Implementing End Result Specifications
QC/QA/ERS/TQM

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Abstract

Quality of materials and workmanship directly influences the life of pavements, maintenance costs, levels of service and user costs. Background concepts of quality, quality control (supplier/contractor QC), quality assurance (owner QA), performance and specifications (general and product - method, end result (ERS) and performance) are introduced. Sampling and testing requirements for pavement materials - characteristics, sampling, statistics, testing and retesting - are examined. Practical examples are drawn from aggregates, hot-mix asphalt and hot in-place recycling to illustrate the concepts and their application from both contractor and agency viewpoints. Emphasis is placed on QC/QA guidance and understanding ERS basics, rather than statistics.

While undoubtedly controversial in the current tendering process milieu, bonus, value engineering and life-cycle cost selection concepts as incentives to innovation and quality improvement for desired performance are discussed. The importance of agency-contractor partnering for quality, and mechanisms to achieve this are described as a component in total quality management (TQM). Even the most sophisticated ERS can yield deficient pavements if all involved do not carry out their responsibilities effectively. The evolution of ERS and performance-based requirements does not require a revolution in thinking, but rather a clear understanding of the concepts involved and the eventual advantages to both agencies and contractors through quality management.
INTRODUCTION

"The common law of business balance prohibits paying too little and getting a lot. It cannot be done. If you deal with the lowest bidder it is well to add something for the risk you take and if you do that you will have something to credit for something better."
John Ruskin, 19th Century English Philosopher (1)

"We go out and buy pavements like we would zucchini. All we care about is price."
Damian J. Kulash, Executive Director, Strategic Highway Research Program, 1993 (2)

"I want it on time and in the proper hands. I want it done correctly, accurately, exactly, precisely, perfectly, efficiently, reliably, expertly, proficiently, faithfully, totally, absolutely, unequivocally, unmitigatedly, maturely, flawlessly, supremely, unsurpassedly and certainly without fault. I want it unharmed, unbotched, untainted and unscrewed-up. And most of all I want it done CHEAP."
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"Who cares about quality? Virtually everybody. In a recent Gallup Canada survey of people’s attitudes to business, 91 percent of Canadians said that they considered quality goods and services to be the most important criterion for good corporate citizenship."
The Quality Ultimatum, Royal Bank Special Business Report, 1992 (3)

At this challenging time for pavement infrastructures, with increasing loadings and decreasing capital and maintenance funding, it is imperative that specification and tendering systems evolve to reflect end result
requirements enroute to full performance-based asphalt technology parameters such as rutting resistance, fatigue endurance and service life durability. End result specifications (ERS), based on statistical quality assurance concepts (4) and effectively communicated through agency-contractor interaction (5), appear to provide the necessary balance of agency-contractor responsibilities for life-cycle cost effective methods and materials of asphalt pavement construction, including innovation (6). The growing use of performance related criteria for hot-mix asphalt (gradation, asphalt cement content and compaction, for instance) in end result specifications will hopefully develop to end performance requirements (deformation, fatigue and thermal cracking properties, for instance) when efforts such as the Strategic Highway Research Program define the necessary aggregate, asphalt cement and mix properties, develop and demonstrate appropriate testing equipment and procedures, and provide the necessary quality control (QC)/quality assurance (QA) guidance (2). The performance requirements will probably develop over the next ten years, or so, and undoubtedly reflect established European asphalt technology and contracting procedures (6).

