ODOT–OSU Quality Assurance Training Program: An Example of Successful Outreach Activities

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Recently, the Oklahoma Department of Transportation (ODOT) has adopted statistically based quality control and quality assurance (QC–QA) specifications for their highway construction projects. In response to training needs, ODOT entered into an agreement with the school of civil engineering at Oklahoma State University to develop and implement a QC–QA training program. The program consists of seven instruction modules that cover different aspects of construction methods, process control, and acceptance sampling and testing procedures. The development, organization, implementation, and evaluation of the QC–QA training program are described. The new specifications are briefly reviewed.

For a number of years, the Oklahoma Department of Transportation (ODOT) has pondered the idea of adopting statistically based quality control and quality assurance (QC–QA) specifications for their highway construction projects. But not until 1987 did ODOT decide the time was right to convert their recipe-type specifications to QC–QA specifications. Under the new specifications, the contractor is responsible for quality control of processes, whereas ODOT is responsible for assurance and acceptance of the finished product. In a sense, the QC–QA specifications are not end result specifications because ODOT will continue to monitor the contractor's process activities and to place some restrictions on materials and methods used.

The primary advantage of the QC–QA specifications for ODOT is the placing of responsibility for process control, including mix design, inspection, and testing, in the hands of the contractor or producer. Oklahoma's healthy increase in highway construction projects has overtaxed ODOT manpower resources needed to run the job for the contractor under the old specifications. Figure 1 shows the dollar amount of highway contracts awarded by ODOT from FY1982 to FY1989. During FY1988, contracts averaged over $28.5 million per month and at any point in time as many as 500 major construction projects were underway throughout the state. Other advantages for ODOT are the reduction in the number of disputes between the owner and contractor and the ability of the owner to enforce the contract requirements more effectively. Terms such as "within reasonably close conformity," which leave considerable room for personal interpretation, are no longer part of the specifications.

Advantages for contractors and producers accrue from their ability to choose materials, methods, and equipment, thereby enabling them to gain an edge over competitors. The risk involved in having an acceptable material or construction rejected by the engineer is defined a priori before bidding, and ambiguous interpretation or enforcement of specifications is eliminated. Most advantageous of all is the fact that acceptance sampling and testing is based on sublots. Sublots give the contractor an early warning and an opportunity to take corrective action before large quantities of nonconforming material or construction are produced.

In planning for QC–QA specifications, ODOT sought input from contractors and other states, which have implemented similar programs. The Association of Oklahoma General Contractors (AOGC), Oklahoma Asphalt Pavement Association, and Oklahoma Concrete Paving Association have been involved in the development of the new specifications. The ultimate goal has been to ensure that highway products built in Oklahoma will have good serviceability during their design lives at minimum overall costs.

Recognizing that attainment of quality depends on the motivation, knowledge, and attitude of all parties involved, ODOT sponsored a QC–QA training program for their testing and inspection employees as well as the contractor's production and quality control personnel. The school of civil engineering at Oklahoma State University was chosen by ODOT to accomplish the training tasks.

OVERVIEW OF ODOT QC–QA SPECIFICATIONS

In order to facilitate future revisions of the specifications, ODOT chose the special provision to introduce QC–QA specifications. Five special provisions have been developed for asphalt concrete pavement, portland cement concrete (PCC) pavement, structural concrete, embankments, and bases. The first two special provisions have been included in four contracts awarded in 1989. Special provisions for embankments and bases are still under review by ODOT. For each type of construction, six or seven quality characteristics have been identified for acceptance purposes. Table 1 presents the applicable characteristics for asphalt pavement, PCC pavement, and structural concrete. In addition, requirements for other material characteristics as described in the ODOT Standard Specifications must also be satisfied.

