Quality Assurance: Specification Development and Implementation

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The benefits of using quality assurance (QA) specifications can be lost if the specifications are poorly developed or improperly implemented. Ten steps must be followed in developing a QA specification. At each step, critical decisions affect the specification's effectiveness. Each of the steps and the factors that should be considered in making decisions are discussed. Particular emphasis is given to the handling of rejected lots and the development of pay adjustment schedules. The activities required for the successful implementation of QA specifications are also presented and emphasize the need for training of both agency and contractor personnel.

Quality assurance (QA) specifications offer many potential benefits when compared with the specifications traditionally used for highway construction. For example, QA specifications provide the contractor a more direct incentive for achieving quality; they reduce the adversarial relationship between the inspection staff and contractor; and top management of the highway agency benefits by being placed in a much better position for supporting construction quality. However, these benefits can be realized only if the QA specifications are properly developed.

The steps required to develop QA specifications are presented, and many of the decisions that must be made are discussed. The percent-defective approach for the development of QA specifications and pay schedules is emphasized. Other approaches (*1,2,3*) may be just as appropriate, if not more appropriate, in many cases. Although these other approaches are not discussed, most of the steps and considerations described would also apply to them.

QA SPECIFICATION DEVELOPMENT

Step 1—Identify Item

The first step in developing a QA specification is to determine whether a particular item is important enough to warrant the cost and effort associated with a formal acceptance program. This decision should consider

1. The likelihood of the item being inadequate without a formal QA program;
2. The risk of failure if the item is inadequate;
3. The consequences (cost and safety) of failure; and
4. The effort and cost associated with the QA program.

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Step 2—Determine Controlling Property

Once the construction item has been identified as warranting use of a QA acceptance program, the characteristics that are to be controlled must be identified. The ideal characteristics are those properties of the item that control the item's performance or acceptability and that are considered in the design of the item. In some cases, the specific property cannot be controlled but another related property can be (e.g., embankment compaction and soil moisture in lieu of some strength measure). Typical controlling properties for pavement construction include thickness, smoothness, compressive strength, density, aggregate gradation, and asphalt content.

Step 3—Select Method of Test

Once the controlling property has been identified, the specific method of test must be selected. The test should directly evaluate the property identified in Step 2. Generally, a standard test procedure that has been adopted by AASHTO, ASTM, or other recognized standardization body should be used. Because the standardized test procedures are published, the details of how they are performed are readily available to contractors, consultants, and testing firms. Also, the results generated from the standardized tests are more universally acceptable and, as a result, have a better chance of being accepted if disputed in court. In the absence of an acceptable standardized test, the agency should either fully describe the test within the specifications or develop and disseminate publication of its own test methods.

In selecting the test method, both the accuracy and precision of the test should be considered. An accurate method of test will, on the average, result in the correct value, but the individual test results may vary considerably from the correct value. A precise test will consistently give the same value (if the true value remains unchanged), but the value given may not be correct. The ideal test is both accurate and precise. Test procedures deviate from both accuracy and precision to varying degrees.

Of these two components of testing error, the lack of precision may be more troublesome for the QA program. The lack of precision results in testing variation that contributes significantly to the apparent variation of the construction and can make the determination of the actual variation quite difficult. To compensate for poor precision, the number of tests required for a given level of risk must be increased.

The lack of accuracy, on the other hand, can be accommodated by use of calibration. For example, some agencies use nuclear density tests for asphalt density control even though they believe that the result is not accurate. However, this test is precise (and fast) so they calibrate the nuclear density reading through correlation with core densities from a test strip.

Other factors that must be considered in selecting the test method are the effort and level of expertise required of the tester and the speed and timeliness with which test results can be made available. Testing effort and expertise obviously reflect cost and resource commitment. Judgment must be exercised as to whether the required commitment is warranted. The rapid determination of acceptability is important for both the agency and the contractor to check on the contractor's quality control efforts and to limit the possibility that significant quantities of unacceptable work are incorporated into the project.