All involved with the implementation of end result specifications look forward to streamlining, working 'smarter', continuous quality improvement and moving from the too common five project stages of euphoria, disillusionment, search for the guilty, punishment of the innocent and distinction for the uninvolved, to enhanced project goals and objectives: financial - under budget and reasonable profit; schedule - on or ahead of time; quality - acceptable or better level; avoidance of disputes; and environmental harmony (7). Emphasis is placed here on understanding ERS
concepts and QC/QA guidance, rather than on statistics. Comprehensive procedures and guidance are available on the preparation of end result specifications for transportation construction materials (8-10), notably the recent statistical quality assurance work of Afferton, Freidenrich and Weed (4). Pearson and Lynch have provided very practical insights on Ontario's development and implementation of hot-mix asphalt gradation and asphalt cement content end result specifications (11), which will be extended over the next several years to include compaction, recovered penetration, air voids, smoothness and thickness. Quality control and quality assurance are dealt with in a number of publications from theoretical background (12,13) to applied asphalt technology (14-18), including value engineering (19). Information on Total Quality Management (TQM), which is now involving all sectors, is available through the maestros Deming and Juran (20,21), or applied specifically to the construction industry (22,23). Anderson has developed an excellent manual on partnering (agency contractor 'teamwork' to manage conflict) in highway construction (5), a related TQM component that is gaining wide acceptance, with current trial projects in Ontario.

QUALITY AND SPECIFICATIONS

The quality of materials incorporated and work performed directly influences the useful life of a pavement, maintenance costs, level of service and user costs. Materials are a key economic factor to pavements, as their total in-place cost is about 40 to 50 percent of the total cost of highway projects. Quality can be defined as the characteristics of a product (materials and methods of pavement construction, for instance) that provide a level of performance in terms of serviceability (functional and
structural) and life (design life). Quality control (QC) ensures that the specified ‘ingredients’ (aggregates and asphalt cement, for instance) are combined and placed so that the product (hot-mix asphalt) will have the desired level of performance. Quality assurance (QA) is all of the activities necessary to verify, audit and evaluate quality (18). With the move to ERS, the contractor/subcontractors/suppliers take on QC responsibility (hot-mix plant process control, for instance), while the agency/consultant uses QA for assessing acceptance (level of compaction achieved, for instance).

ERS, based on properties considered indicative of potential performance, places direct responsibility on the contractor to control (QC) materials and methods, but also requires equitable, contractually clear agency inspection, testing, price adjustment (penalty/bonus), retesting and referee protocols. Even the best statistical quality assurance ERS can yield poor pavement performance if all parties involved (contractor, subcontractor, suppliers, agency and consultant) do not carry out their respective duties and responsibilities effectively (24).

Specifications

The general and product specifications for a paving project reflect the agency’s (owner’s) viewpoint of what the contractor is to achieve, hopefully in an equitable and objective fashion. General specifications relate to standard contract requirements such as control of the work, legal responsibilities, payments, etc. It is in the area of product specifications, which establish the requirements that materials and methods
must meet, that statistical quality assurance mandates a move from method specifications ('recipe') to ERS. Method specifications describe what is wanted and how it is to be achieved by the contractor (25). Contractor responsibility is then essentially to follow procurement 'rules' with little, or no, incentive for performance improvement, or innovation.

End result specifications (ERS) describe the requirements for the completed work (25) with the contractor clearly responsible for QC, and incentives (penalty/bonus) for the contractor/subcontractors/suppliers to do better and innovate. There is actually a balance of responsibilities with ERS for agency statistical quality assurance and contractor process control, which obviously lends itself to partnering. A clear separation between method and result type specifications is imperative, as a mixed type specification creates ambiguity and 'schizoid' requirements, and has resulted in considerable past contractor scepticism of any potential advantages to be gained through interaction with agencies to implement statistical quality assurance through ERS.

Scope of Quality Assurance

The scope of quality assurance (QA) from an agency (owner) viewpoint can be summarized in five questions:

1. what do we want? - planning and design;
2. how do we order it? - construction plans and specifications;
3. did we get what we ordered? - inspection, sampling and testing;
4. what do we do if not what was ordered? - acceptance/rejection -
a. accept substandard (marginal or borderline)
b. do not accept (repair or reject)
c. assess price adjustment (penalty); and

5. what do we do if 'better' than ordered? - bonus (controversial)
   and value engineering.

