ARE YOU GETTING YOUR MONEY'S WORTH IN STREET CONSTRUCTION

Charles F. Scholer, Director
Highway Extension and Research Project for Indiana Counties and Cities

Presented at the Annual Meeting of the Indiana Association of Cities and Towns
Fort Wayne, Indiana

September 21, 1988

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Reference: "Quality Assurance for Local Governments", Report No. FHWA-IP-83-1, Federal Highway Administration, U.S. Department of Transportation, February 1983.

EXECUTIVE SUMMARY

Poorly built and maintained roads are both expensive and inconvenient to taxpayers. The quality of work performed on roads and streets directly influences the useful life of the facility, maintenance costs, levels of service and user costs.

QUALITY ASSURANCE is a broad term that refers to all of the activities necessary to verify, audit and evaluate quality. Quality control is one element of quality assurance. There is a need for this broad concept of quality assurance because the quality of a road or street is influenced by many activities other than just field operations. Planning establishes quality goals and broad objectives. Design implements those objectives and sets the specific levels of quality to be achieved. The preparation of plans and specifications establishes the rules under which the quality will be achieved. Construction builds the project to the level of quality specified. Finally, maintenance activities retain the level of quality required.

A quality assurance program does not have to be complicated. It should simply be a common sense approach to ensuring that the public dollar is well spent. A quality assurance program should address four questions:

- What do we want?
- How do we order it?
- Did we get what we ordered?
- What do we do if we didn't get what we ordered?

Quality assurance activities should include the control of work performed by developers, permittees and in-house forces as well as contractors. Most new construction at the local level is performed by commercial and residential property developers. These roads should not be considered a "gift." They frequently represent significant additions to a local agency's responsibilities.

The implementation of a quality assurance program in a local government involves changing public policy. The engineer must understand this political process to be successful. The perceptions, attitudes and needs of all concerned individuals and groups should be considered. A quality assurance program may require reorganization, staffing changes and training. These changes can all be on a phased, systematic basis and need not be overly expensive or traumatic.

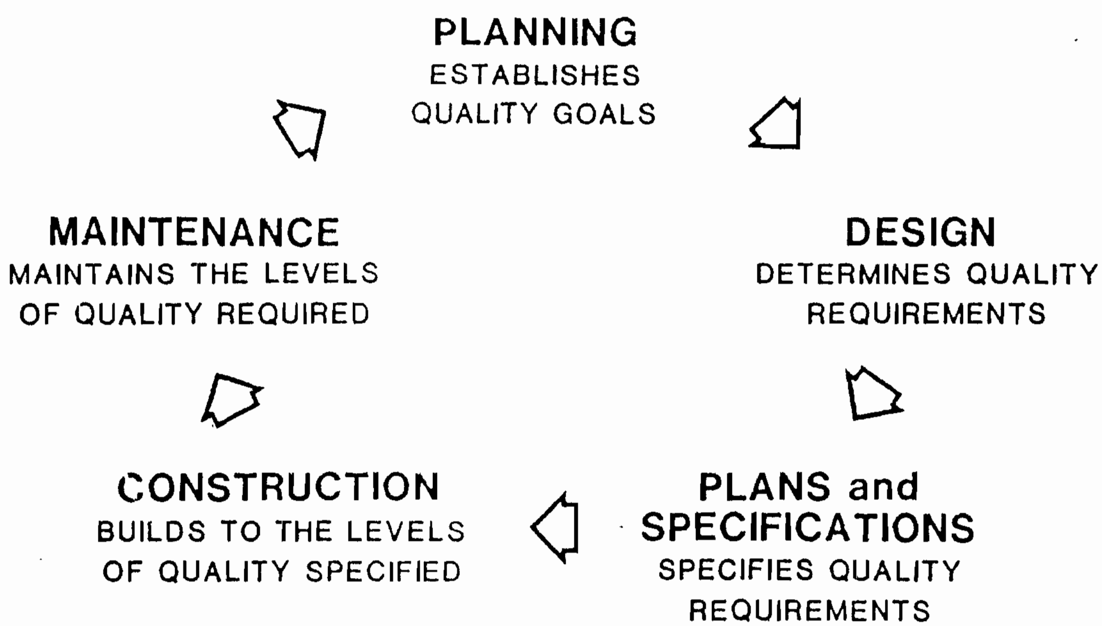
QUALITY ASSURANCE IS A BROAD TERM

THAT REFERS TO ALL OF THE ACTIVITIES

NECESSARY TO VERIFY, AUDIT AND

EVALUATE QUALITY

Figure 1-1
QUALITY ASSURANCE ACTIVITIES



INSPECTION
(Did we get what we ordered?)

THE ROLE OF THE INSPECTOR

Streets and roads represent a tremendous investment on the part of the citizens of a community. The primary responsibility of the inspector is to ensure that the taxpayer gets his money's worth and an acceptable end product. The inspector in a highway agency is required to monitor, check, observe and record construction, maintenance and rehabilitation activities to ensure compliance with the specifications, plans and other contract provisions. The place, frequency and thoroughness of inspection may vary depending on the construction activity, the type of contract, the type of specification, and the quality of work exhibited by the construction organization. The need for inspection is always present and the role of a qualified, competent inspector is critical in assuring an end-product of acceptable quality.

The inspector acts as a representative of the engineer within the scope of the authority delegated to him. To perform the duties and responsibilities of an inspector, an individual should:

- Inspect all work performed and all materials furnished to the project.
- Bring any deficiencies in work or materials to the attention of both the contractor and the engineer.
- See that all sampling and testing required by specifications or job site conditions, are performed.
- Perform certain tests and take samples for testing by laboratory personnel.
- Reject materials and suspend work that is not in compliance with specifications until the problem can be brought to the attention of the engineer.

The inspector should ***not***:

- Change, revoke or suspend any requirements of the specifications without specific approval of the engineer.
- Assume direct supervision of the work.
- Accept or solicit gifts or special favors from contractors.

PLACE OF INSPECTION

Inspection is generally required at three different places:

- **Field** - The major requirement is at the point of construction activity.
- **Supplier or contractor facilities** - It is often necessary to inspect activities at batching and mixing plants, aggregate quarries or crushers and precast facilities. Plant inspections are often conducted by personnel from the materials testing laboratory. Since many plants may provide material to state projects as well as local govern-

ment projects, an opportunity may exist to share the inspection effort.

- **Other related facilities** - From time to time it may be necessary to inspect other facilities involved with the construction activity such as testing laboratories, borrow pits and disposal sites.