Step 4—Define Acceptability Limits

Perhaps the most critical and difficult part of developing a QA specification is the determination of exactly what levels of quality are acceptable and what levels are unacceptable or rejectable. In general, some specification limit has probably already been established for the property. This limit may be used as a beginning point for selecting an appropriate acceptability limit but it must be used with caution. For the QA specification, the agency must decide (a) whether the existing limit is realistic, and (b) if it is, the percentage of construction it is willing to tolerate outside the limit (percent defective).

Typically, the acceptable quality level (AQL) is set at 10 to 20 percent defective. This percentage must be evaluated with care, particularly when applied to a specification limit borrowed from a traditional specification. The traditional specification limit is typically viewed as an absolute limit when, in fact, it usually permits 50 percent defective. If an AQL of 10 to 20 percent is applied with an existing specification limit, the agency may be unintentionally tightening the quality requirements. This change may force an increase in the normal construction quality and cause an unwarranted increase in bid prices. Conversely, if it is set too high, bid prices may go down but at the expense of poorer overall performance and higher maintenance costs. The first action in defining AQL should be to examine past performance. This examination should not be based on hard data from past projects and should not be limited to the expert opinion and/or intuition. Also, the data examined should be obtained in an unbiased manner and should not be limited to project record data, which are frequently biased.

There should be three objectives in the examination of past performance. First, the examination should attempt to determine what general property level can be expected to give good performance. Second, an attempt should be made to determine the property level that generally gives poor performance. The third objective is to identify the quality level generally achieved in the past and whether that quality gave acceptable performance. If past performance was generally acceptable and the past quality level can be reasonably identified, that level can be the basis for setting AQL. If performance was less than acceptable, AQL should be set somewhat higher than the quality achieved in the past.

In addition to examining past performance, the agency should also look at the capabilities of the contractors on current projects. Obviously there is no need to set quality requirements lower than the good contractor, using normal diligence, is capable of achieving. It would be disastrous for the contractor and the agency if quality requirements were set higher than the contractor can achieve.

Contractor capabilities can be examined to some degree by analyzing test data from current and recent projects. However, it must be recognized and accepted that non-QA sampling and testing are generally biased. To get a true picture of current construction quality, an independent random sampling and testing program is necessary. This program should include sampling and testing from a number of projects, including a range of contractor quality from poor to excellent.

Step 5—Identify Reasonable Risks

The key to understanding QA sampling and testing is the recognition that true quality is never known; it is only estimated from the samples. As a result, there is always a risk that acceptable quality will be judged as unacceptable and that unacceptable quality will be judged as acceptable. Once the acceptability limits have been established, the agency must define the degrees of risk that are to be assumed by the contractor and the agency.

The manner in which the risks are shared between the agency and the contractor should be based on the importance of the item and the severity of the consequences of its failure. For an important item that results in severe consequences if it fails, the agency risk must be small but the contractor risk may be somewhat greater. For minor items having only limited impact in the case of failure, the agency may assume a relatively higher risk with a smaller risk being placed on the contractor. The QA sampling plan is designed to limit these risks to acceptable levels considering the cost and impact of an incorrect decision.

Step 6—Select a Sampling Plan

The acceptance sampling plan is selected based on the principles of small sample statistics. The objective of the selection is to balance the cost and effort of testing against the risks of an incorrect acceptance-rejection decision. Because acceptance sampling is based on a small sample, there is always a risk that the test results will indicate that acceptable work is unacceptable and that unacceptable work is acceptable. The use of larger sample sizes reduces the risks but increases the cost, effort, and time involved in testing and reaching a decision.

A necessary and key element of selecting the sampling plan is to determine and examine the plan's operating characteristics (OC) curve (Figure 1). The OC curve is a plot of the probability of accepting the construction versus the quality of the work. It is a function of the sample size and acceptance level, and it identifies the level of risks involved. The OC curve displays the ability of the sampling plan to discriminate between acceptable and unacceptable work. An ideal OC curve would show a 100 percent probability of acceptance at the AQL and 0 percent thereafter. However, because of the use of small samples, no OC curve can match this ideal.