Contractors are responsible for furnishing and maintaining a quality control system that will provide reasonable assurance that the product will meet contract requirements. Contractors are required to submit a quality control plan outlining inspec-

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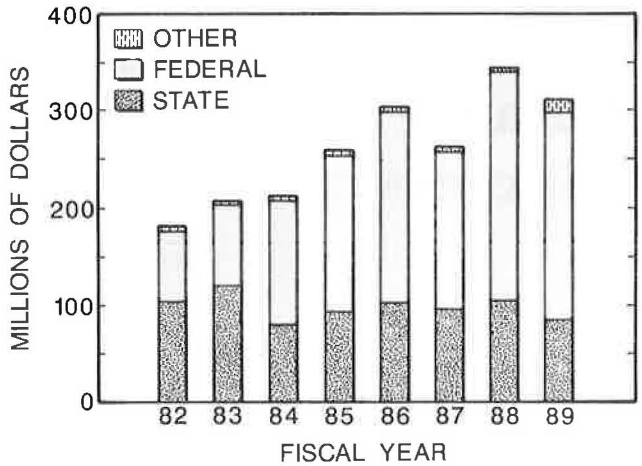

FIGURE 1 Dollar amount of highway construction awarded.

TABLE 1 QUALITY CHARACTERISTICS FOR PRODUCT ACCEPTANCE

Product Type	Quality Characteristics
Asphalt Pavement	Asphalt Cement Content Gradation Air Voids Hveem Stability Roadway Density Surface Smoothness
P.C. Concrete Pavement	Unit Weight Gradation Air Content Strength Thickness Surface Smoothness
Structural Concrete	Unit Weight Air Content Strength Cover on Steel Cracking Surface Smoothness

tion and testing procedures to be used. The special provision for asphalt concrete requires the contractor to formulate a job mix formula acceptable to the engineer.

Acceptance decisions are based on a prescribed amount of material or construction, which is referred to as a lot. Lot size is 4,000 tons for asphalt pavement, 10,000 square yards for PCC pavement, and 200 cubic yards for structural concrete. These lot sizes were determined based on economic, engineering, and statistical considerations. For acceptance testing purposes, a system of stratified random sampling is used by the resident engineer. Each lot is divided into four equal sublots and sample units are selected from each sublot using a random number table.

Pay schedules have been established for each of the quality characteristics presented in Table 1. Each pay schedule is used to determine an individual pay factor (PF) for the corresponding characteristic. Table 2 presents example pay schedules for asphalt content and Hveem stability of asphalt concrete pavements. The value of PF depends on the average of the deviations of test results from a specified standard, which may be a maximum, minimum, or target value. When a target value is specified, such as in asphalt cement content, deviations above or below the target are considered equally bad. An incentive pay factor of up to 1.05 is allowed for exceptional surface smoothness. A weighted average of individual PFs, known as the combined pay factor (CPF), is used to adjust the contract price. If a test result appears to deviate markedly from the majority of test results used for acceptance purposes, the suspected value must be closely examined by the engineer to determine its validity. The examination covers the procedures used in sampling and testing and, if necessary, a statistical analysis performed in accordance with ASTM E178-80 using an upper significance level of 2.5 percent.

ESTABLISHING A TRAINING PROGRAM

ODOT's decision to adopt QC–QA specifications was met with skepticism and concern by highway contractors. The fact that the proposed specifications would establish variable pay factors to be determined by ODOT quality assurance testing was of paramount concern. Also, the contractors were concerned about identifying a sufficient number of qualified personnel to perform their own quality control responsibilities. The questions most frequently asked by contractors were, "Who would do the ODOT quality assurance testing and how would these tests be done?" A number of individuals stated that their experience was that the testing and sampling procedures used by ODOT and contractor personnel were not uniform across the state, which tended to increase the variability of test results far beyond the inherent variability normally expected in testing and sampling results.

Contractor personnel were not alone in their concerns about the new specifications and procedures to be implemented by ODOT. Many of ODOT's district and residency personnel were also skeptical of the proposed changes. As with the contractors, ODOT personnel doubts probably resulted from a lack of understanding of the proposed changes as much or more than from the changes themselves.

The lack of understanding and resistance to the proposed changes that would arise among ODOT and contractor personnel, once the proposed changes were announced, were anticipated early in the planning stages by ODOT, AOGC, and FHWA management. Representatives from the school of civil engineering at Oklahoma State University were invited to a meeting with ODOT, AOGC, and FHWA personnel to discuss the proposed QC–QA specifications and the anticipated ramifications among the affected personnel.