FREQUENCY OF INSPECTION

The concept of risk analysis should be understood when establishing inspection frequencies. Inspection represents a cost to the local government that is invested to minimize the risk of accepting poor quality workmanship and materials. If the amount of inspection effort is reduced, the risk that must be accepted will increase. A risk analysis must trade-off the expense of inspection with the degree of risk that can be accepted and the costs associated with a product or material failure.

Ideally, it would be safest to have continuous inspection of all activities. For most activities this is not justifiable, either technically or economically.

The following factors should be considered when establishing an inspection program:

- Availability and capability of in-house personnel.
- Availability and capability of local private engineering firms.
- Compatibility with sampling and testing program, specifications and other elements of the quality assurance system.

The financial constraints that most local governments have faced in recent years have made it difficult to introduce new programs which require any increases in staff. The trend toward placing more responsibility for quality control on the contractor and their engineers may lessen the impact upon local government staff, although some in-house inspection capability is highly desirable.

The inspection requirements for most construction activities can be grouped into four frequencies. Table 7-1 lists the appropriate activity for each frequency.

One Time

Certain activities should under normal circumstances require only one inspection. An example could be centerline survey and stakeout. Unless station markers have been disturbed or if there is reason to believe that an error was made, there should be no necessity for a second check. Another example would be to check construction equipment when it first arrives on site. Again, unless the equipment does not perform properly or an item has been replaced, there is no need to repeat this check.

Critical Point

A critical point inspection is essentially a one time inspection that must be performed at a specific point in the construction sequence, before the next phase of construction takes place. Checking reinforcing steel and forms before placing concrete is an example.

Use of one time and critical point inspections can greatly reduce the inspection manpower needed. However, a major problem with critical point inspections can be scheduling and notification by the contractor. It is essential to establish a procedure requiring notification in advance of the need for a critical point inspection. Failure to notify the inspector should be considered a serious infraction of the specifications.

Intermittent Spot-Checks

Many construction activities can be adequately inspected and controlled by random or regular spot checks. These would include inspecting subgrade for elevation, compaction, and moisture content at intervals as the work proceeds.

Continuous Monitoring

Some operations, due to their inherent critical or variable nature, require the full time presence of an inspector. Placing of structural concrete is a good example of when full time or continuous inspection would be justified.

Appendix B contains lists of various typical highway construction processes giving inspection elements, their desirable frequencies and remarks regarding where these frequencies may need to be changed or varied. These are not comprehensive, but are given as a planning guide for the amount of inspection required for various types of highway construction activities.

Table 7-1
SUGGESTED INSPECTION FREQUENCIES

FREQUENCY	INSPECTION ACTIVITY
ONE TIME	Check contractor's equipment. Inspect material at supplier's facilities for source approval. Inspect laboratory and testing facilities for approval prior to use. Check initial layout, closing error and survey. Inspect centerline survey and stakeout. Review office and record procedures for contractor and consultant. Final check on pavement surface for texture and ride. Final check on finish of structures. Final check on drainage. Final acceptance check on utility, lighting, signing and pavement marking. Final Measurement of work for payment. Check erection plans, falsework plans and workshop drawings.
CRITICAL POINT	Inspect subgrade, subbase and base before placing the next structured layer. Inspect forms, falsework and reinforcement before placing concrete. Check bearing surface before placing foundations. Check all material to be covered before backfill operations. Check bearings before placing bridge superstructure. Check excavations before placing drainage structures or utilities. Check temporary shoring before work in deep excavations. Check grade before placing sod for compliance with plan and adequate drainage. Inspect other miscellaneous critical points in specialized situations.

Table 7-1
(Continued)
SUGGESTED INSPECTION FREQUENCIES

FREQUENCY	INSPECTION ACTIVITY
SPOT CHECKS	Check construction layout and elevations. Inspect fill material aggregates and stockpiles for contamination and proper handling. Inspect stockpiles of other materials (such as pipes and reinforcing steel) for damage. Inspect backfilling and embankment operations for compliance with specifications. Inspect drainage structures, manholes, catch basins, pipe laying and other minor structures for proper materials, conformance with plans and damage. Inspect subbase for line, level, moisture content and compaction. Check for all required tests and samples: - asphalt temperature, density - concrete, slump, cylinders - soil bearing capacity, moisture content and density. Check safety requirements traffic control, falsework, shoring of excavations, scaffolding, etc. Inspect concrete during curing.
CONTINUOUS	Structural or paving concrete production at batch plant. Bituminous concrete production at plant. Placement of paving concrete. Placement of bituminous concrete. Pile driving operations. Rolling and compaction operations of bituminous materials. Placing of structural concrete.

THOROUGHNESS OF INSPECTION

All the activities and frequencies of inspection must be further qualified by other requirements which may affect the thoroughness or depth and degree of inspection required. Checklists are helpful to ensure complete coverage. Sample checklists are shown in Appendix C. The following are factors to consider when establishing the thoroughness of inspection.

Engineering Requirements

When one particular substandard element is likely to cause extensive failures in the facility being constructed, the element should be considered critical. Depending upon how critical a certain material, product or activity may be, consideration should be given to increasing or decreasing the depth of inspection for that construction element. This could be based on the engineering properties, the soil conditions, anticipated service conditions or new and unusual materials or techniques to be used in the construction process.

Project Type Requirements

The type of project will also affect the degree of inspection needed. A bridge will require more intensive inspection than subgrade construction. A major roadway will warrant more inspection than a rural, unpaved road.

The thoroughness or degree of inspection necessary at the jobsite will also depend on whether the construction is being done in-house or by others.

In-house Construction

At the jobsite the local agency will need only as much inspection as is necessary to have confidence that the quality is equal to the standards required. Although he will be inspecting the work of his own employees, the engineer will find that spot checks are absolutely essential. For example, a newly appointed county engineer visited a bridge construction site where one of the county's crews was driving piles. Although the crew foreman had been building bridges and driving piles for years he had no idea of the bearing achieved by any of the piles driven at the site. He used a forty-foot pile and drove it in until there was only enough pile left for cutoff. Whether or not he obtained or exceeded the required bearing is anyone's guess. An inspection procedure for in-house work quickly corrected this situation.

Contract Construction

More in-depth inspection is required to document quantities for contract payment and to insure compliance with the terms of the contract.

DOCUMENTATION

Another primary responsibility of the inspector is documentation. Documentation consists of making records of the work accomplished in terms of pay quantities and compliance with specifications. Detailed formal documentation of pay quantities is required on contract projects. When responsibility for various parts of the quality control plan are assigned to a contractor, supplier, private engineering consultants or private testing laboratories, similar documentation should be required from them as well.