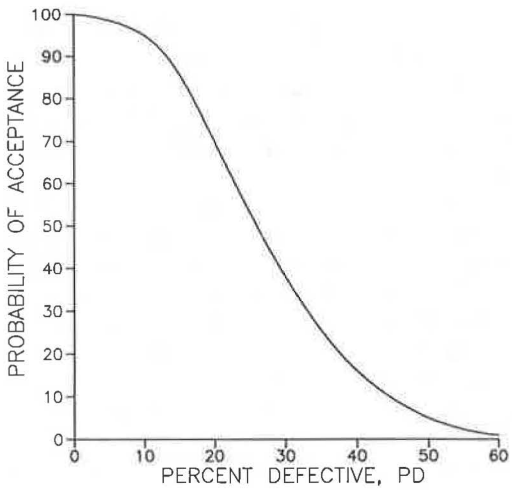

FIGURE 1 OC curve for example sampling plan.

Fortunately, there is almost always a gray area of acceptability between the acceptable and rejectable quality levels. A sampling plan is selected that limits the risks of rejecting AQL work and accepting RQL work. An example borrowed from AASHTO R9-86 (pp. 1145–1178) illustrates the selection process:

EXAMPLE: The specification limit for an aggregate base course is 7% passing the #200 sieve. Past experience has shown that bases meeting this specification (7% or less passing the #200) perform well while bases having 10% or more passing the #200 sieve perform poorly. The typical standard deviation for #200 material in base course samples is about 1%. Since 10% is 3 standard deviations (10−7) above the specification limit, a base material that averages 7% passing the #200 would have virtually nothing exceeding 10% passing; but, in terms of the specification limit, a material averaging 7% passing the #200 would be fifty percent defective (Figure 2). Thus, a logical value for RQL is fifty percent defective.

The selection of AQL is not as simple or logical. However, a small amount in excess of 7% passing would not create a major problem. Therefore, AQL is set at ten percent defective.

The risks deemed to be acceptable are 5% probabilities of either rejecting AQL work or accepting RQL work. An examination of sampling plans in AASHTO R9 reveals one that just meets these criteria. Under this sampling plan, 8 samples will be taken and the percent passing the #200 sieve determined for each. The mean (X) and standard deviation (S) of the test results are used to calculate a quality index (Q):

$$Q = \frac{7 - X}{S}$$

The base course is accepted if Q is equal to or greater than 0.665. The OC curve for the sampling plan (Figure 1) shows that the probability of acceptance is 95% at ten percent defective (AQL) and 5% at fifty percent defective (RQL).

Note that the example sampling plan involves both the mean and standard deviations of the test results. To have a good QA specification, it is vital that both parameters be included in the acceptance process. Some agencies have developed plans based on only the mean (or average) of the test results. Although these plans control the average quality, they permit acceptance of work that is extremely variable.

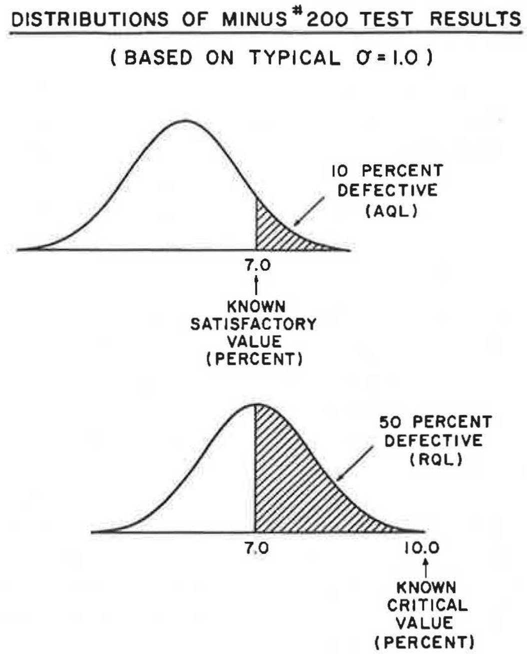

FIGURE 2 Illustration of AQL and RQL for example selection of an acceptance sampling plan.