A statistical quality assurance ERS addresses the agency's five questions in a systematic way and hopefully provides equitable contract documents that place entire QC responsibility on the contractor/subcontractors/suppliers, with agency statistical acceptance procedures (QA). With experience, ERS should expedite work, reduce costs, engender partnering and foster innovation, while assuring attainment of quality.

Scope of Quality Control

The scope of quality control (QC), in an ERS framework, from a contractor's viewpoint involves four aspects:

1. QC is the method the contractor/subcontractors/suppliers use to ensure the product/work will be accepted;

2. contractor/subcontractors/suppliers impose a QC system of inspection, sampling and testing (process control) on themselves;

3. without QC a contractor/subcontractor/supplier cannot know whether a proper level of quality is being achieved until the product/work is either accepted, price adjusted or rejected by agency; and
4. QC may not be specified, but is none the less important.

It should be noted that QC is, strictly speaking, a component of QA, but it has become desirable to separate it as the contractor now has control of construction quality. However, agencies often specify minimum QC requirements and/or monitor QC (United States Federal Aviation Administration, for instance (26)) to reduce QA costs, i.e. minimize testing duplication. Quality control data is very useful for substantiating ERS retest requests, but should not be used as simply a check on agency QA data.

Contractors regularly involved with ERS have developed the necessary QC, with appropriate sampling and testing equipment and procedures, and technically qualified staff, to assist in achieving desired quality. This QC mobilization does take time, so agencies should allow for an interactive introduction period for any new ERS. For hot-mix asphalt ERS, the contractor also has responsibility for mix designs, subject to agency approval, which requires a consultant or contractor certified laboratory that is involved in correlation programs.

Supplier Quality Control

For many hot-mix asphalt paving projects, the contractor obtains aggregates from a commercial source supplier. The process control gradation data (QC) from the aggregate supplier (or contractor aggregate production) is used in developing the job mix formula (JMF). This JMF then has ERS tolerances applied by the agency for QA acceptance, price adjustment and rejection decisioning. It is imperative the aggregate gradations stay on a
relatively ‘tight’ band to avoid price adjusted or rejectable hot-mix asphalt production. Price adjustments on products (hot-mix asphalt) can exceed component costs (aggregates) and lead to supplier-contractor disputes.

The requirements of an aggregates QC system can be summarized as:

1. qualified staff - certified, primary job function, responsibilities defined and current on technology;
2. laboratory and testing equipment - permanent, dedicated, adequate laboratory space, equipment requirements met, and equipment certification and inspections current;
3. sampling and testing procedures - standard procedures followed, specifications and manuals available, participate in certification and correlation programs, and sampling and testing frequencies established;
4. inspection procedures - checklist, equipment able to provide specified product, and effective and efficient operations;
5. records and process control - standardized record keeping, process control checks and analysis of changes;
6. communications - corporate commitment to quality control, quality control-operations interaction and trouble shooting process; and
7. effectiveness - achievement of quality objectives.

As will be indicated later, such a QC system forms a key component of Total Quality Management (21).
Hot Mix Plant Quality Control

The current Ontario Ministry of Transportation ERS for hot-mix asphalt involves acceptance and price adjustment based on gradation and asphalt cement content (lot of four sublots) for the job mix formula (JMF) tolerances (mean and range) shown on the left side of Table 1 (II). From these JMF tolerances, and a reasonable assumption (experience) of standard deviations, the paving contractor (hot mix supplier) can develop plant process control warning and action limits as indicated on the right side of Table 1. The use of these warning and action limits with standard process control charts (12,14) assists the hot-mix supplier in: reducing mix variability; monitoring mix quality over time; making hot-mix plant process corrections to 'prevent' rejectable mix production; and timely detection of production trends and out-of-control conditions (12). Applicable process control (QC) software, with necessary control chart graphics, is available to the hot-mix supplier from a number of sources (28).