After several meetings and lengthy discussions, the decision was made to develop a training program in asphalt and PCC testing procedures that would be required by the QC–QA program. Personnel from ODOT, contractor organizations, suppliers of highway construction related products, and testing concerns would be invited to participate in the proposed training. A major goal of the training would be to improve uniformity in testing and sampling procedures throughout Oklahoma's highway construction industry while simultaneously garnering synergistic effects to abate the concerns of

TABLE 2 EXAMPLE PAY SCHEDULES

Quality Characteristics	Pay Factor	1 Test	2 Tests	3 Tests	4 Tests*
		Average of Deviations From Target (Without Regard to Signs)			
Asphalt Cement	1.00	0.00-0.70	0.00-0.50	0.00-0.40	0.00-0.35
Content (Extraction	0.95	0.71-0.80	0.51-0.57	0.41-0.46	0.36-0.40
or Nuclear)	0.90	0.81-0.90	0.58-0.64	0.47-0.52	0.41-0.45
	0.80**	0.91-1.00	0.65-0.71	0.53-0.58	0.46-0.50
	unacceptable	Over 1.00	Over 0.71	Over 0.58	Over 0.50
<u>Target</u> JMF, Percent (%)					
		Average of Deviations From Target (Without Regard to Signs)			
Asphalt Cement	1.00	0.00-0.30	0.00-0.21	0.00-0.17	0.00-0.15
Content	0.95	0.31-0.35	0.22-0.25	0.18-0.20	0.16-0.18
(Digital Printout)	0.90	0.36-0.41	0.26-0.29	0.21-0.24	0.19-0.21
	0.80**	0.42-0.46	0.30-0.33	0.25-0.27	0.22-0.23
	Unacceptable	Over 0.46	Over 0.33	Over 0.27	Over 0.23
<u>Target</u> JMF, Percent (%)					
		Average of Deviations From Minimum (Considering Signs)			
Hveem Stability	1.00	(-)1	(-)0	(-)0	(-)0
(Lab. Molded	0.90	(-)3	(-)2	(-)1	(-)1
Specimens)	0.80**	(-)4	(-)3	(-)2	(-)2
	Unacceptable	Over (-)4	Over (-)3	Over (-)2	Over (-)2
<u>Minimums</u>					
2500 ADT or more & All City Streets	40				
Less than 2500 ADT	35				

* If more than four tests are conducted, the allowable deviations will be determined by dividing the allowable deviations for one test by the square root of the number of tests actually conducted.

** Unless otherwise directed by the Engineer, products testing in this range are unacceptable, and shall be removed and replaced at no additional cost to the Department.

the affected personnel and to improve ODOT and contractor communication.

The school of civil engineering at Oklahoma State University was asked to prepare a proposed training program outline. In order to assist in the proposal preparation and to serve as a starting point, ODOT provided a list of the tests that it felt would be required to achieve a satisfactory QC–QA program. A team was assembled to begin developing the training program syllabi. Working with ODOT Materials Division personnel through the spring of 1988, with frequent meetings to report progress and to solicit input from ODOT management and AOGC and FHWA personnel, the program outline was completed and accepted by ODOT in the summer of 1988.

The accepted recommendation included five-day training programs in aggregates, asphalt materials, asphalt paving, concrete materials, concrete construction, and soil mechanics, and a 3-day course in statistical quality control in highway construction. A list of laboratory equipment required for each course (or module as they soon came to be called) was developed by the faculty, coordinated with the ODOT Materials Division, and accepted by ODOT management. A cost estimate of $40,000 to develop course materials, purchase training aids and materials, and convert an open bay area of 2,500 ft^2 into a suitable training facility was presented to ODOT. Because of the number of training sessions anticipated, a training facility separate from the school's teaching and research facilities was felt essential. ODOT also was requested to purchase and loan laboratory equipment worth approximately $250,000 to the school of civil engineering. Figure 2 shows a wide-angle photograph of part of the training facility.