Field Diary

A field diary is a basic form of documentation. As a general rule the inspector shall keep a daily log or diary for each project. The inspector's field diary can be of critical importance in settling disputes and determining causes and solutions to particular problems. This is often the agency's only record of what transpired on the job site. It is extremely important that the log be kept complete and up to date. As a minimum, the log should include:

- An entry for each day.
- A description of the day's construction activities, name of contractor's superintendent on the job, number and type of crews, number and type of contractor's equipment, weather and temperature.
- Any measurements made to determine pay quantities or compliance should be recorded, with sketches if necessary, to clarify dimensions (if pay quantity data is recorded in separate field books there should be a cross-reference.)
- A daily summary of weight tickets, delivery tickets and other materials used on the job.
- A record of significant conversations with and directions given to the contractor.
- A record of problems or potential problems with the progress or execution of the work.
- A record of dealings with test laboratories.
- Any visits to the project by local, state, federal or other officials.

Other Documentation

The engineer's field diary, along with those of his inspectors, serves as an overall record of the project. However, other forms of documentation will also be necessary such as:

Weight and Delivery Tickets - Tickets for ready-mix concrete, processed aggregate, hot-mix asphalt and other construction materials are often used as official and quantity records. They should be signed or initialized by the inspector present, placement location should be indicated and time and date recorded. This can also serve as a record of certain field tests, such as concrete slump or asphalt mix temperature.

Correspondence - Any verbal instructions to the contractor by the inspector should be followed up with a letter from the engineer. Copies of all correspondence should be retained.

Certificates of Compliance - Materials accepted on a certification basis should be accompanied by a certificate, along with any verification tests that have been performed.

Laboratory Test Results - All test results should be kept with the project file.

SAMPLING AND TESTING
(Did we get what we ordered?)

INTRODUCTION

The engineer must have a basis upon which to approve materials and material sources. Sampling and testing form this basis. Sampling is a process of selecting a part (sample) which will be used to judge the whole (lot). Tests made on a sample measure the characteristics of only that sample. The validity of conclusions drawn about the lot based upon test results of a sample depends in large part upon sampling techniques. Sampling is used simply because it is not possible or practical to test all of the material used on a project. The task would not only be time consuming but some tests destroy the material being tested.

Sampling and testing is only one part of a quality control program. Inspection must be used along with sampling and testing. It is the inspector's job to catch obvious problems, even though they have not been detected by the sampling and testing program. As with inspection, the establishment of a sampling and testing program involves a risk analysis. On one hand is the cost of the program and on the other is the risk of failure. A proper balance of costs and risks must be sought.

Sampling and testing provide the basis for approval of materials.

The only way in which the value of many characteristics, such as density and slump, may be determined is by some form of measurement. If measuring devices and those who use them were perfect, it would be possible to make a direct determination of the true values of the measured quality characteristic. In actual practice, however, we must recognize the fact that the measured values typically reflect errors of measurement as well as variations in the quality of the material measured.

If the true characteristics of a material were known, the distribution might look like that shown in Figure 8-1.

Figure 8-1
TYPICAL DISTRIBUTION CURVE

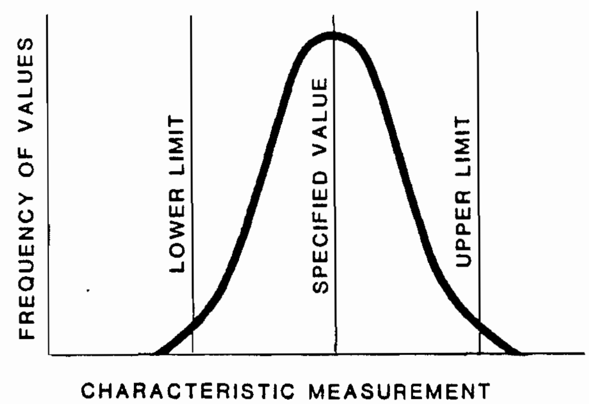


Figure 8-1 shows the majority of the material falling within the specification limits but this may not always be the case. The objective of sampling and testing is to make an estimate of the shape of the distribution curve and the relationship of the true value with the specified limits.

Material characteristics can be related to target shooting, where the bull's eye represents the specification limits. Measurement properties are precision, accuracy and exactness.

- Precision indicates that good quality control is being exercised because there is very little variability. Precision is the variability of the shot group on a target.
- Accuracy would indicate that the quality control is oriented properly but says nothing about the variability of the measurement. On a target, the determination of the center of the shot group is a measurement of accuracy.
- Exactness is the combined effects of accuracy and precision. Exactness indicates both the degree and effectiveness of quality control.

These concepts are illustrated in Figure 8-2.

Conclusions about exactness are made through sampling and testing measurements. It is similar to being able to see only a small proportion of the shot group, rather than the whole pattern.

SAMPLING

Purpose of Samples

There are four primary reasons for sampling materials, as follows:

Source Approval - Samples are taken and tested to provide approval of a material source proposed by a contractor for a project.

Job Control - Samples are taken on a day to day basis during production or use of a material, and include check samples of materials from approved sources, plant samples taken at the place of production or assembly and worksite samples taken at the project site. As the name implies, job control samples are taken by the public agency to insure adequate quality control.

Record Sample - These samples are taken for evaluation of ***testing procedures*** and may be required on state or federal aid projects.

Acceptance - These are samples taken from a finished product to determine compliance with the specifications. An example would be pavement coring. The objective of acceptance sampling is to determine a course of action — reject or accept the work. Acceptance sampling is ***not*** a job control technique.

Types of Sampling

Errors and defects in sampling can be introduced by an improperly applied sampling technique and by the technique itself. There are five commonly employed sampling techniques.

Judgment Sampling - Sampling is based solely upon the judgment of the laboratory technician or inspector responsible for selecting the sample. The sample is selected to represent the overall quality or condition of a given quantity of the materials being sampled.