Highway performance is generally not controlled by the average construction quality but by the quality extremes. The use of both mean and standard deviations is necessary to control these extremes.

Other decisions that must be made in establishing the complete sampling plan are (a) whether to use an attributes plan or a variables plan; (b) whether to use random sampling or stratified random sampling; and (c) what quantity of work should constitute a lot. An attributes plan is one in which individual samples are categorized as good or defective and in which acceptance is based on the number defective. A variables plan is one, like the example, in which a property is measured on some continuous scale. Variables plans require fewer samples for a given level of risk and are normally preferred for most highway applications.

A lot must represent a population of consistent construction operation. Generally the lot should be as large as possible and still ensure that a single population or process is being sampled. With larger lots, more samples can be taken and the risks of incorrect acceptance or rejection can be reduced.

Step 7—Handle Rejected Lots

A major feature of the QA specification is the inclusion of explicit methods for handling construction items that are found to not conform to the desired quality standard. There are three possible ways of treating such construction: (a) remove and replace the work, (b) rework until the desired quality is achieved, or (c) accept the work at a reduced level of pay.

Each of these methods can be appropriate; for some types of construction, all three may be used in the same specification. Of course, in many cases reworking is not possible (e.g., concrete strength) and even when it is possible, provisions must be included to ensure that effective reworking occurs.

Reworking also implies retesting. Most QA specifications include some retesting provision even for items that cannot be reworked. Careful consideration must be exercised in establishing retesting provisions because they have a very significant effect on the risks associated with the sampling plan. Perhaps the best way to visualize this effect is to consider a very simple example.

EXAMPLE OF RETESTING CHANGING RISKS

Suppose bags of beans are being sampled and that only red beans are considered acceptable. The sample consists of drawing just one bean from a bag. If the bean is red, the bag is accepted. If the bags are filled 50-50 with red and green beans, there is a 50 percent probability of accepting any one bag. However, what happens if the supplier is allowed to "rework" and resubmit each rejected bag. If nothing is done to them, the rejected bags again have a 50 percent chance of being accepted. Thus, the retesting provision has caused the probability of acceptance to jump from 50 to 75 percent (50 percent + 50 percent of 50 percent).

In establishing a retesting provision, one must decide whether the provision is to be for true retesting, in which the original test results are discarded, or whether additional tests will be made and used with the original test in judging acceptability. Both approaches have advantages and disadvantages.

Advocates of additional testing argue that cost is associated with testing and that it is wasteful to discard valid test results. In fact, as illustrated by this simple example, retesting without considering the first results can increase the likelihood of accepting poor quality work. At the same time, however, there may be some question as to the validity of the first tests. Obviously, if the tests are not valid they should be discarded and replaced.

The acceptance of marginally unsatisfactory work at a reduced price is generally considered to be the hallmark of a QA specification. Most QA specifications include some pay adjustment provision that provides for the acceptance of poorer-quality work at some descending scale of pay. The pay adjustment schedule should not be arbitrary and must be fair to both the highway agency and the contractor. This can be accomplished by basing the schedule on the effect of quality on future operation and maintenance costs. Pay adjustment schedules are discussed in detail later.

There is also the danger that a retesting provision can be used by the contractor as a method of quality control. This risk can be limited by requiring the contractor to pay for all failing tests at a rate high enough to encourage the maintenance of the contractor's own quality control (QC) program.