In October 1988, the decision to move forward with the training program was received and work began in earnest to develop course materials and visual aids at OSU while ODOT began ordering the laboratory equipment. Priorities for ordering equipment and course development were established for the seven modules on the basis of ODOT's plans for timing the introduction of the new QC–QA specifications in their contract lettings. The order of priority approved by ODOT was aggregates, asphalt materials, concrete materials, asphalt paving, soil mechanics, concrete construction, and statistical quality control. A target date of February 1, 1989, was established to have the first module (aggregates) ready for presentation.

The aggregate module was conducted during the week of February 6, 1989, and the other modules, with the exception of concrete construction, were offered on a schedule agreed to by ODOT and the school of civil engineering. The structural concrete module was delayed three months because the course content needed revision to satisfy both ODOT and contractor concerns that arose. After several meetings with ODOT and contractor personnel, all of whom had extensive experience in the design and construction of concrete pavements and structures, the course outline was approved. At this time all courses are being offered.

PROGRAM CONTENT

In meeting the major goal of the QC–QA training program, which is to improve uniformity in testing and sampling procedures in highway construction throughout Oklahoma, each participant must understand the reason for each test, the proper way to perform the test, the range of results for each test, and the consequences of not achieving specified or desired results. Participants also need to become familiar with variations in test results that will result from deviations in acceptable and uniform sampling and testing procedures and the impact on product quality, and ultimately, on the pay factors.

All modules except the statistics module begin on Monday morning and run through noon on Friday. Depending on the tests being presented, students are frequently required to arrive by 7:00 a.m. and often depart as late as 6:00 p.m., but efforts are made to limit the lecture portion of the day to no more than three 50-min sessions. The statistics module is a 3-day course, but a 1-day introductory course is also offered. The statistics courses are offered at various locations around the state. A brief description of module content follows.

- Aggregates. Instruction includes familiarization with aggregate types and sources in Oklahoma. Production, processing, and handling of aggregates are thoroughly discussed. Aggregate properties, with heavy emphasis on sampling and testing procedures, are covered. Tests include sieve analysis and materials passing the No. 200 sieve, specific gravity and absorption, sand equivalent, fractured faces, clay lumps, soundness, alkali reactiveness, freeze-thaw, Los Angeles abrasion, liquid limit, plastic limit, standard proctor compaction, and a number of related sampling and field lab tests. This course must be taken before attending asphalt, concrete, and soils courses.
- Asphalt Materials. Instruction emphasizes ODOT asphalt concrete mix design procedures. Production and testing of asphalt cement and methods of combining aggregates to meet specifications are included. The Gyratory-Shear Method of mix design is thoroughly covered. All pertinent ODOT and AASHTO test methods are presented. These tests include temperature and volume relations, testing asphalt cements, combining aggregates, gyratory shear mix design, mixing and

FIGURE 2 Training facility.

molding test specimens, bulk specific gravity, density and void analysis, and Hveem stability tests and other related procedures.

- Asphalt Paving. This module provides course participants with instruction in the operations of the various types of hot-mix asphalt plants and hot-mix sampling and testing procedures. Paving operations including delivery of hot-mix asphalt to the job site, placement of mixture on the roadway, and compaction of the mix to target density are covered. Other topics include roadway preparation, paved and unpaved surface inspection, prime and tack coats, heater planer and cold milling specifications and operations, compaction principles, inspecting the finished pavement (surface texture and tolerance, pavement density), and other related topics.
- Concrete Materials. This course is designed to give participants a working knowledge of concrete used in highway construction. Mix design of concrete according to the American Concrete Institute's ACI211.1 is introduced. Topics covered include important properties of concrete; PCC and admixtures; fineness of cement; field tests for concrete; laboratory testing; mix design; batch proportions and adjustments for moisture; adjusting trial mix for yield, slump, and air; tests on hardened concrete; and special testing.
- Concrete Construction. Instruction expands on the material presented in the concrete materials module to include producing, transporting, placing, curing, and testing of PCC both for paving and structural projects. Topics covered include preplacement activities such as grade requirements and methods of checking line and grade, form requirements, steel placement, admixtures, joint details, ordering and receiving concrete, placement and consolidation, finishing, construction problems in concrete pavements and concrete structures, and a number of related tests and topics.
- Soil Mechanics. Instruction is directed toward exposing participants to the common soils tests used in earthwork construction quality control programs. Tests include Atterburg Limits, compaction, relative density, and in-place methods of testing. Compaction quality control procedures and soil modification methods are discussed in detail. Attendees receive instruction in all pertinent standard test methods and ODOT standards.
- Statistical Methods of QA–QC. This program is designed to give participants familiarity with quality control and quality assurance through process control and acceptance sampling. Topics covered include statistical sampling, methods of describing data, sources of variability in highway products, and the basics of normal distributions. Control charts, acceptance plans, producer's and buyer's risks, specifications, and tolerances are introduced. Attendees learn to do manual calculations and are then given instruction in the use and application of calculators to the QA–QC process.