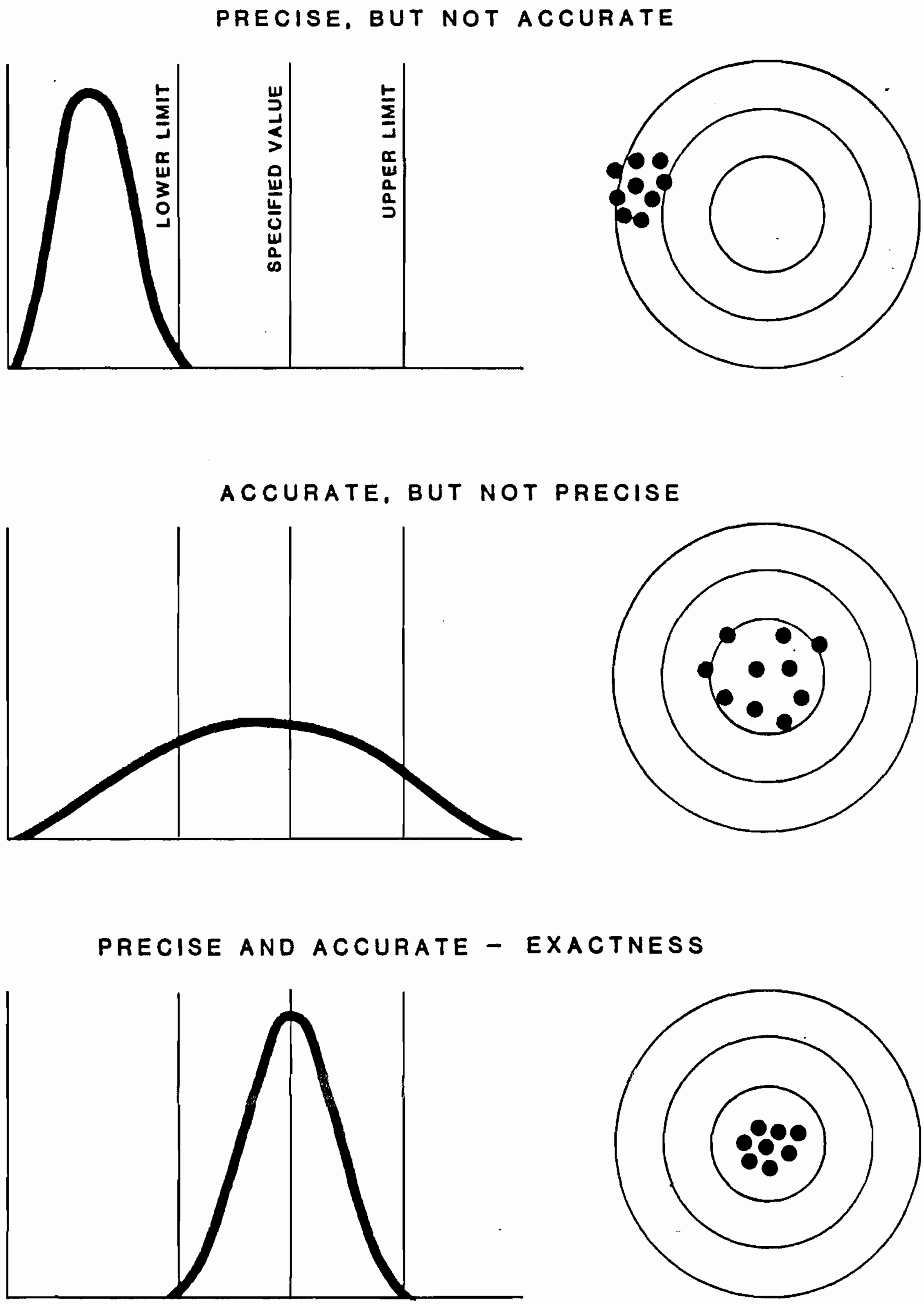
A major argument against judgment sampling is that there is the chance of both conscious and unconscious bias. As an example of conscious bias, the inspector may select the sample from what he believes to be the worst of the lot. If the inspector is correct, the contractor may be unjustly penalized because a small portion of the material is unsatisfactory. Naturally, the unsatisfactory material should not be ignored. When questionable material is encountered, the material should be rejected or additional tests should be called for to define the nature and limits of the problem. An example of unconscious bias would be always taking pavement cores along the centerline, where compaction is usually higher. Unconscious bias is not the result of any preconceived notion about the quality of the material, but can, none-the-less, bias the test results.

Despite these drawbacks, judgment sampling continues to be widely used on the belief that an inspector can select a representative sample and that the engineer can apply engineering judgment to settle disputes over questionable material.

Quota Sampling - Quota sampling is the selection of a phase of production or geographic area as the basis of sampling. For example: the collection of an asphalt concrete mixture during the first hour of production or drawing aggregate samples every time the source is changed. This type of sampling will detect known defects, cycles and patterns. The disadvantages are that it requires a thorough knowledge of the construction process and materials characteristics to select the proper quotas, and that it does not reveal defects that occur during phases of production when samples are not taken.

Systematic Sampling - Systematic sampling involves the selection of successive observations at uniform intervals in a sequence of time, area or activity. An

Figure 8-2
ACCURACY, PRECISION AND EXACTNESS OF MEASUREMENTS



example would be taking a slump test from every third ready-mix concrete truck. This sampling technique will identify both known and unknown defects; has low inherent risk (risk introduced as a result of the technique itself) and high reliability; and is not difficult to schedule. The main disadvantage of this technique of sampling is that it may not detect cycles and patterns of variability of the material if they occur at different frequencies or times as the sampling schedule.

Stratified Sampling - This type of sampling is the selection of two or more independent parts of a given quantity of material, or lots. For example: two compaction tests every 500 centerline feet of base course. When products are categorized by lots, they are divided into strata or parts based on a reasonable breaking point for different component parts, or for different operators. Stratified sampling detects known defects, unknown defects, cycles and patterns has high reliability. It is easy to schedule.

Random Sampling - Random sampling involves the selection of a sample so each increment comprising the sample has the same chance of being chosen from the lot. This technique of sampling identifies known defects, unknown defects, cycles and patterns. It has low inherent risk, low risk in unknown situations, and high reliability. The sampler does not exercise any judgment concerning where to select samples. This form of sampling provides an unbiased, representative estimate of material characteristics.

Normally, no one type of sampling is used alone. Each offers advantages and disadvantages for various types of information gathering purposes. Only the last three, however, should normally be considered for true acceptance sampling. The large sums of money usually involved in the acceptance of construction projects warrant a sampling technique with high reliability.

Table 8-1 summarizes the advantages and disadvantages of each sampling type.

Sample Size

Although purely statistical methods are beyond the scope of this manual, a discussion of sample sizes must include some elementary statistical concepts. To do this some definitions are necessary:

- A **LOT** is defined as an isolated quantity of material which is produced from a single source under similar conditions. Stated another way, a lot is a measured amount of construction assumed to be produced by the same process. For example: a day's production of subgrade, or one mile of asphalt hot-mix surfacing could be considered lots. Lots can be divided into sublots for sampling purposes.
- A **SAMPLE** is that portion of the lot that is taken to represent the whole.
- **OBSERVATIONS** (also known as INCREMENTS OR TEST PORTIONS) are the individual portions of material which will be tested or measured.
- The **SAMPLE SIZE** is the number of observations. The size of a sample is often referred to as "n" in statistical equations.