Step 8—Define Contractor QC Responsibility

Under the QA specification concept, the responsibility for process control is placed solely on the contractor. That means that all testing done for the purpose of setting proportions, determining the adequacy of roller patterns, and so on, is to be done by the contractor. Agency testing is limited to the determination of acceptability. The agency must decide how explicitly to define the QC activities of the contractor.

Some QA specifications have simply stated that QC is the responsibility of the contractor without stipulating any QC requirements. Other specifications have stated specific testing and documentation requirements. Still others have stipulated that the contractor is to submit a QC plan for review and approval.

The agency might also consider including the contractor's QC test results into its own acceptance program. A frequent criticism from opponents of QA specifications is that they result in a duplication of testing effort. Agencies can avoid much of this duplication by using the contractor's tests as a part of the acceptance process. To do this, specific requirements for contractor QC activities must be stated.

A good example is the procedure for bituminous concrete, used by the West Virginia Department of Highways (*4*). West Virginia established guidelines for contractor QC that set minimum acceptable testing and documentation requirements. The contractor must adopt a QC plan that fits within these minimums and must use a certified technician to conduct the sampling and testing. The department observes at least some of the contractor's QC testing and has the option of using these tests for acceptance or of performing its own tests. (Any provisions along these lines must be developed with care so as not to violate FHWA Technical Advisory T5080.11, which requires acceptance testing to be performed by the agency.)

Step 9—Convert to Specification Language

The QA plan that has been developed must be converted to specification language. This means that the plan must be spelled out in a clear and unambiguous manner that is open to only one interpretation. The specification must precisely define the construction requirements to be fulfilled by the contractor and must clearly define the role of the agency and its representatives (inspectors). The division of responsibility for process control and acceptance must be clear and distinct. The acceptance provisions must explicitly describe the consequences for nonconforming construction and must present them in a manner that cannot be misinterpreted.

Step 10—Review for Practicality

Once the entire QA specification has been drafted, an independent review should be made to ensure that its provisions are practical and enforceable. The review must consider the consequences of the specification to the agency as well as to the contractor. A concerted effort should be made to ensure that the acceptance and penalty provisions are fair. The acceptance criteria should be reviewed to ensure that the specification does not require an unnecessary improvement in quality and that it provides adequate guarantees that the needed quality will be achieved.

PAY ADJUSTMENT SCHEDULES

Most QA specifications include provisions for adjusting the pay given for work that does not meet the desired quality. The pay adjustment schedule provides a rational way to accept work that is not quite up to the desired quality level but not so bad as to warrant removal and replacement. In a sense, the pay adjustment schedule may be considered a way of transition from AQL work, for which full pay is warranted, to RQL work, which must be removed. The pay adjustment schedule also serves as a buffer that helps accommodate the uncertainty associated with acceptance testing.

There are two types of pay schedules—stepped and continuous. Stepped pay schedules provide for reduced pay in specific steps for various ranges of quality. For example, a specification might call for 100 percent pay for 15 or less percent defective (PD), 98 percent pay for 15.1 to 20 PD, 95 percent pay for 20.1 to 25 PD, and so on. The continuous pay schedule, on the other hand, is expressed as an equation, usually with an upper limit (100 percent pay) and a lower limit beyond which removal and replacement is required. For example, a continuous pay schedule could call for all lots having an estimated PD in excess of 15 but less than 50 to be paid for using the equation:

$$\%\text{Pay} = 100 - (\text{PD} - 15)$$

The stepped pay schedule has been used most often, probably because it is easy to view the schedule and see how it will be applied. Also, with the stepped schedule, no computations are needed. However, there is a disadvantage. The difference in pay between steps is generally quite significant to the contractor. This can prompt serious disputes when test results fall very close to the border between pay categories. Even small pay differences may appear to be significant when the tests are borderline. The continuous pay schedule avoids the problem of borders. Borders simply do not exist (except at the rejection end).

