asked to provide their best prediction of the strength of their masonry prisms based on the component strengths of the mortar and the clay brick units using mechanics of composites previously discussed. We have found that competitions intensify the students desire and motivates them to apply the theories that have been introduced to them.

Other *application* type activities have been added where students instrument specimens with strain gauges and LVDTs to measure the modulus and Poisson's ratio of concrete. The concepts of the functions of these measurement devices are discussed in the laboratory as well. Strain gauges are used to measure the deformation of wood loaded in different directions with respect to the fibers. These measurements are used to enforce the concepts of anisotropy and creep in wood. New experiments have also been introduced where students use the rotational viscometers to measure the viscosity of asphalt at different temperatures and rate of loading. The data analysis enforces the rheological properties of asphalt binders to support the discussion in the lectures. It is also at this stage that field trips are used to further educate students on the factors surrounding the use, environment, and manufacture of materials in everyday application.

Summary

The laboratory course curriculum on materials for civil engineers at Texas A&M University fits nicely into a learning cycle prescribed by the ELM in such a manner that the laboratory sessions themselves become concrete experiences that continually feed back into the subject matter at the high cognitive levels introduced during lecture periods. In this manner, education of material properties and their roles in mechanics and behavior of materials is firmly elucidated and presented in an integral manner. At the same time, the authors are in the process of satisfying their desire to include more scientific concepts and improve the linkage between the fundamental material properties and the behavior of construction materials under different loading and environmental conditions. The ELM addresses the seven aspects of learning and actually expands them in a limitless number of dimensions. This methodology reinforces key concepts while covering the various styles of learning affording all students the greatest opportunity for learning and ultimately enhancing their professional careers. The teaching opportunities that are potentially available in this manner are motivating for not only the student but also for the instructor to continually seek improvement in how instructional materials are presented and how student can be effectively challenged to magnify their learning experience.

References:

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3. Young, J., F., Mindess, S., Gray, R., Bentur, A. The Science and Technology of Civil Engineering Materials, Prentice Hall, 1998.