Improving Highway Specifications for Constructibility

By J. T. O'Connor,[1] F. Hugo,[2] Members, ASCE, and E. M. Stamm[3]

Abstract: Project constructibility, the measure of ease with which a facility can be constructed, is keenly affected by the quality of technical specifications. Poor specifications can cause delays, rework, and claims, as well as restrict contractor innovation and flexibility. This paper explores the nature of specification-related obstacles to the construction of highway projects. In accomplishing this objective, many specific problems are identified and relevant problem details are captured in a formalized structure. A structure of problem types is developed, and problems are analyzed with respect to classification frequencies and apparent causal factors. Highway specification constructibility concerns and corresponding solutions are communicated through a series of hierarchy-of-objective-technique (HOT) diagrams. This technique represents a new, powerful, yet rather simple method of structuring objectives, strategies, tactics, and specific solutions to problems. In addition, a procedure is proposed for the periodic updating of standard highway specifications. Major findings indicate that pavement specifications are most problematic, that specification content is the most common general class of problem, and that "gold plating" or excessive specification requirements is the most frequent specific type of problem.

Introduction

Most engineers would prefer to deal in numbers rather than words. However, project constructibility is keenly affected by the quality of specifications—that critical word-based mechanism through which designer expectations and requirements are communicated to the field. Of course, contractor performance suffers if expectations are not clearly communicated. Poor specifications can cause delays, rework, and claims from misunderstandings, as well as restrict contractor innovation and flexibility. Studies continue to indicate that owners and designers pay a heavy price for poor specifications.

The objective of this paper is to explore the nature of specification-related obstacles to the construction of highway projects. In accomplishing this objective, a multitude of problems were identified, details of problems were captured in a formalized structure, a structure of problem types was developed, and problems were analyzed with respect to classification frequencies and apparent causal factors. In addition, a procedure is proposed for the periodic updating of standard highway specifications, an activity undertaken by virtually every state or province at one time or another.

Constructibility: Concepts, Past Findings, and Highways

Constructibility may be defined as a measure of the ease or expediency with which a facility can be constructed (Hugo et al. 1989). Constructibility

[1]Assoc. Prof., Dept. of Civ. Engrg., Univ. of Texas, Austin, TX 78712.
[2]Prof., Dept. of Civ. Engrg., Univ. of Stellenbosch, Stellenbosch, South Africa.
[3]Proj. Control Engr., Exxon Res. and Engrg., 180 Park Ave., Florham Park, NJ 07932-0101.

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is enhanced by the optimum use of construction knowledge and experience in the planning, design, procurement, and field operations phases to achieve overall project objectives ("Constructability" 1986). The Construction Industry Institute ("Constructability" 1986) identifies 14 concepts supportive of good constructibility practices. One of these concepts focuses on the significance of specifications to constructibility: "Constructability [*sic*] is enhanced when construction efficiency is considered in specification development." This concept encourages a deliberate and exhaustive effort at maintaining high-quality, constructible specifications and is expanded on the "Constructability Concepts File" (1987):

1. Underlying guide specifications should offer clear-cut options.
2. Project specification development should be deliberate and comprehensive, involving the appropriate personnel and adequate time.
3. Clarity of communication should be sought.
4. Referencing of excluded material should be minimized.
5. The cost-saving potential of "or equal" specifications should be balanced against the risk involved.
6. Specifications should be kept current and reflect current technology.

Most authorities agree that the communication of project information remains a serious barrier to project success. In other research, conducted by one of the writers, focusing on process plant construction (O'Connor 1986), it was found that 22.1% of all constructibility problems related to effective communication of engineering information, plans, or specifications. Two primary aspects were considered: information availability and information understandability. Information availability, a more common problem than understandability, addresses information timeliness, content, accuracy, and cross-referencing. Information understandability covers such issues as information clarity, format, and method of presentation.

Highway-project constructibility can be particularly challenging for a variety of reasons, as stated by Hugo et al. (1989). For example, some highway construction technologies are changing rapidly, and, as with most construction, the work force is transient and site conditions can vary greatly. Nearly all projects are subjected to severe public scrutiny involving open competitive bidding, thereby separating the planning and execution phases and largely precluding a fast-tracked approach to construction. Design standards, authored by a multitude of organizations, abound and often limit, if not discourage, selective innovation. The requirement for nonproprietary specifications often leads to vagueness. In general, the perception is that project durations are longer than necessary and that construction costs can probably be lowered. As a result, specifications supportive of constructibility become an important element for improving project performance.

Specifications: Complexities and Problems

The role of specifications is well known: "A specification is a precise statement describing the characteristics of a particular item" (*Manual* 1985). "Specifications are written instructions used in conjunction with drawings to fully describe and define the work that is to be accomplished, along with the methods and quality that will be required" (Jellinger 1981). Of course,

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TABLE 1. Specification Problem Areas (Nielsen 1981)

Problem area (1)	Frequency (%) (n = 200, approximately) (2)
"Or equal" specifications	24.7
Phrasing ambiguities	12.5
Conflicts between plans and specs	12.4
Inaccurate technical data	11.8
Inspection requirements	5.5
Safety and health requirements	4.9
Tolerance problems	3.1
Typographical errors	1.5
Other	23.6

specifications are often employed, particularly in highway construction, to stipulate methods of quantity measurement and payment.

