Development of A Field and Laboratory Based Coursework in Asphalt Technology

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Abstract

A field and laboratory based coursework in asphalt technology was developed at Worcester Polytechnic Institute (WPI), with the help of a grant from the National Science Foundation. At present, there is a severe lack of opportunity for the undergraduate students to gain field experience and learn application of statistical concepts in quality control in asphalt technology. The objectives of the newly developed coursework are to provide the undergraduate students tools for field experience in asphalt pavement construction, including quality control techniques, and to teach the concepts of statistical quality control through analysis of real time quality control test data. A thorough knowledge of all aspects of asphalt mix design and construction, and an experience of using real time data for statistical quality control is provided to help understand the link between design and construction, and identify potential problems during production, construction, and life of the pavement. As part of the field and laboratory work for the newly developed course, students used testing equipment in the field and analyzed data with portable computers and data analysis software. The students participated in the fieldwork to gain experience in operation of equipment, understand techniques of proper interpretation of test results and making decisions based on test results.

I. Introduction

More than 94 percent of the nation's highways are paved with asphalt mixes and about \$90 billion is spent every year in designing, constructing and maintaining asphalt pavements. In 1987, in response to a growing national concern over the condition of the highway system in the United States, Congress established a five year, large scale, applied research program – the Strategic Highway Research Program (SHRP), aimed at improving the performance, durability, safety and efficiency of the highway system. About \$50 million dollars was spent in developing the next generation mix design system for asphalt pavements – the Superpave (Superior Performing Asphalt Pavement) system. Studies have shown that full implementation of Superpave can save as much as \$637 million per year (1). However, to implement Superpave properly, and realize its full benefit through improved performance, the industry and state departments of transportation (DOT) must ensure that mix production, laydown and compaction in field projects are controlled

to maintain compliance with Superpave specification and mix design. One of the key points of the National Policy on the Quality of Highways, which was established by representatives from the American Association for State Highway and Transportation Officials (AASHTO), Federal Highway Administration (FHWA) and industry in 1992, is continuing commitment for quality products, information and services through “adherence to specifications, use of qualified personnel,, adequate assurance of quality achievement in...construction..” (2) Realizing the need for proper quality control procedures, AASHTO conducted a study on developing field procedures and equipment to implement SHRP asphalt specifications – National Cooperative Highway Research Program (NCHRP) project 9-7. The two important end products of this research program are a training program for quality control of asphalt pavement construction and a rapid triaxial test designed specifically for quick and effective testing of asphalt mixes for quality control purposes (3).

While all of this activity has been going on in industry and research laboratories across the country, education and training for undergraduates in asphalt technology has been sadly lagging behind. Civil engineering undergraduate courses at colleges and universities have been severely lacking in asphalt technology content (4), and results of research from SHRP and NCHRP have remained largely unknown to undergraduate students (5). At present, civil engineering students are not adequately prepared in newly developed technologies in asphalt pavement design and construction.

II. Challenge for undergraduate educators

How can we make sure that today’s young and dynamic engineering students are educated in the latest asphalt technology so that they can apply these techniques effectively into practice? The answer is by providing practical education and training in asphalt mixture production facilities, equipment of construction, methods of construction, contracts, plans and specifications, basic statistics, and quality control techniques. With this goal in mind, the Civil and Environmental Engineering (CEE) department at WPI has adopted a philosophy of strong practical experience in its undergraduate coursework. It has introduced practice-oriented textbook (6), project work on real life problem (Major Qualifying Project, required for every undergraduate for graduation), and guided field trips in coursework. This type of approach has been recommended in several cases, and its use has generally resulted in very positive responses from students, teachers and practitioners (7-12).

However, on reviewing the role of the laboratory in supporting coursework, one question that we have asked ourselves is “How can we make the laboratory experience more realistic and similar to working in field projects?” We think that the answer to this question is by taking the laboratory to the field, and conducting tests, specifically quality control related tests. Hence we feel that one very important thing, which is required for strengthening undergraduate education in asphalt technology, and which should be included as part of coursework, is field experience in

construction, specifically quality control techniques. The undergraduate students, who will be building and maintaining the pavements in near future, should be exposed to the construction and quality control techniques, so that they can have some real life field experience by the time they graduate, and do not experience a “shock” at their first exposure to construction site in their job. Also, the concepts of statistical quality control, involving representative sampling, use of statistical methods, and interpretation of statistical analysis for decision making, can be taught more effectively through analysis of real time data. This can also help in closing the gap between theory and practice – and help in understanding the application of statistical concepts for quality control in field projects. This understanding of statistical concepts for quality control is not only required in asphalt technology, but in all aspects of civil engineering construction. If the students learn these concepts through practical experience and not through lectures only, they will have a much better understanding of the concepts.