Many highway agencies have traditionally relied upon single "representative samples" (which is an "observation" by the above definition). Regardless of the selection technique used, single observations will not account for natural variations in the materials and cannot be considered truly representative. In a given quantity of material, there is likely to be some material that is within the specification limits and some that is outside the limits. The true quality of a lot should be a measurement of the amount of material within the specification limits, but with only one observation there is no way of knowing that. When test results of a single "representative sample" indicate that a material is unacceptable, it is fairly common to take a second test to "verify" the first. If different results are obtained with the second sample a problem still remains as to which represents the "true" quality.

The larger the size of the sample, the lower the risk of accepting unsatisfactory material. However, as the size increases the cost of sampling and testing also increases. The size needed depends on three factors:

- The desired level of confidence in the test results. The larger the sample size, the higher the level of confidence.

Table 8-1
SAMPLING TYPES

	Identifies Known Defects	Identifies Unknown Defects	Identifies Cycles and Patterns	Inherent Risk	Risk in Unknown Situations	High Reliability	Difficulty of Selecting Sample	Simple Organization
JUDGMENT SAMPLING (Sampling based solely on judgment of sampler)	YES	NO	?	?	HIGH	YES	HIGH	YES
QUOTA SAMPLING (Making judgment distribution of sample by time of day, location, etc., according to distribution of facts)	YES	NO	YES	?	HIGH	NO	HIGH	YES
SYSTEMATIC SAMPLING (Selecting successive observations at uniform intervals in a sequence)	YES	YES	NO	LOW	?	YES	LOW	NO
STRATIFIED SAMPLING (Selecting each of two or more parts independently from a corresponding part)	YES	YES	YES	LOW	?	?	LOW	NO
RANDOM SAMPLING (Selecting sample in such a manner that each individual has some chance of being chosen)	YES	YES	YES	LOW	LOW	NO	LOW	NO

- The amount of error that can be tolerated. Less error requires a larger sample.
- The amount of variation of dispersion of the characteristic being measured. Highly variable material requires larger samples.

Of these three factors, the most important is the variability of the material. Obviously, if a material were perfectly constant, a sample size of one would be sufficient.

Frequency of Sampling

The frequency at which samples are taken is one of the major considerations in establishing a sampling program. Frequency is determined by sample size and lot size. Frequency is increased by increasing sample sizes and by decreasing lot sizes. Factors affecting frequency are:

- **Variability of product** - Materials that have highly variable quality characteristics should be sampled more frequently.
- **Usage** - Materials or products that will serve a critical function should be sampled more frequently.
- **Previous experience** - Materials or products from a source that has not been used before or those that have had a previous history of poor performance should be sampled more frequently that those with a record of good performance.
- **Significance of tested materials** - If the characteristic of the materials being tested has little significance in relation to the actual usage, the sampling frequency could be decreased.
- **Agreement with specifications** - When test results or visual inspections indicate that a product may not be in compliance with the specifications, increased sampling frequency is warranted.
- **Purpose or type of sample** - Acceptance sampling certifies the level of quality achieved in an end-product. It also verifies the quality control exercised over the construction process. In many cases acceptance sampling can be reduced by using job control test results.

Sámpling and Field Inspection

It is important to remember that a sampling and testing program is intended to provide an overall estimate of quality. It is not intended to replace inspection or to find occasionál substandard areas (although it frequently does). One sample with ade quate inspection may be more valuable than numer ous samples with little or no inspection. By samplin; one typical area, an inspector can, by careful visua observation, detect and reject materials and product: with different, undesirable characteristics. Additionally, by observing operations and noting placement locations on material weight and delivery tickets, the inspector can reduce the need for extensive testing at later date that might be needed to "bracket" an area of non-complying material. It should also be noted that many samples can be obtained far more easily and less expensively during construction, such as uncompacted bituminous concrete and fresh concrete as opposed to pavement cores.

TESTING

Testing as used in this manual refers to the process of making tests to determine the degree of compliance of delivered or constructed material with the specifications. All tests should be directly related to the specifications. A testing method not referenced in the specifications may not be legally enforceable.

Examples of items that should be tested include:

- **Bituminous construction** - Test for density, asphalt content, aggregate gradation, temperature, thickness, viscosity and penetration.
- **Portland cement concrete construction** - Test for slump, water-cement ratio, temperature, percentage of air, compression strength, and dimension (length, width, height, thickness).
- **Surface treatment** - Test binder and stone application rate, gradation, viscosity and penetration.
- **Aggregate bases and shoulders** - Test gradation, density, moisture content, and thickness.
- **Sub-base and earthwork** - Test plasticity index, density, and moisture content.

Testing by In-House or Other Laboratories

The actual tests may be performed in-house by a private laboratory or another governmental agency such as a state or neighboring local jurisdiction. Although all testing can be done by contract, it will probably be advantageous to run some tests in-house depending on the frequency of tests, turn around time needed, availability of contract laboratories, set up costs, laboratory space, and other measures of cost effectiveness. The following items may be used to determine if an in-house testing capability is warranted:

- **The number and types of tests necessary** - State and private laboratories can assist in determining the type tests required for a planned construction or maintenance program and a rough idea of the number of tests necessary.
- **Availability of outside laboratories** - Some state laboratories are not able to recapture the costs of performing tests for local governments and, therefore, cannot perform a large number of tests for local engineers. If commercial or state laboratories are not accessible or cannot provide adequate turnaround on test results, a strong argument can be made in favor of in-house testing.
- **Contract testing costs** - Because of their high volume and inherent efficiency, private laboratories often can provide testing services at a cost lower than the in-house cost, particularly for those tests that are run infrequently.
- **Testing equipment** - To provide accurate test results, precision equipment is necessary. Testing equipment can vary considerably in purchase price. Initial costs, service life, replacement parts, space requirements and calibration and maintenance costs should be considered.
- **Available space for laboratories** - Many tests require sizeable equipment that must be permanently installed. If an agency is considering establishing a laboratory, space requirements must be considered.
- **Manpower requirements** - The number of laboratory technicians and their salary must be considered. If the number of tests anticipated is not sufficient to require a full time technician, it may be possible to train an employee who would normally be assigned to other tasks when not performing laboratory testing.
- **Cost effectiveness** - By comparing the annual equipment and manpower costs for in-house testing with the cost for contract testing an analysis of the cost effectiveness can be performed.