The development of the pay adjustment schedule must be fair to both the highway agency and the contractor. It should ensure that the contractor receives pay for "normal, good" quality work and that the adjusted pay for poorer-quality work is commensurate with its effect on the highway agency. A common basis for the development of the pay schedule is the effect of quality on the life of the facility and the future additional costs to be expected due to the poorer quality.

Expected pay curves should be generated to evaluate any proposed pay schedule. The expected pay curves are similar to OC curves and may be developed from them. The expected pay curves are a plot of the pay percentage a contractor can expect to receive versus the quality of the construction. Examples of expected pay curves are shown in Figure 3.

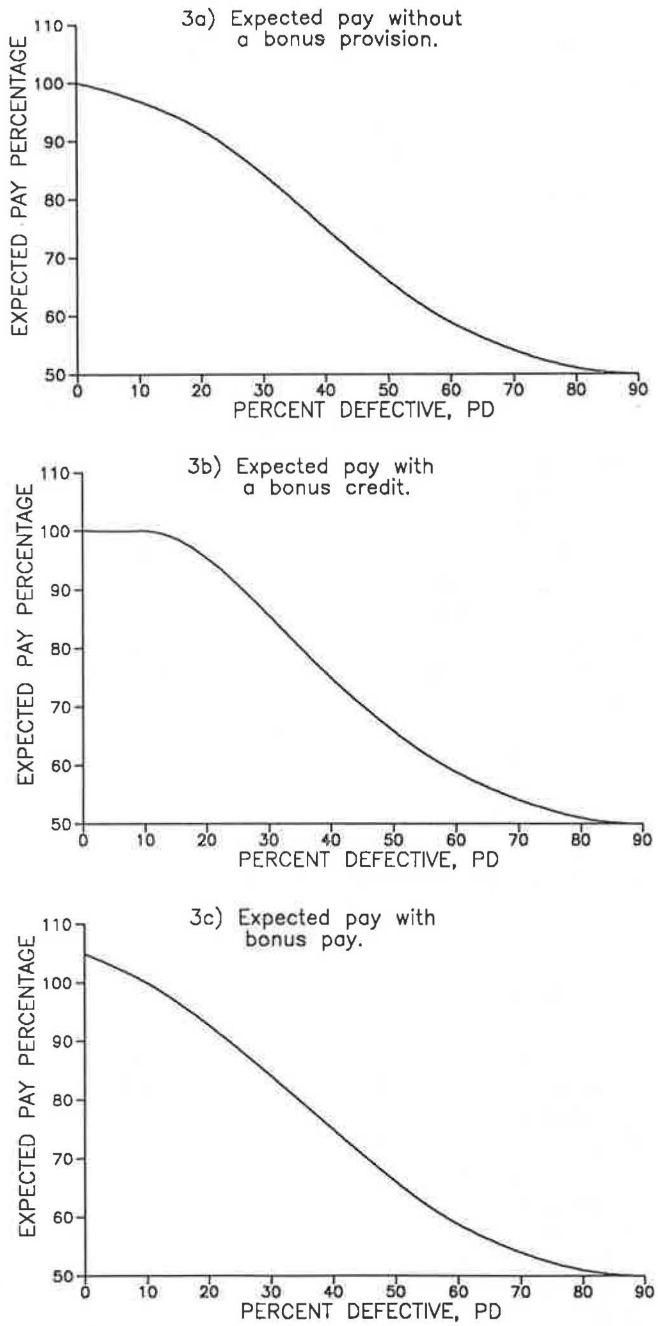

FIGURE 3 Expected pay curves illustrating the effect of bonus provisions.

BONUS PROVISIONS

An unfortunate consequence of most pay schedules that have been used is that the expected pay for the typical contractor is less than the contractor's bid. Most pay schedules provide a maximum pay equal to 100 percent of the bid price with no incentive for superior quality work. The philosophy has been: "We specify what we want and that is what we will pay for. If we wanted better quality, we would have asked for it."