STATISTICAL QUALITY ASSURANCE

For a construction end result specification to be technically sound, defensible, effective and equitable it must be based on the now well established fundamental principles of statistical quality assurance. Excellent technical guidance on developing an ERS is given in the American Association of State Highway and Transportation Officials (AASHTO) recommended practice for sampling plans (percent defective or percent within tolerance) (10), that can be followed step-by-step in conjunction with agency direct experience with local materials and contracting practices.
### TABLE 1. TYPICAL AGENCY HOT-MIX ASPHALT ACCEPTANCE GRADATION AND ASPHALT CEMENT CONTENT TOLERANCES AND SUPPLIER PROCESS CONTROL WARNING AND ACTION LIMITS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Agency (a) Tolerances on JMF (c)</th>
<th>Supplier Process Control (b)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Four Sublots</td>
<td>Single Test</td>
<td>Mean ±%</td>
<td>Range %</td>
<td>Mean ±%</td>
<td>Range %</td>
<td>Mean ±%</td>
<td>Range %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Running Mean and Range of Four Tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve Size, mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 4.75</td>
<td>5.0</td>
<td>6.4</td>
<td>3.2</td>
<td>6.4</td>
<td>9.8</td>
<td>4.9</td>
<td>9.8</td>
<td>4.9</td>
</tr>
<tr>
<td>2.36</td>
<td>4.5</td>
<td>5.8</td>
<td>2.9</td>
<td>5.8</td>
<td>8.8</td>
<td>4.4</td>
<td>8.8</td>
<td>4.4</td>
</tr>
<tr>
<td>1.18</td>
<td>4.0</td>
<td>5.1</td>
<td>2.6</td>
<td>5.1</td>
<td>7.8</td>
<td>3.9</td>
<td>7.8</td>
<td>3.9</td>
</tr>
<tr>
<td>0.600</td>
<td>3.5</td>
<td>4.5</td>
<td>2.2</td>
<td>4.5</td>
<td>6.8</td>
<td>3.4</td>
<td>6.8</td>
<td>3.4</td>
</tr>
<tr>
<td>0.300</td>
<td>3.0</td>
<td>3.8</td>
<td>1.9</td>
<td>3.8</td>
<td>5.9</td>
<td>2.9</td>
<td>5.9</td>
<td>2.9</td>
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<tr>
<td>0.150</td>
<td>2.5</td>
<td>3.2</td>
<td>1.6</td>
<td>3.2</td>
<td>4.9</td>
<td>2.4</td>
<td>4.9</td>
<td>2.4</td>
</tr>
<tr>
<td>0.075</td>
<td>2.0</td>
<td>2.6</td>
<td>1.3</td>
<td>2.6</td>
<td>3.9</td>
<td>1.9</td>
<td>3.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Asphalt Cement</td>
<td>0.30</td>
<td>0.38</td>
<td>0.19</td>
<td>0.38</td>
<td>0.59</td>
<td>0.29</td>
<td>0.59</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
<td>0.59</td>
<td>0.38</td>
<td>0.59</td>
<td>0.38</td>
</tr>
</tbody>
</table>

a. Adapted from Ontario Ministry of Transportation (II).

b. Supplier process control limits developed from reasonable assumption of agency tolerances for four sublots as standard deviation values (II,27). Warning and action limits were then taken as limits outside which 1 in 5 and 1 in 20 test results, respectively, may fall due to chance (12,14). Example only.

Specific process control limits will depend on agency acceptance requirements and supplier experience.

c. Supplier responsible for job mix formula (JMF) in accordance with Marshall method of hot-mix asphalt mix design (II).

For the ERS novice, Afferton, Freidenrich and Weed, through Transportation Research Board activities, have recently provided a virtual handbook for writing reliable specifications (4).