III. Development of a field and laboratory based coursework

Realizing the need for training undergraduate students on quality control concepts and methods, WPI proposed a Course Curriculum and Laboratory Improvement (CCLI) project to the National Science Foundation (NSF) for developing a coursework which will provide the undergraduate students the required tools to gain field experience in asphalt pavement construction, and understand quality control techniques required for good construction of asphalt pavements. With the help of a grant from NSF, a laboratory and field work based course was developed: 1) to provide the undergraduate students field experience in asphalt pavement construction, including quality control techniques, and 2) to teach the concepts of statistical quality control through analysis of real time quality control test data.

Prior to the development of the new course, a laboratory course, Asphalt Technology, CE 305X was offered in the Civil Engineering department at WPI. This course was developed by the author of this paper, and is conducted with the help of theoretical lecture and laboratory work with existing Superpave volumetric asphalt mix design equipment. The students design and compact different asphalt mixes as part of their laboratory work, and learn basic theories of statistical concepts through class lecture. However, at present there is no opportunity for collecting real time data from paving projects in the field, no scope of gaining field experience in construction techniques, and no opportunity to apply those concepts to draw statistically valid conclusions about the quality of a field project. A set of equipment was selected to fill these voids. The set of equipment enabled the students to work in the field during construction, collect data from the field, analyze those data, and understand the statistical nature of production and quality control. The enhancement of the course through the introduction of this equipment provided undergraduate students an overall first hand view of how things work in the field and how things are managed and controlled during construction. This gave them an opportunity to work on open-ended problems, and apply their theoretical knowledge in real life situations. This experience cannot be obtained through class or laboratory exercises.

The idea of exposing students to hands-on training for efficient teaching is not new. However, quite recently, this idea has been applied in the field of asphalt technology. For example, the Civil Engineering department at Purdue University has started a course on Superpave technology recently based on course material that was developed at the National Center for Asphalt Technology at Auburn University (5). The newly developed course on Asphalt Technology at WPI takes this innovation one step further – it integrates Superpave technology from laboratory with newly developed field quality control techniques for efficient implementation of Superpave technology in the field. This integration is believed to be necessary for ensuring that tomorrow's professionals are capable of constructing good and long lasting asphalt pavements. A similar approach of integrating construction site experience with classroom experience has resulted in very good response in the case of construction management courses (13). Also, the involvement of students in sampling, data collection, and the use of real time data and its analysis have resulted in better understanding of theory, and development of communication skills (14). Analysis of real time data not only provides students with immediate feedback on the progress of the study, but also easily allows the instructor to interact with the student in evaluating the data, as it is collected (15).

In order to provide the undergraduate students the opportunity of field experience and work with real time data, it was envisaged that the students would need to test asphalt mixtures during production and in the field. The results of these tests would then be analyzed with portable computers, and the results of the statistical analysis would be used to make conclusions regarding the quality of mixtures, and take decisions regarding any change that is required to improve quality. Hence, the primary requirement for this field experience is equipment for testing and portable computers with statistical software for analysis of data.

IV. Tools and methods of learning

Density is the single most important property of asphalt mixes. Poorly compacted asphalt mixes with low density can result in excessive consolidation, rapid oxidation, and cracking of pavements, whereas over-compacted asphalt mixes with high density can cause rutting, and bleeding of asphalt binder. Hence, the density of asphalt pavements must be controlled accurately during construction. Since most of the Superpave asphalt mix design system that is used today is based on volumetric properties of asphalt mixes, a great deal of emphasis is placed on checking and controlling proper levels of volumetric properties, such as density during construction. Although cores from constructed asphalt pavements can be tested for density in the laboratory, such methods are time consuming and cannot provide real time answers. Almost all of the asphalt paving industry and state DOTs have switched over to in-place density gauges for rapid and non-destructive determination of density for quality control. However, understanding of technology and sufficient experience are needed for efficient use of in-place density gauges. Currently there are two types of density gauges in use – a nuclear and a non-nuclear gauge. A nuclear gauge uses the interaction of gamma radiation with matter to measure density. The primary disadvantage of using the nuclear density gauge is that to use it, properly trained and certified

personnel must be available for taking proper care against possible radiation. Transportation of the nuclear gage needs specialized equipment, and the device must be re-certified on a regular basis. The industry has been looking at an alternative device for a long time. The non-nuclear density gage is fast, does not involve the risk of radiation, and hence does not require certified personnel to use it. Its use requires a very small amount of training (about 15 minutes). This tool is being used increasingly by the industry for determination of density of mixes for quality control purposes. TransTech Corporation has designed, developed the non-nuclear gauge, and sells this gauge under the trade name of Pavement Quality Indicator (PQI). The PQI is one of three pieces of equipment that was used in the newly developed course. The use of this requested equipment by the undergraduates gave them an opportunity to have field experience in a nondestructive construction quality control technique that is being used by professionals in the industry and state DOT for field projects. It enabled the students to collect density data from the field, compare actual real time data with specification, understand statistical variability, and learn the statistical parameters more effectively.