It is not recommended that the decision on whether to develop an in-house testing capability be based solely on economics. Other factors such as turnaround time and scheduling flexibility can be very important.

Depending upon local conditions, the following tests would be recommended when starting an in-house program.

- Sieve analysis for aggregate gradation.
- Slump of fresh concrete.
- Percent entrained air in concrete.
- Asphalt temperature.
- Density.
- Moisture Content.

The following tests are examples of those which may be more cost effective if performed by contract initially.

- Asphalt extractions.
- Coring (in-place thickness).
- Concrete compression.
- Foundation borings.

The detailed test procedures which must be followed are beyond the scope of this manual. Procedures for specific tests can be found in either the ASTM or AASHTO Standards and often are included in state construction and materials manuals. It is important that testing be performed in strict compliance with whatever standard is adopted. If the reliability of the results are questionable then the test is useless for control or acceptance purposes.

Supplier, Contractor and Inspector Activities

The role of the testing laboratory, whether in-house or contract is related to the activities of the supplier, the contractor and the inspector. Building a road of acceptable quality depends upon the combined efforts of each of these groups:

Supplier - The supplier must maintain constant control over the production process to ensure that the material consistently meets the specified level of quality. It is not acceptable for the materials to meet specifications only when laboratory personnel are present.

Contractor - The contractor must maintain constant control over the handling, storage, placement and use of materials in order to produce a street, road or structure of acceptable quality. Material that leaves the suppliers plant in satisfactory condition will not result in a satisfactory end-product unless the contractor exercises proper quality control.

Inspector - The inspector and the laboratory must work together. The inspector may assist the laboratory by taking samples and performing many of the on-site tests. The laboratory performs tests, evaluates test results and other engineering data and provides technical support to the inspector. The inspector acts as the final check point in the construction process and plays an important role in detecting changes in materials quality that have resulted from improper handling, shipping, storage and other causes. The inspector must recognize that testing is based on samples. It is likely that some of the materials shipped to the jobsite may be out of specifications even though it has been previously tested and accepted. In this case the material should be rejected by the inspector before placement.

CERTIFICATION

It is often possible to rely on the manufacturer's quality control procedures and accept a certificate of compliance with visual inspection rather than performing complicated and expensive tests. This process is referred to as certification. Certification should consist of a statement that the product or material complies with the agency's specifications, along with appropriate test results documenting the statements. The importance of visual inspections should not be forgotten when using certification. Where warranted, plant operations should also be checked occasionally on an unannounced basis.

Several states have adopted procedures for certification of a wide range of products based upon the supplier's or manufacturer's quality control with limited testing by state personnel. If the state highway agency is regularly testing a supplier's product, it may be possible to puchase these standard state products on a certification basis, based upon the results of the state's tests.

Certification is a valuable tool for reducing the amount of testing. When to certify and when to test is a decision that is based on following considerations:

- When it is necessary to verify that the construction method has provided compliance with specifications, such as compaction of base material, testing should be performed.
- If wide variations in quality are known to have occurred, the agency may wish to test the material.
- Large quantities of an item may justify testin
- When new or questionable sources of supply used both certification and testing may desireable.
- If the cost of an item far exceeds the cost testing then certification should be considerec
- If a material requires sophisticated and exp sive testing, certification should be used.

Examples of items that can be accepted by cert cation are:

- Aggregates.
- Asphalt products.
- Portland cement.
- Corrugated metal pipe.
- Reinforced concrete pipe.
- Reinforcing and structural steel.
- Paint.
- Guardrail.
- Fertilizer, seed and mulch.
- Weed control and other chemicals.
- Deicing chemicals.

A more detailed list is contained in Appendix D. should be noted that the use of certification may n be permitted for certain types of materials and proc ucts on state and federal-aid projects. This poir should be clarified with appropriate officials whe state or federal participation is used.

References

1. **Computer Aids and Statistics in Quality Assurance** 1980, National Research Council, Transportation Research Board, Transportation Research Record 745.

2. **Highway Quality Assurance, Process Control and Acceptance Plans,** undated, Federal Highway Administration, Demonstration Project #42 **Quality Assurance,** October 1979, National Research Council, Transportation Research Board, NCHRP 65.

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4. **Urban Transportation Operations Training** - Design of Urban Streets, 1981, Federal Highway Administration, GPO: 1981 0-524-189/296.

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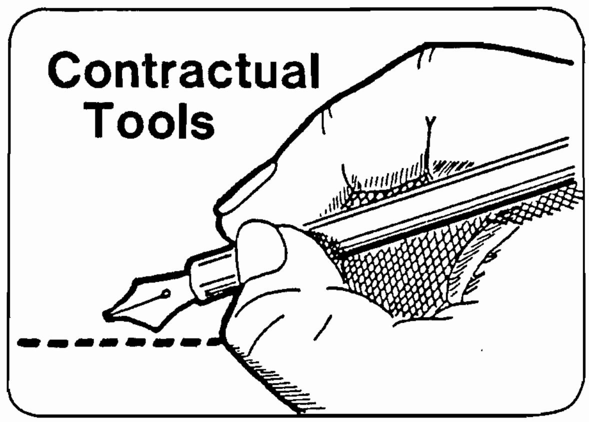
ACCEPTANCE
(What do we do if we don't get what we ordered?)

INTRODUCTION

Acceptance is the procedure through which a highway agency agrees that an item of work, unit of material or project has been furnished in accordance with the specifications. The acceptance procedure should provide recourse to the public agency if there has not been compliance with the specifications. Acceptance is an important element of quality assurance because it provides the answer to the question "What do we do if we don't get what we ordered?" Appendix D contains suggestions on acceptance inspection, sampling and testing procedures. This chapter will emphasize contractural devices for protection against non-compliance of the specifications.



The contract can provide tools for acceptance.

LIQUIDATED DAMAGES

The concept of liquidated damages is an important protection mechanism. Liquidated damages are not penalties. They should be structured to represent the cost of inconvenience to the public for not completing a project within the specified time. This cost can be based on the average daily cost to the public agency for staffing and administering contracts of various sizes. The cost of liquidated damages must be determined during the preparation of the job specifications and clearly established in the contract. Care must be taken not to arrive at liquidated damages in an arbitrary manner, otherwise they could be considered penalties.