The general objectives of a construction ERS can be summarized from AASHTO and Afferton et al as (10,4):
1. communicate to the agency and contractor, in a clear and unambiguous manner, exactly what is wanted using statistical measures to describe the desired end result (primary objective);

2. give contractor/subcontractors/suppliers prime responsibility for controlling the construction materials and methods (QC), with the agency primarily responsible for determining the acceptability of the finished work (QA);

3. provide sufficient incentive for contractor to achieve the desired quality (end result), or better, through adjusted pay schedules with reductions for 'deficient' quality and suitable bonuses for 'superior' quality;

4. pay 100 percent, on average, for acceptable work, and be equitable in the adjusted pay schedule for work that differs from the desired quality (end result);

5. be realistic in defining acceptable quality levels (AQLs) and rejectable quality levels (RQLs) - AQLs high enough to satisfy design requirements but not requiring extraordinary methods or materials, and RQLs low enough to truly justify rejection; and

6. be clear to the contractor/subcontractors/suppliers on the appropriate target level of quality to receive full payment.

These objectives are reflected in the fundamental concepts of statistical quality assurance (4):

1. relationship between quality and performance - quality characteristics are considered that are related to the potential performance of the product;
2. choice of appropriate statistical parameter - preference for lot percent defective, the estimated percentage of lot falling outside specification limits (or counterpart, percent within limits) as it can be applied to most construction quality characteristics; and encourages uniformity through control of both average level and variability of the product;

3. acceptable and rejectable quality levels (AQLs and RQLs) - often developed from experience (empirical) and typically checked through simulation and/or monitoring of the acceptance procedure;

4. attributes and variables plans - variables plan, which applies to quality characteristics measured on a continuous scale (statistical parameters such as mean and standard deviation, with basic assumption of normal distribution), is generally more discriminating than attributes plan of essentially pass-fail;

5. operating characteristics curves and risk analysis - operating characteristics curves (OC) must be constructed to ensure the acceptance procedure will function as intended in terms of equitably controlling agency and contractor risks (buyer-seller risks);

6. computer simulation - simulations are routinely used to test new statistical acceptance procedures before implementation and can be based on computer simulation data (simple to understand and apply) or demonstration trial projects;

7. lot sizes and sample sizes - time or quantity limits are used to define lots (day’s production, for instance) with a sample size (sublots) minimum of 3 for variables plans and typically 4 or 5;
8. random sampling procedures - stratified random sampling is typically adopted (single sample from each equal-sized sublot) to avoid clustering within a lot;

9. basis for pay adjustments - generally based on experience, or preferably, quality-performance relationships where established, and advantageous to be continuous (equation-type) to provide a smooth progression of payment as the quality varies; and

10. justification of bonus clauses - bonus clauses (incentive provision of typically up to three to five percent) for either early completion or superior quality appear to be both cost-beneficial and in the public interest, but remain controversial.

Afferton et al provide much supporting information and illustrative examples of the above comments that should be reviewed before embarking on ERS development (4).

Value engineering, the systematic analysis process for a product (pavement) to identify how its required function(s) should be achieved at the lowest possible cost consistent with requirements for performance, maintenance, safety and aesthetics, may offer a rational approach to bonus incentives (19). Life-cycle costing (analysis that considers the total cost of a pavement over its design life) and value engineering will certainly jointly become imperative in quality considerations associated with the move to build, operate and transfer (BOT, privatization) major transportation projects in Canada (current Highway 407 in Ontario, for instance).
ERS for Hot In-Place Recycling

The recent development of an ERS for runway hot in-place recycling, that is to go beyond the recent Ontario Ministry of Transportation ERS (29), to include mat density, joint density and air voids provides an opportunity to illustrate some of the statistical quality assurance concepts. It is recognized that asphalt pavement compaction, along with a properly designed and placed hot-mix asphalt, is a primary factor influencing satisfactory pavement life (30). In addition, poorly constructed or compacted longitudinal joints contribute to poor pavement performance (31).

The United States Federal Aviation Administration (FAA) hot-mix asphalt pavement specification (26) appears to be the most advanced ERS for runways, and provides guidance on materials acceptance criteria based on a number of hot-mix asphalt and completed pavement characteristics: stability; flow; air voids; mat density; joint density; thickness; smoothness and grade. Use of this FAA ERS by any other agency obviously requires detailed consideration of current specifications, quality requirements and contracting procedures.