The entire course syllabus is also shown in Figure 1, in order to show how the use of this equipment fits into the overall structure of the course, and how it forms an indispensable link in the course. The basic objective of the module in which this equipment is used is to provide an understanding of production of asphalt mixes and construction of asphalt pavement. Prior to this module, the students are provided with a module regarding characterization tests and mix design of asphalt mixes. The understanding of production and construction forms the critical link between mix design and characterization concepts and identification and solution of problems, which is presented in the module immediately following the production and construction module.

At times, the measured volumetric properties of asphalt mixes such as density may fail to detect changes in gradation of aggregates or asphalt content of mixes and will indicate the process is in control when it is not. This can occur most commonly when the asphalt and gradation are varying simultaneously. Therefore, field test devices are needed to measure performance-based engineering properties for the purpose of quality control. Research project NCHRP 9-7 has recommended fast and effective triaxial testing equipment for quality control testing of mixes. This test is based on the triaxial testing principle that is used for testing soils. The asphalt paving industry and state DOTs will be using this test in the future as regular quality control tests during asphalt mixture production and pavement construction. However, at present very few people other than the researchers and manufacturers of this equipment have any experience with this equipment. Hence, there will be a significant learning curve required by the state DOT personnel before they can use it effectively.

Educating the undergraduates will not only facilitate the implementation this technology and ensure better pavements, but also reduce the number of hours needed to train new employees. The second equipment used in this newly developed coursework is the rapid triaxial test equipment – an equipment which is a versatile, low cost tool for quick evaluation of critical properties of asphalt mixes. The use of this equipment as part of an asphalt technology course

Figure 1. Syllabus for Asphalt Technology Course

Figure 2. Use of triaxial device

enables the students to understand the application of fundamental principles of material behavior in real life application of quality control testing. Similar to using triaxial tests for teaching fundamental principles of soil strength parameters, this test helps in teaching the stress-strain relationships for asphalt mixes. The direct benefits are an understanding of the relationship between theory and practice, an appreciation of the need for quick and effective tests and the quality control process. The equipment was used to illustrate the concepts of quality control during production of asphalt mixes (Figure 2). A module on mix design is presented to the students before the presentation of the production and construction module.

V. Understanding statistical concepts for quality control

An asphalt mix is produced in a plant with certain proportions of asphalt, aggregate and other additives, if any, according to a job mix formula, which is developed during mix design. When the produced mix is laid down and compacted in the field, there can be construction-related problems, such as, difficulty in achieving required density, or unstable mix under rollers. If a mix is designed properly, the cause of these problems is mostly related to problems during production. If the problems are not identified during production, a huge quantity of mix may be wasted, and a significant amount of work may have to be redone, and left unattended, construction-related problems can have significant detrimental effect on the performance and durability of a pavement. Hence, the identification of any problem during production forms the vital link between understanding mix design concepts and understanding construction-related problems in the field.

On-site analysis of data obtained from triaxial testing and in-place measurement with the PQI

requires portable computer with statistical analysis software. Since the data collection and analysis can be conducted in groups of students, five portable computers with software were procured for this course. The students used SatView software to analyze data to complement theoretical knowledge of statistical concepts. The specific items include

1. Determination of lot size for sampling,
2. Concept of random and representative sampling,
3. Determination of number of tests to be performed,
4. Concepts of target value, precision and accuracy, realistic tolerance,
5. Use of average, standard deviation, normal distribution,
6. Concepts of sampling error, material variability,
7. Use of standard deviate, statistical tables, percentage within and outside specification,
8. Use of different types of quality control charts, and identification of trends.

Accordingly, the steps of the field work consisted of setting up lots, determination of in-place density and rapid shear strength of plant produced mixes, analysis of in-place density data for determination of mean, standard deviation, percentage within limits and percent pay for contractor based on a given pay factor table, as well as analysis of shear strength data for identifying any indication of change in quality. The overall scope of activity is shown in Figure 3.

The use of real world data collection and analysis enabled the students to understand the concepts of quality control testing clearly. It showed them the sequence of work that must be performed to make objective and rational decision about the quality of paving jobs.

VI. Summary

A laboratory and field experience based course in asphalt technology was developed at Worcester Polytechnic Institute (WPI). This course will educate and train the undergraduate students in state of the art technology that is used by the industry and state departments of transportation (DOT) by providing a combined laboratory and field experience in asphalt technology. In this project, some key equipment is used to provide field experience to the undergraduate students. This equipment includes a density gauge and a rapid triaxial test equipment, and a set of portable computers with statistical data analysis software. This equipment is used along with the existing equipment at WPI in a course in asphalt technology for providing field experience and to teach quality control techniques through analysis of real time data. The innovation involved in this project is the exposure of construction, specifically, quality control techniques to undergraduate students through practical hands-on experience. Students taking this course are expected to graduate from WPI as knowledgeable and quality conscious civil engineers with fieldwork experience.

Figure 3. Overall scope of laboratory and

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