INCENTIVE-PENALTY CLAUSES

Penalties cannot legally be assessed in a contract unless there are corresponding incentives. There are situations when local agencies may wish to consider the use of incentive-penalty clauses, such as when projects or phases of projects involve particularly hazardous situations and it is worth paying a premium to minimize the exposure time. An example may be a bridge replacement that involves alternative one-way traffic movement on a heavily traveled road. The contract could provide an incentive-penalty clause for the period of time during which the hazardous traffic condition would exist. Such a clause would establish the desired period of time and provide for a penalty if the time is exceeded and a similar incentive, or bonus, if the time is less than specified. For the above example, the contract may specify 20 days, with a $500 a day incentive-penalty. The incentive-penalty amount would be in addition to the liquidated damages.

Agencies using this type clause must choose the target time very carefully. If it is unreasonably restrictive the result will be very expensive bid prices or a lack of competition. On the other hand, if the target time is not restrictive enough then it could be very expensive to the agency.

PRICE ADJUSTMENTS

Price adjustments usually involve reductions in the amount contractors will be paid as a result of noncompliance with the specifications. Agencies should establish a minimum acceptable level of quality for important items of work, below which the work will be not accepted. Realistically, however, there is a "gray" area between this bottom line and the desired level of quality where the remove and reconstruct option is simply not feasible. In those cases a system of adjustments can be established that require the contractor to offset the anticipated additional maintenance costs to be incurred by the agency by adjusting the contract price. Types of specifications for which price adjustments might be considered are base course thickness, surface thickness and compaction of asphaltic concrete. Sample price adjustment specifications can be found in Appendix E.

PERFORMANCE BONDS

Local agencies should require performance bonds of contractors equal to 100 percent of the contract price, which is used to guarantee satisfactory completion of the contracted work. A performance bond will provide protection against a lack of performance on the part of a contractor but should not be used as a substitute for adequate inspection and testing. In many cases, it is only through inspection and testing that a lack of performance can be detected.

MAINTENANCE BONDS

Maintenance bonds can provide some protection against undetected poor workmanship and substandard materials. Maintenance bonds can be required of from 25 percent to 100 percent of the contract amount. They should cover a period of two to four years. Maintenance bonds typically require that the local agency perform an inspection prior to expiration of the bond. If no failures are found the bond will be released. If failures are found the contractor can be given the option of performing the repairs or the bond can be cashed to off-set costs to the agency for repair. As with performance bonds, maintenance bonds should not be used as a substitute for adequate inspection and testing. Poor quality work may not become evident until after expiration of the maintenance bond.

ENFORCEMENT

There are several effective contractual devi available to answer the question "What do we dc we don't get what we ordered?" If they are not us however, they are useless. Agencies should not hesitant to assess liquidated damages, adjust pa ments and cash maintenance bonds when the acti is justified. Just as with any other specification, these clauses are in a contract then the public is pa ing for them. They should be enforced just as rigi as any other specification.

DEVELOPMENT AND PERMIT OPERATIONS

INTRODUCTION

Chapters 4 through 9 of this manual dealt with quality assurance activities as they relate to operations internal to a local government. Chapter 10 will deal with similar activities as they apply to the actions of developers and permittees.

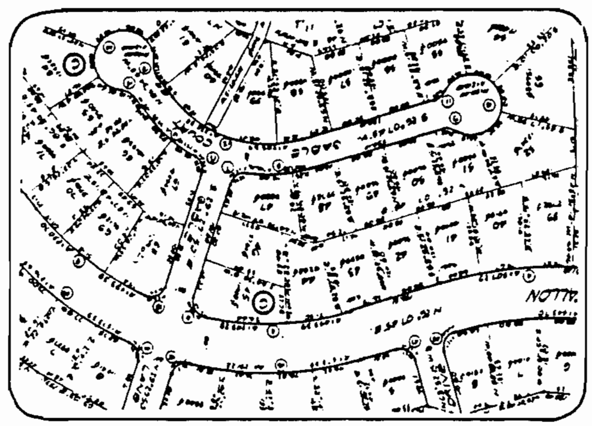
Development Projects

Most new road and street construction at the local level is performed by commercial and residential property developers. The roadway networks constructed by these developers are dedicated to the public and turned over to the local highway agency for maintenance. The establishment of adequate quality control procedures for these types of projects is extremely important because the public agency is not able to exercise day-to-day control of the work. However, such projects must not be viewed as a "gift." These roads frequently represent significant additions to a local agency's maintenance and operational responsibilities. Ordinances and regulations should be adopted that require the same design standards and quality control that would be expected of contract projects for similar types of roadways. Materials and construction specifications and sampling and testing procedures required for contract projects should apply equally to development projects.

The difficulty lies in enforcement. A binding contract provides a powerful enforcement tool which is not available for development projects. Development projects must be controlled with fees, performance guarantees, maintenance bonds and approval and acceptance actions. All of these mechanisms should be established in subdivision regulations that have been approved by the Board.

Permit Projects

Permit projects are those performed by others within the public right-of-way. Permit projects usually involve public or private utilities installing or repairing their physical plants or other facilities that are sharing right-of-way with a roadway.



Subdivisions can be significant additions to any agency's responsibilities.

Utilities serve an essential need of the public that must be recognized. The sharing of right-of-way for roadway and utility purposes is usually in the best interest of the public. The quality control issues that concern the engineer are that the physical plant involved be adequately designed and constructed so as to not interfere with the safe operation of the roadway and that any disturbance to the roadway be adequately reconstructed. For example, the engineer must insure that utility poles are placed so that they do not interfere with the visibility of street signs and that they will not become significant roadside hazards. The proper repair of cuts into the roadway surface to repair underground utilities represents the most common quality control problem.

The permit is a device that public agencies employ to control any work performed in the right-of-way by others. Because the right-of-way is owned by the agency for roadway purposes, the agency has the right and duty to restrict and control activities by utilities or others within that right-of-way. Public agencies should enact the necessary ordinances and regulations to insure that utility work meets acceptable design and construction standards. Testing, inspection and acceptance of the quality of roadway reconstruction, such as the repair of utility trenches, must be clearly established in the permit and adequately enforced by the agency.

PLANNING AND DESIGN (What do we want?)

Land-use planning is performed by local governments for the following reasons:

- To protect the health, safety and general welfare of the citizens.
- To ensure that development progresses in an orderly, efficient and coordinated fashion.
- To ensure that development enhances community values and goals.
- To conserve land and building values.

The key to quality assurance in developer-built roads is an effective interface between land-use planning and highway planning and design. The planning function normally results in ordinances controlling land development. These ordinances should insure that requirements for quality built roads and streets are consistent with the design and construction of other facilities within the jurisdiction.