However, this philosophy fails to recognize the effect of chance and the laws of probability. Regardless of its true quality, each lot has some probability of being rejected (or accepted at reduced pay). Because of that risk, the probability of accepting work that meets the AQL is always less than 100 percent. Consequently, the expected pay for work of this quality is less than 100 percent unless some provision is made to adjust for the risk.

This discriminatory feature can be avoided by including a bonus provision in the pay schedule. There are two options for the bonus provision. The bonus provision either may result directly in bonus payment (pay in excess of the bid price) or may simply be used as a crediting provision to balance the risk and offset unwarranted penalties. With the crediting approach, the contractor is provided credit for lots of superior quality and is able to draw from that credit when a lot is found to require a penalty. One way of doing this is to provide a schedule with pay percentages in excess of 100 percent but to limit the overall project pay to not exceed 100 percent.

The crediting approach, however, is not without risks. It may promote greater variability and result in lower overall quality. If a contractor builds up enough credits early in a project, he may be tempted to use those credits near the end.

Figure 3 illustrates the effect of bonus pay on the contractor's expected pay. Figure 3a shows the expected pay for a typical pay plan that does not include a bonus provision. Note that the expected pay is equal to the bid price (100 percent) only for zero percent defective, which is unattainable (unless very loose control limits are used). Figure 3c illustrates a similar pay plan with a provision for 105 percent pay for superior work. This pay plan has been designed so that the expected pay at AQL (10 PD) is 100 percent. If this pay plan were modified to provide only a crediting provision, Figure 3b would represent the expected pay.

The bonus provision also serves as a very strong incentive to the contractor for high-quality work. In fact, there is reason to believe that a bonus provision for superior work provides a stronger incentive than does the more usual penalty provision for poor work. The penalty provision provides only an economic incentive. The bonus provision provides both an economic incentive and a psychological incentive from the pride that comes with achievement. Also, the pride of achievement is felt not only by the contractor but by everyone connected with the project, including the workers and the highway agency's inspection staff.

IMPLEMENTING QA SPECIFICATIONS

The implementation of QA specifications should not be undertaken without careful planning and preparation. Many within the highway construction community are unfamiliar with statistical concepts and have grown quite accustomed to "business as usual." This attitude is especially true within the contractor community but is also true for many seasoned and experienced highway agency personnel. In some cases, the distrust of QA concepts is based on experience with trial usage of QA specifications that were not well designed or were implemented without proper preparation. The following activities should take place as part of the implementation process.

LONG-RANGE PLANNING

The implementation of QA specifications should begin with the development of a long-range plan to govern the development of the specifications and to gain the support and acceptance required for the specification use to be successful. The initial phase of the plan must be to establish full support from the agency's top management. Quality begins as an attitude and requires support from the top if it is to be achieved. Top management must first be convinced that good quality is needed and then be convinced that a properly developed QA plan will help ensure that quality.

Contractors and material suppliers must also be included and considered in the long-range planning. Their input and advice should be sought in determining where to begin using QA, what to test for, and how fast to proceed with implementation. A key element in approaching the contractors and suppliers is to make it clear that (a) their ideas and advice will be carefully considered, and (b) the use of QA will permit them to have greater control over their work.

Training Program

The implementation of QA concepts requires much preparation. Perhaps the most important preparation is the training of all parties who will be affected by the QA specification. Consequently, a training program must be conducted for agency personnel, contractors, and suppliers.

Agency training should be directed at two levels and conducted in two phases. The first phase and level would be for middle management (construction, project, and resident engineers). This phase should focus on statistical applications and QA concepts. The objective of this phase is not to train the engineers in the details of the specifications that will be used (they can read the details) but to educate them about why QA is being adopted and how it works. A major goal of this phase should be to convince those skeptical of the approach that it is valid.

The second training phase for the agency should begin near the time that the QA specification is being implemented. In fact, it probably should begin just before the first QA project and be geared toward training the inspectors and technicians for their roles under QA. This phase is especially important because the role of the inspector is changed somewhat under QA and because any testing that the inspectors and technicians may perform (or witness) is vitally important. In this regard, this phase may include two types of training: (a) inspector training, and (b) technician testing training.

