

Creating Professional Laboratories versus Academic Laboratories for Construction Materials Courses

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ABSTRACT

Most Civil Engineering programs contain courses related to construction materials – Portland cement concrete (PCC), aggregates, soils, and hot-mix asphalt (HMA). Traditionally, laboratory sessions associated with these courses have been taught using an ‘academic’ approach, which differs in many respects from method used in professional materials laboratories. Examples of differences include the use of an instructor-developed or third-party ‘laboratory manual’ versus professional specifications (i.e. American Society for Testing and Materials [ASTM]) or American Association of State Highway and Transportation Officials [AASHTO]); the use of pre-prepared test samples versus field sampling; and the requirement for session-by-session ‘laboratory write-ups’ versus the development of a professional materials-related or design report. Consequences of using an academic approach to laboratory experiences include engineers in the workforce who are not equipped to read, understand, and apply professional testing specifications, and newly-graduated engineering interns ill-equipped to prepare a professional laboratory report. The University of Arkansas has conducted materials testing training and certification programs for the Arkansas State Highway and Transportation Department (AHTD) for over eight years; in that time a significant number of engineers, including construction contractor, consulting, and AHTD personnel, have cycled through the program. In many cases, engineers report that the training and certification program was their first experience in truly scrutinizing and fully understanding testing specifications. Construction materials laboratories contained in the Civil Engineering program at the University of Arkansas use a professional-laboratory approach. Keys to successfully implementing the approach include incorporating a ‘cradle-to-grave’ (e.g. sampling to design report) program within the laboratory; providing current professional testing specifications; testing students regarding specification details; providing state-of-the-practice testing equipment; and providing faculty incentive to become and remain active in testing specification organizations. This paper details the laboratory programs provided by the Civil Engineering program at the University of Arkansas, including ‘lessons learned’ regarding implementation of a professional approach. The University of Arkansas program could serve as a model for other programs seeking to move from a more academic approach to a professional approach in construction materials laboratories.

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INTRODUCTION

Civil engineering programs contain a variety of elements and sub-specialties. However, most (if not all) undergraduate programs feature at least one laboratory experience related to construction materials – Portland cement concrete (PCC), aggregates, soils, and hot-mix asphalt concrete (HMA). Understandably, such experiences are an integral part of a civil engineering education. Traditionally, laboratory sessions associated with construction materials are taught using an ‘academic’ approach, as opposed to using an approach which mimics procedures used in a professional materials testing laboratory. The undergraduate civil engineering program at the University of Arkansas (UA) has successfully implemented a ‘professional’ approach in construction materials laboratories. Feedback from construction industry personnel suggests a high degree of satisfaction with the preparation of UA graduates regarding ability to perform materials tests and subsequently prepare test reports.

ACADEMIC VERSUS PROFESSIONAL LABS

There are necessary differences between professional materials testing laboratories, in which production and efficiency are driving forces, and an academic laboratory, in which instruction is the primary driving force. However, the *approach* used in many undergraduate laboratory courses widens the gap between the academic and professional

settings. Three common practices found in many university laboratories illustrate this point.

In many undergraduate laboratory courses, students are required to use a ‘laboratory manual’, developed either by the instructor or by a third party. Indeed, there are a variety of such manuals commercially available. Some manuals feature standard testing specifications; others, however, provide students step-by-step instructions for conducting materials tests. Commercial testing laboratories, by comparison, typically use standard test methods – the most common being methods published by the American Society for Testing and Materials (ASTM) or the American Association of State Highway and Transportation Officials (AASHTO).

Field sampling of construction materials is not commonly emphasized in undergraduate laboratories. Even less common is the practice of actually having undergraduate students *physically sample* materials. A more common practice is to have materials – aggregates, soils, etc. – present in the laboratory when needed. Interestingly, proper field sampling has long been recognized as an integral part of materials characterization and quality control. The scope of work for many commercial laboratories includes sampling of materials in addition to testing.

Civil engineering programs commonly use laboratory experiences as opportunities for developing communication skills in undergraduate students. Many programs require a laboratory ‘write-up’ after each laboratory session. This is particularly true of sophomore and junior level materials *analysis* labs compared to senior level *design* labs. This is not common practice for commercial testing laboratories;

rather, a single materials characterization report is typically prepared for submittal to the client.