PROGRAM PRESENTATION

The requirements for administering the program are met by the college of engineering's extension office, which provides accounting and billing services, prepares mailers and publicity, accepts registrations, and conducts registration and distribution of program materials on the first morning. Additionally, extension staff provide some personal services for the participants, including assisting in obtaining room reservations, identifying restaurants and other services, delivering messages, and other assistance as needed to make the student's stay on campus more enjoyable.

Classes are conducted in a classroom equipped with the latest in projection equipment, cushioned seating, and large work tables. The classroom is located across the hall from the laboratory facility. The general format of the instruction is to introduce the test or sampling procedure to be taught, show a video and discuss the proper procedures for conducting the test, adjourn to the laboratory where the tests are run individually or in teams of four students, and reassemble in the classroom to discuss the test results and lessons learned. The 24 students, which is maximum enrollment, are placed into teams of 4 students on the first morning on the basis of questionnaires completed by the students as they sign in. A special effort is made to ensure a mix of the students from ODOT with those from contractors, suppliers, and testing organizations. Also, the more experienced students are spread throughout the six laboratory teams to take advantage of their expertise and experience by assisting the less experienced students.

Laboratory teams formed with personnel from various organizations were intended to improve communications between personnel from throughout the highway construction industry, and the practice has been successful. The fact that the experience level of the students varies from extensive to none at all creates a challenge for the instructor to present the material so as not to bore the former or totally confuse the latter. Experienced students are called on to relate their personal experiences or observations and requested to assist the less experienced students, resulting in an interest level that has remained high for most. Many experienced technicians, who discovered that they had not been following correct procedures over the years, began to develop a better understanding of the purpose of the tests and the effect of poor test results. Such realizations also contributed to maintaining a high level of interest in the instructional material for the experienced students.

The training program was designed primarily for technicians who would be performing the tests in the field or at the plant for the contractor's process control and for ODOT personnel who would be conducting the QA testing. However, a number of organizations have elected to have engineering personnel in decision-making positions attend as well. Most of these individuals have been favorably impressed by the program and have expressed gaining a greater appreciation for the data they were required to examine and evaluate. Likewise, many of the engineers who attended the technician training program felt that the experience would be valuable in fulfilling their supervisory responsibilities as well as in decision making related to the determination of pay factors or in negotiating claims.

The 24 slots for each module are generally committed on a first-come basis with the exception that seven positions are reserved for ODOT. The first time that aggregate, asphalt materials, and concrete materials were taught, the 24 slots were divided equally between ODOT and AOGC. ODOT personnel from the division in which the first QC–QA specification contracts were to be let received these slots, and contractors who were on the prequalified bidding list and were expected to bid on the contracts were offered the others. By the end of 1989, 11 months into the training program, 600 students will have completed one of the modules.

Instructor recruitment for this extensive and continuing training program has proven to be an enlightening experience. ODOT provides several lecturers for specific topics. Others come from the Oklahoma Geological Society, the Oklahoma Asphalt Paving Association and other trade associations, active contractors with extensive experience, and personnel from materials suppliers associated with highway construction in the state. But most are retired ODOT, FHWA, and contractor personnel with extensive knowledge of highway construction who want to make a contribution to the training of young engineers and technicians. The honorariums they receive for their participation appear to be far less important to them than the feeling of satisfaction they derive from making a contribution to the efforts to raise the quality of construction in Oklahoma.