Training for the contractors and suppliers may require three phases. The first phase should concentrate on management. This phase will be similar to the first phase of the agency training; that is, it will concentrate on providing the contractors and suppliers an understanding of QA and statistical concepts. In fact, with proper planning some or all of this phase might be held together with the training for the agency's middle management.

Perhaps the most important objective of the first training phase for contractors is to alleviate their fears and objections regarding QA. Experience has shown that most contractors are opposed to and afraid of QA when first confronted with it. However, once the good QA specifications have been implemented, most contractors (especially the better contractors) favor QA.

The second phase for contractors and suppliers will involve providing some training for the contractors' technical staff. Through the years, most contractors have come to rely on the inspector for production control. In particular, the testing of materials and the proportioning of mixes have been left in the hands of the inspector. This phase should be geared to providing some assistance to the contractors in resuming these responsibilities. Along these lines, some highway agencies have established technician certification programs. This phase may well be conducted in conjunction with the training of the agency's testing technicians.

The third phase for the contractors and suppliers should come just prior to the bid letting that involves use of the QA specification. This phase may be conducted as a pre-bid meeting in which the details of the specification are presented. The training in the third phase should be geared toward the estimators and the job superintendents.

Initial Specification Draft and Review

An initial specification should be drafted following the steps outlined earlier. The initial specification should be complete and ready for insertion into a construction contract. However, those involved in its development must view it as a draft subject to critical review and significant modification.

The draft specification should be subjected to critical review both internally and externally by those who will be most affected by it, the contractors and suppliers. The internal review should be conducted by persons not associated with the draft's development and should include engineers experienced in design, construction, and materials.

The contractors' and suppliers' reviews should be made by firms or individuals selected by their representing agencies (e.g., Associated General Contractors, paving associations). Their reviews need not govern the revision of the draft but must receive sincere and careful consideration. A very important part of the successful implementation of QA is to get acceptance by the contractor-supplier community.

Transition and Trial Period

The initial use of QA should begin slowly. An abrupt change from traditional specifications to QA specifications could be disastrous. "Bugs" in the specification will need to be worked out, and both agency and contractor personnel will require some time to adjust. Therefore, a trial period should be used to phase in the specification. One approach that has been used is to seek a contractor willing to work under the specification voluntarily. Another approach is to have a mock usage of the specification on a job by simply simulating its use and determining the effect it might have had if it had been in force. A third approach is to place the specification in only a few contracts, perhaps beginning with one.

Specification Adjustment

The final phase of implementation is the adjustment period. Once the specification has been used, a debriefing should be held. Comments regarding effectiveness and problems should be sought from everyone associated with its use. From these comments, adjustments should be made to improve the specification for future use.

SUMMARY

Once the decision has been made to develop a QA specification for an item of construction, the property (or properties) that relate to the performance of the item must be identified and an appropriate method of test must be selected. An acceptance sampling plan must then be adopted that provides a reasonable assurance that acceptable construction will not be rejected and that unacceptable construction will not be accepted. In addition to the acceptance plan, procedures need to be established on how to handle construction that is found to be noncompliant with the acceptance standard. Normally these procedures will involve the development of a pay adjustment schedule that provides for reduced pay based on the degree of noncompliance. The acceptance plan and pay adjustment schedule should be analyzed using OC and expected pay curves. Care must be exercised to ensure that the pay adjustment plan provides full pay for acceptable construction quality. This will necessitate the use of a bonus provision. The QA specification is completed by identifying the contractor's role and responsibility relative to process control (QC).

The implementation of the QA specification should not be done hastily. A long-range plan is needed for specification development and for training all parties who will be affected by its use. For the implementation to be a success, top management support must be obtained and the contractor-supplier community must be involved throughout the development and training process.

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