The FAA ERS acceptance of air voids, mat density and joint density is based, on the percentage within specification limits (PWL) determined from: the average of test results ($\bar{X}$); the standard deviation of test results ($S_n$); the specification tolerance limit(s) (U for upper and L for lower); and the respective Quality Index(ices) ($Q_U$ and/or $Q_L$). The lot size is typically one day's production or 2000 tons (1800 tonnes).
For mat density and joint density (lot of four sublots) $Q_L$ is given by:

$$Q_L = (\bar{X} - L)/S_n$$

where $L$ is the specification tolerance limit of 96.3 percent for mat density or 93.3 percent for joint density, and $\bar{X}$ is the recompacted Marshall density.

The PWL is determined by entering Table 2 with $Q_L$ to determine $P_L$ as

$$PWL = P_L$$

in this case.

For air voids (lot of four sublots), $Q_L$ and $Q_U$ are given by:

$$Q_L = (\bar{X} - L)/S_n$$

and

$$Q_U = (U - \bar{X})/S_n$$

where $L$ and $U$ are the specification tolerance limits of 2.0 percent and 5.0 percent, respectively.

The PWL is determined by entering Table 2 separately with $Q_L$ and $Q_U$ to determine $P_U$ and $P_L$, and with

$$PWL = (P_U + P_L) - 100$$

in this case.

If the PWL for mat density and air voids exceeds 90 percent the lot is acceptable. For a PWL less than 90 percent, payment is made as follows:

<table>
<thead>
<tr>
<th>PWL</th>
<th>Percent of Contract Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>90-100</td>
<td>100</td>
</tr>
<tr>
<td>80-90</td>
<td>0.5 $PWL + 55.0$</td>
</tr>
<tr>
<td>65-80</td>
<td>2.0 $PWL - 65.0$</td>
</tr>
<tr>
<td>below 65</td>
<td>remove/replace</td>
</tr>
</tbody>
</table>

No bonus provision is provided in the FAA ERS, but these could be readily developed by other agencies for specific applications.
TABLE 2. TABLE FOR ESTIMATING PERCENT OF LOT WITHIN LIMITS (PWL) (a)

<table>
<thead>
<tr>
<th>Percent Within Limits (PWL), PL, and PU</th>
<th>Positive Values of Q (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 3</td>
</tr>
<tr>
<td>100</td>
<td>1.1541</td>
</tr>
<tr>
<td>99</td>
<td>1.1524</td>
</tr>
<tr>
<td>98</td>
<td>1.1496</td>
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<td>97</td>
<td>1.1456</td>
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<td>96</td>
<td>1.1405</td>
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<td>95</td>
<td>1.1342</td>
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<td>94</td>
<td>1.1269</td>
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<td>93</td>
<td>1.1184</td>
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<td>92</td>
<td>1.1089</td>
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<tr>
<td>91</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>0.7904</td>
</tr>
<tr>
<td>73</td>
<td>0.7636</td>
</tr>
<tr>
<td>72</td>
<td>0.7360</td>
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<td>71</td>
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<td>52</td>
<td>0.0725</td>
</tr>
<tr>
<td>51</td>
<td>0.0363</td>
</tr>
<tr>
<td>50</td>
<td>0.0</td>
</tr>
</tbody>
</table>

a. Partial table only. Adapted from United States Federal Aviation Administration (26).

b. If the value of Q does not correspond to a figure in the table, use the next higher figure.

If the PWL for joint density exceeds 90 percent, the lot is acceptable. For a PWL less than 90 percent, the contractor must evaluate the method of compacting joints, and for a PWL below 80 percent, stop production until the reason for poor compaction is determined and corrected.
The importance of contractor compaction QC is clear, as delay time can be very costly. Also, it is highly desirable to achieve joint density to the same specified level as mat density, given the criticality of longitudinal joint compaction to asphalt pavement performance (31). A bonus provision would clearly foster contractor joint compaction equipment and method innovation to meet this performance objective.