Students are given a 2- to 3-hr written examination at the conclusion of the course. This examination is open book with objective-type questions on the various tests conducted during the course. A number of problems are given that require manipulating data and plotting test results. The failure rate has ranged from 0 to 25 percent of a class, but the failure rate for all modules since the program began in February is 5 percent. Students who fail the examination are allowed to retake the examination the next time that particular examination is offered. To date, no one who has retaken the examination has passed although some improvement in their scores was noted.

PROGRAM EVALUATION

Following the final examination, students are asked to submit a completed evaluation form, which was distributed on the first day, on the course content and each instructor who lectured during the module. Most of the comments have some degree of validity and many have resulted in modifying course content, procuring additional equipment, implementing additional safety precautions, and replacing visual aids. Additionally, three instructors have not been invited back for further participation on the basis of consistently poor student evaluations. Each module is continuously examined and evaluated to improve the quality of the level of instruction and technical content.

Occasionally, a negative comment is received from an employer who felt that by sending an employee to one of the 5-day training modules a totally proficient and technically competent materials technician would be gained. However, in these training modules, as in most learning experiences, the student can only be exposed to the information. Constant application of the information over a period of time is required to gain or develop any degree of proficiency. Thus, ODOT and AOGC are striving to educate their constituents that the purpose of the QC–QA training program is not to create instant technicians, but to provide their employees with a firm technical base from which to develop.

As a result, one lesson learned is making clear the purpose of the training program early so as not to distort individual or corporate expectations. Another is that the modules should be scheduled to concentrate on the nonconstruction season from November through March. From April through October, meeting the minimum number of students required to break even economically was difficult.

It was anticipated that some individuals might have difficulty with the basic mathematics required to manipulate the data resulting from testing and sampling which would be required in the training modules. In order to ensure that all students possessed the basic mathematics skills to successfully complete the training, a 20-question mathematics test was developed and administered by the state's extensive vocational-technical network. All individuals, except those with proof of having taken a college algebra course, are required to take and achieve a designated score on the test before being accepted into a module. One problem area not anticipated was that several students have had reading problems. Usually, these students are experienced technicians who have a firm grasp of the technical procedures and can work with numbers but cannot use reference specifications or read and comprehend examination questions. A solution for this problem has not been identified, but consideration is being given to adopting a comprehensive reading examination requirement.

In the future, the number of students to be trained is expected to remain constant for the next year. After that, the number of module offerings will probably decline to a level where the number of technicians in the industry can be maintained as individuals enter and leave the industry.

CONCLUSIONS

A training environment in which ODOT, contractor, and other industry personnel study and socialize together improves communications and enhances professional respect. This benefit was evident by the number of business cards and telephone numbers exchanged each Friday as the participants were preparing to depart.

Effective training is feasible in which the students have varying levels of education and experience. Students prefer a curriculum heavy on hands-on laboratory experience and light on formal lecture. Video tapes are not well received for test demonstration purposes and slide presentations get only marginal acceptance. Live demonstrations and presentations are greatly preferred by most participants.

Instructors having diverse backgrounds and proven field experience are important. However, expertise, experience, and knowledge of the subject alone are not sufficient to make an instructor well received by the students. Instructors must have the ability to speak publicly, remain on the subject being presented, and not run over the allotted time. Instructors should not be used for extended periods of instruction or laboratory work because a variety of personalities and personal demeanors seems to keep the interest level of the participants higher.

Only time will tell the impact of the ODOT QC–QA training program on the quality of highway construction in Oklahoma. Similarly, the impact of the QC–QA specifications on the highway construction industry has yet to be determined. However, a great deal of personal and professional satisfaction has been derived by a substantial number of individuals from academia, state and federal governments, and the private construction industry who were responsible for developing and initiating this program to improve the quality of highway construction projects in Oklahoma.

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