Design standards should be established for development work that take into account the type of development (residential, commercial or industrial) and the functional classification of the roads to be built. All standards should be consistent with the standards for like facilities built by the public agency. All of the features mentioned in Chapter 5 for geometrics, hydraulics, structures, pavements and traffic control should be included. The following particular items should be included in development standards:

- Subdivision layout and design.
- Spacing for streets and block lengths.
- Minimum right-of-way.
- Set-back requirements for buildings.
- Access control requirements.
- Driveway connection design.
- Curb, gutter and sidewalk requirements.

Agency standard drawings should be required for development plans. This will help to minimize the adverse impact of new roadways on the agency's maintenance program.

The subdivision plat approval process is the point at which design standards should be enforced. The design of subdivision roads and streets should be reviewed with the same care and thoroughness as those designed by the agency.

Permit projects are usually of considerably smaller scope than development projects. Collectively, however, work done by permit can have a significantly adverse effect on the roads and streets of a local government if they are not adequately controlled. Design standards should be developed and included as a part of permits. Design standards that should be developed include:

- Driveway connection design.
- Utility cut repair.
- Off-set requirements for utility poles and other surface installations.

The planning process should coordinate major utility work with roadway improvement projects. The too common situation of a new pavement being destroyed by a major utility project ***can*** be avoided.

SPECIFICATIONS (How do we order it?)

Since the public agency cannot exercise day-to-day control over a developer project, performance specifications may be particularly attractive. Locations that have much more development construction than agency construction may wish to consider performance specifications. Regardless of the type, the specifications developed for agency operations should be required of development and permit work also. Some modifications to the general specifications are in order to account for the special relationship involved.

Engineer-of-Record Concept

The relationships in specification enforcement are clearer if the Engineer-of-Record (EOR) concept is understood. Any public roadway construction project, whether built in-house, by contract or developer, should be controlled by an EOR. For agency contract work, the EOR may be the city or county engineer or it may be a private consulting engineer. For development work, the EOR should be a professional engineer retained by the developer or by the local government. In the latter use, the expense can be billed to the developer, or included in the fee structure.

Although EOR's are usually paid by the developer, they should normally report directly to the public highway agency exercising control over the project. The EOR should be of unquestionable professional integrity because he will be expected to act as representative of the local government in enforcing the specifications, yet his client may the owner of the work.

The EOR should supervise the inspection, sampling and testing necessary for day to day job control. The public agency engineer should be responsible for the inspection, sampling and testing necessary for acceptance.

Adapting Specifications

The general specifications should be prepared to allow for the Engineer-of-Record concept and to delineate the responsibilities of the EOR and the agency. It should not be necessary to prepare separate specifications for agency and development work if the definitions and relationships are properly written. The specifications should be referenced in the appropriate ordinances controlling land development. It will normally be a good practice to hold a preconstruction meeting at the appropriate stage of subdivision plat approval. This meeting should be attended by the agency engineer, agency quality control personnel, the developer, the Engineer-of-Record and the developer's contractor. The terms of the plat approval, specification requirements, inspection, sampling and testing responsibilities, and acceptance procedures should be discussed and understood by all present.

INSPECTION, SAMPLING AND TESTING (Did we get what we ordered?)

Inspection

Development projects should require the same inspection as agency operations. The basic difference is who performs the inspection. The EOR should be responsible for day to day inspection activities. Certain critical point and one-time inspections should be performed by the local government. For example:

- Prior to placing the first base or sub-base layer, the grading and drainage should be inspected and approved.
- Prior to placing each succeeding pavement structural layer, the previous layer should be inspected and approved.
- Pavement surface, curb and gutter, bridges and signing all should be inspected and approved prior to final acceptance.

The appropriate ordinances should clearly establish the notification requirements for agency inspections. Developers that fall to notify the appropriate officials of inspection requirements should be penalized with special fees or higher bonding requirements.

Sampling and Testing

As with inspection, sampling and testing requirements for development work should be similar to the requirements for agency operations. The primary difference is who performs the sampling and testing. It should be the Engineer-of-Record's responsibility to perform job control sampling and testing. The engineer should review job control testing documentation as a part of the inspection program. Sampling and testing required for acceptance can be performed by either the agency laboratory or by the EOR under direction of the engineer. Some local governments include the cost of acceptance sampling and testing for development projects in their fee structure.

ACCEPTANCE (What do we do if we don't get what we ordered?)

Local governments find the above question the most perplexing when dealing with development work. Despite the fact that this type of work is done at no expense to the governmental unit, a clear acceptance procedure must be established. The engineer must have the authority to refuse acceptance of roadways that were not constructed to the stipulated level of quality until acceptable corrections are made. In the final analysis, this is the most effective tool available for development projects and should not be overlooked.

Price Adjustments

Price adjustments, as explained in Chapter 9, can apply to development work as well as agency operations. For those items of work that do not fully comply with the specifications, but not so deficient as to justify complete rejection, an additional fee can be collected and placed in escrow to offset anticipated additional maintenance costs. The fee should be a percentage of the cost of the quantity of material found to be in non-compliance, calculated on the basis of current average bid prices obtained from the state highway agency.

Maintenance Bonds

The use of maintenance bonds are strongly recommended for development work because of the lack of day to day control by the local government over the construction. The discussion of maintenance bonds in Chapter 9 can be applied directly to development projects.

Final acceptance of a subdivision should include a field inspection by the engineer and a certification by the Engineer-of-Record that all work was completed in compliance with the appropriate requirements.

References

1. **Planning County Road Systems,** July 1972, National Association of County Engineers, Action Guide Series, Volume V.

BENEFITS OF QUALITY ASSURANCE

* Greater Value for Money Spent
* Decreased Maintenance Costs
* Improved Performance
* Fairness to all Concerned
* Avoid Legal Hassles
* Common Sense Approach

IMPLEMENTATION

Mayor
Council
Street Dept. - City Engineer

NON-GOVERNMENTAL GROUPS

* Construction Oriented Groups
* Private Utilities
* Contractors
* Developers
* Consultants
* Material and Equipment Suppliers
* Non-construction Oriented Groups
* Home Builder's Associations
* Citizen or Community Associations
* Business Associations and Chamber of Commerce
* Real Estate Industry Associations
* The General Public (Through Planned Public Information Programs)

HOW CAN WE DO ADDITIONAL WORK

* New Staff

* Use of Consultants or Testing Laboratories

A.

Are You Getting Your Money's Worth in Street Construction?

HERPICC

•

In Cooperation with

•

Indiana Counties

•

Indiana Cities and Towns

•

Indiana Department of Highways

•

Federal Highway Administration