TOTAL QUALITY MANAGEMENT (TQM)

TQM has become a quality buzz word in the construction industry, and the appropriate application of Total Quality Management has contributed to the improved overall performance of many agencies and contractors (22,23). Partnering, an integral part of TQM in the construction sector, is rapidly becoming a project strategy for agency-contractor commitment and communications (5).

TQM incorporates all of the activities associated with the continuous improvements of quality and productivity (service), with emphasis on: customer-supplier relationships; employee involvement in decision making; team work; rigorous analysis of work as a process; statistical quality control; and managerial focus on leading. Excellent guidance on implementing TQM in the construction industry has been developed by the Associated General Contractors of America, including a dynamic video to do it! (23). More specifically, the important TQM elements applicable to construction (hot mix paving, for example) appear to be: commitment and leadership; process emphasis; training; team work; fact based decision making; involvement; and service. The emphasis on work (service) as a
The growth of partnering in the Canadian transportation construction industry offers the golden opportunity to reduce adversarial relationships and unnecessary ‘frictional' costs.

CONCLUDING COMMENTS

Contractors and their suppliers have generally developed the necessary capabilities to meet the new QC sampling, testing and analysis requirements associated with ERS, and without too much trauma. Agency retesting and referee protocols are available to deal with testing issues. The adoption of ERS requires continuing agency-contractor interaction for effective, equitable implementation, and monitoring to ensure that the statistical quality assurance objectives are met. Partnering, as a TQM component, provides an appropriate mechanism for the day-to-day resolution of problems associated with ERS implementation and associated agency QA disputes. Agency-contractor workshops have proven to be an excellent forum to communicate on quality and prepare for new ERS requirements.

Incidentally, Federal Express Corporation has a money-back guarantee!

ACKNOWLEDGEMENTS

Agency, contractor, supplier and consultant insights and inputs from quality control/quality assurance seminars and workshops have proven most helpful in developing implementation concepts for asphalt technology end result specifications: Ontario Hot Mix Producers Association/Ontario Road Builders’ Association/Ontario Ministry of Transportation joint seminars (Hot
process and process control (statistical process control) should be noted.

For TQM to be most effective in the construction industry, it is critical that agencies and contractors interact effectively, essentially the objective of partnering. The owner (agency) takes the lead by setting the necessary environment for cooperative contracting. This requires proper processes for: quality related cost and risk sharing; routine project management; and dispute avoidance and resolution. The challenge then shifts to contractor TQM based performance.

TQM facilitates an agency/contractor partnership attitude (partnering) to facilitate the successful completion of construction projects (5). Partnering is essentially a proactive, cooperative, team work effort, in the spirit of respect, trust and cooperation between the key players in the contractual relationship, for problem identification and resolution, conflict resolution and enhanced performance. Partnering can reduce costs, improve timing and reduce (or hopefully eliminate) claims. This can be summarized schematically:
Mix Process Control for Quality Pavements and Higher Profits, 1989; End-Result Specifications - Turning Penalties into Profits, 1991; Partners in Quality, 1992; and Partners in Quality II - Quality Management and the Environmental Challenge, 1993; Aggregate Producers' Association of Ontario seminar (Specifications - Focus on Asphalt and Ready-Mixed Concrete Aggregates, 1991); and Transportation Association of Canada survey and workshop (Survey of Process Control, Quality Assurance and End Result Specifications, 1992; and Implementing End Result Specifications in Paving Processes, 1993). Moderating agency-contractor role reversal teams during the Partners in Quality seminars indicated the criticality of effective communications to achieving statistical quality assurance objectives. The time taken by Kenneth Afferton (New Jersey Department of Transportation) and Norman Anderson (Washington State Department of Transportation), to discuss the state-of-the-art of managing quality and partnering, respectively, is most appreciated.

REFERENCES


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