Potential Consequences

The differences between an ‘academic’ and ‘professional’ laboratory experience could result in negative consequences for civil engineering graduates. Two potential consequences are identified. Civil engineering graduates whose laboratory experiences were primarily ‘academic’ in nature are not well-equipped to read, understand, and apply standard testing specifications. An associated danger is that students may not have been instructed using the most up-to-date specification information. A second potential consequence relates to students not gaining experience in the preparation of a complete materials characterization or laboratory design report.

These consequences were highlighted through feedback from engineers participating in training and certification programs conducted by the University of Arkansas. For over eight years, the Center for Training Transportation Professionals (CTTP) located at the UA has conducted materials testing training and certification programs for the Arkansas State Highway and Transportation Department (AHTD). CTTP operates personnel training and certification programs in the areas of aggregates, soils, Portland cement concrete and hot-mix asphalt. In addition, CTTP provides certification services for laboratories working on AHTD construction projects. A significant number of engineers, including construction contractor, consulting, and AHTD personnel, report that the training and certification program was their *first* experience in truly scrutinizing and fully understanding testing specifications – with some reporting that the CTTP programs forced them to *read* testing specifications for the

first time. The laboratory certification program also required many materials testing organizations to prepare a laboratory Quality Manual – documenting equipment, processes, etc. – for the first time.

UNIVERSITY OF ARKANSAS MATERIALS LABORATORIES

The undergraduate civil engineering program at the University of Arkansas requires students to complete three construction materials laboratories: Structural Materials (Portland cement concrete, aggregates, wood, steel), Soil Mechanics (soils), and Transportation Materials (aggregates, asphalt binder, asphalt mixtures). Each of these laboratory experiences is conducted using a ‘professional laboratory’ approach. The specific goals of each laboratory are not identical; for example, the soil mechanics laboratory is best described as a materials characterization effort, while the transportation materials laboratory is focused on producing a complete hot-mix asphalt mixture design. However, all the laboratories share common elements, as detailed in the section that follows.

Implementing a Professional Lab Approach

A vital initial step taken by the UA towards implementing a more ‘professional’ model for undergraduate civil engineering materials laboratories involved working closely with commercial laboratories to understand typical operations. This effort was greatly enhanced by the development and operation of the Center for Training Transportation Professionals (described in previous sections). UA alumni working for commercial testing laboratories were instrumental in helping current faculty develop testing programs and reporting formats that are consistent with those used in industry. A number of ‘keys

to successful implementation' of a professional laboratory approach are identified: incorporating a 'cradle-to-grave' (e.g. sampling to design report) program within the laboratory; providing current professional testing specifications; testing students regarding specification details; providing state-of-the-practice testing equipment; and providing faculty incentive to become and remain active in testing specification organizations. A brief discussion of each of these elements follows.

Cradle-to-Grave Program. As stated previously, sampling construction materials is a necessary and vital first-step for characterization and quality control, yet is not included in many academic laboratories. In addition, academic laboratories using a session-by-session write-up approach do not provide students an experience in 'putting the pieces together' to form a complete materials characterization and/or design report. The soil mechanics laboratory at the UA is a good example of the cradle-to-grave concept. In the first physical laboratory session, students go into the field with a drill rig (provided by a local testing firm), prepare boring logs of boreholes, and sample subsurface materials for subsequent testing. These materials are transported back to the UA laboratory for use during the semester. At the end of the semester, students are required to submit a complete site characterization report, detailing soil properties obtained from laboratory testing. It is interesting to note that, when possible, the site characterization report is used in subsequent design courses such as Foundation Engineering and Pavement Design – adding additional reinforcement of the 'cradle-to-grave' concept. Activities such as these described require close cooperation between the department of civil engineering and local materials testing firms.

Current Test Specifications. The UA undergraduate materials laboratories feature testing specifications published by ASTM and AASHTO. Many test specifications are not static; changes occur in some cases yearly. It is vital that students are provided the most up-to-date testing specifications – commercial testing laboratories, particularly those working in the public sector – are required to abide by the most current specifications. Unfortunately, remaining up-to-date can be expensive. Organizations such as ASTM and AASHTO are, however, implementing programs to allow the purchase of single specifications rather than complete sets to reduce expense. In this way, testing firms (and universities) may update only those specifications that feature changes. In order to take full advantage of such a system, faculty associated with the laboratories must be involved with specification bodies (discussed more fully in subsequent sections).

Specification-Based Examinations. There is an old adage (source unknown) that states, “people will rarely do what you *expect*, but will always do what you *inspect*”. In the UA experience, this adage rings true of undergraduate engineering students – the best way to ensure that students read (for understanding) testing specifications is to test students on the details of those specifications. The UA has successfully implemented specification testing, using the certification programs by CTTP and the American Concrete Institute (ACI) as guides. Indeed, undergraduate students in materials laboratories may opt to obtain ACI and/or CTTP certifications in the areas of Portland cement concrete, aggregates, and soils for an additional fee and completion of a performance examination (in addition to the required written specification examination taken as part of the university course).

State-of-the-Practice Testing Equipment. Fully equipped construction materials testing laboratories are not inexpensive – to create, maintain, and/or update. However, if a civil engineering program seeks to provide a ‘professional’ approach to laboratory experiences it is necessary to ensure that testing equipment is current and well maintained – including periodic calibration. One excellent guide for ensuring laboratories meet current commercial requirements is AASHTO R-18, “Establishing and Implementing a Quality System for Construction Materials Testing Laboratories”. Familiarizing students with the requirements of specifications such as AASHTO R-18 and demonstrating how such a specification is implemented within the university laboratory gives students a significant advantage upon graduation in terms of understanding the environment in which a professional laboratory must operate. The UA materials testing laboratories are accredited through the AASHTO Materials Reference Laboratory (AMRL) program in the areas of aggregates, soils, and hot-mix asphalt; Portland cement concrete will be added in 2005. Such accreditation ensures that all testing procedures featured are maintained as state-of-the-practice.

Committed Faculty. Creating and maintaining a professional approach to undergraduate materials laboratories takes significant effort on the part of the faculty involved. Based on the UA experience, it would be problematic to implement such an approach if undergraduate laboratories are *de-facto* controlled and maintained by graduate students rather than faculty members. As discussed previously, one key to the professional approach involves remaining ‘current’ in terms of testing specifications – including test procedures and equipment. Perhaps the best way of remaining current is for faculty to take an active role in specification bodies such as ASTM, ACI, and/or AASHTO. For

this to occur, faculty must be permitted time and/or funding to attend meetings and participate on committees related to the specification bodies. In the case of AASHTO particularly, close coordination between the faculty and the state highway agency (SHA) is vital – typically, only SHA personnel are participants in AASHTO’s Subcommittee on Materials (SCOM).

Lessons Learned

The implementation of a ‘professional approach’ to undergraduate materials laboratories at the University of Arkansas was a process completed over time. During the implementation process, a number of issues were identified. A listing of these issues follows.

- As with most endeavors, communication is vital. Close cooperation between the UA civil engineering department, commercial laboratories, and the state highway agency enabled successful implementation. Based on the UA experience, it would be difficult for a university to fully implement a professional laboratory approach completely internally.
- Administration support is vital. Real resources – funding, faculty time, facilities – are required to fully implement a professional approach. Individual faculty members may implement parts of such an approach, but it is unlikely that a full implementation across laboratories can be successful without departmental support.
- Perhaps the ultimate assurance that university laboratories are well maintained in the same manner as commercial labs is to obtain accreditation from bodies such as AMRL. AMRL accreditation ensures that testing specifications are kept up-to-

date and testing equipment is maintained and periodically calibrated. However, it must be noted that accreditation requires a significant commitment of time and funding. For example, full accreditation under AMRL requires a laboratory to participate in both a laboratory inspection program and a proficiency sample testing program. In the UA experience, it takes one person with a minimum twenty-five percent time commitment to perform all necessary tasks to maintain accreditation under AMRL. The total directly-billed cost, including commercial calibration services for some equipment but excluding personnel costs, for maintaining AMRL accreditation in 2004 exceeded \$15,000.

CONCLUSION

Materials testing laboratory experiences are a necessary part of most, if not all, undergraduate civil engineering programs. The primary focus of such experiences involves instructing students regarding testing procedures and equipment. However, the approach taken in laboratory instruction can range from a more 'academic' style to a more 'professional' style. The University of Arkansas civil engineering program faculty successfully implemented a professional approach to undergraduate materials laboratories, with the goal of preparing students to enter commercial laboratories with perhaps a better understanding of standard test procedures and equipment. Feedback from testing professionals and employers has been positive. Programs seeking a professional approach to undergraduate materials laboratories must commit funding, support faculty, and pursue outside partnerships for successful implementation.

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