When standard specifications are used, such as in highway construction, they are often extended and made structurally more complex with the attachment of special provisions and special specifications. These are specifications that supplement or modify the standard specifications and that have been formulated since the previous revision of standard specifications. A special provision alters an existing standard specification item, while a special specification replaces an existing item or creates a new one. Special provisions and special specifications begin accumulating soon after the adoption of a new standard specification. They can represent a sizable amount of supplemental, yet important, information that often does not conform to the simple, unified structure of the standard specifications.

Table 1 presents both classifications and frequencies of specification problems from the resesarch of Nielsen and Nielsen (1981) into specification-related claims and disputes. This analysis underscores the significance of problems dealing with the "or equal" clause and interpretation difficulties due to ambiguities and conflicts. Of course, many, if not most, specification difficulties never manifest themselves in the form of claims or disputes and thus the Nielsen and Nielsen study may be regarded as an analysis of extreme or costly specification problems.

Specification problems are not rare. Why do specification-related problems occur so frequently? Smith (1981) and others have identified the following causes:

1. Complexity of the construction product and its components.
2. Changing construction technology, including materials, methods, and equipment.
3. Inadequate, difficult-to-define testing and inspection procedures.
4. Interpretation paradigms of inspectors and lack of inspector training.
5. Voluminous, wordy, and redundant specifications; seeking liability avoidance and design conservatism through inclusion of excessive requirements and unnecessary standards.
6. Inadequate information systems for managing the many attributes of construction elements.
7. Lack of standards and standard terminology; imprecision of semantics.

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8. Inadequate design fees leading to rushed work, inadequate analyses of alternatives, and minimal checking or reviews.

9. Human fallibility.

Specifications Supportive of Constructibility

According to Bockrath (1986), desirable characteristics of good specifications include: technical accuracy and adequacy, definite and clear stipulations, fair and equitable requirements, usable format, and legal enforceability. As the basis for the writers' own research, a more detailed structure of desirable attributes or characteristics of specifications that are supportive of constructibility was developed. This is given in Table 2. Major or primary headings relate to the effectiveness of communication of the specification, content of the specification, functionality of the specification, or practicality of the specification. Subattributes related to communication include availability/accessibility and understandability. Subattributes related to content include relevancy (both technical and currentness), definitiveness/completeness, accuracy, and consistency. Functionality of specifications may relate

TABLE 2. Attributes of Specifications Supportive of Constructability

Desirable attribute (1)	Description (2)	Poor condition (3)
	(a) Manner of Communication	
Information availability	Readily available information	Referenced specifications not included or commonly found
Organization	Rationally structured or sequenced; effectively packaged	Unnatural, nonintuitive structure or sequence of specs; repetitive
Proper word choice	Clear, common, incisive technical language without generalizations; avoidance of problem words or phrases	Verbose, wordy; use of uncommon terms; interpretation problems due to poor wording
	(b) Specification Content	
Relevancy/technical applicability	On point, meaningful, appropriate, useful information	Useless information; nonmeaningful tests or methods of measurement or payment; irrelevant verbage
Relevancy/currentness	Referenced technology is current	Reference materials, methods, or equipment are obsolete
Definitiveness/completeness	Definitive, comprehensive, whole, thorough	Missing necessary descriptive information
Accuracy	Correct information or technical data	Wrong information or typographical errors
Consistency	Compatible content with other documents	Inconsistent with project conditions, plans or other specs
	(c) Specification Funcationality	
Functionality/adequacy	Functional, sufficient, nonexcessive	Gold-plated or super-adequate; subadequate or technically inadequate; in excess of needs
	(d) Specification Practicality	
Practicality	Realistic, reasonably executable, realistic tolerances, measurable or biddable quantities	Unstated tolerances, unrealistic tolerances, impractical methods of measurement or payment

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to subadequacy or excessive requirements. Specification practicality relates to either tolerances, contractor flexibility, or methods of quantity measurement or payment. Descriptive phrases and both synonyms and antonyms are listed in Table 2 to give clearer meaning to the terms. Once established, these desirable characteristics of specifications were subsequently used in identifying and classifying specification problems. A data base of problems was structured.

Specification Problem Information Base

The Specification Problem Information Base (SPIB), with 57 entries or records, emerged from lengthy discussions with highway department and contractor personnel and from the review of data collected by highway-department task forces established to update the standard specification. In all, 24 state highway-department personnel and 29 contractor personnel (representing 17 different companies) were interviewed or participated in group discussions over a seven-month period to identify constructibility problems driven by project specifications. Possible solutions or recommendations for change were also documented, although the primary purpose of data collection was to uncover problems without regard to severity or frequency.

Each entry in the Specification Problem Information Base is structured as follows: specification reference number and general title, applicable highway element, problem classification, issues and comments on problem causes and effects, recommendation for problem solution, a listing of the three most critical apparent causal factors affecting the item, degree of consensus among interviewees, and related comments. Three SPIB entries illustrating a variety of problem types are presented in Appendix I.

SPIB Analysis

Table 3 presents the frequency of problem occurrence according to both highway element (earthworks, pavements, drainage, etc.) and problem type or attribute as stated. A total of 64 instances are tabulated, and almost a majority of problems—48.4%—are found to relate to pavements. Many specification problems relate to bridge/structures and earthworks. While the most common general class of problem relates to deficiency of specification content, 39.0%, other common general problem classes include problems with practicality and functionality. The most frequent specific type of problem encountered is "gold-plating" or excessive specification requirements, 25.0%. Overly restrictive tolerances, lack of specification definitiveness, and lack of specification currentness have also been found to be significant (greater than 15.0%). The most populous cross-classification cells relate to pavement tolerances and bridge/structure gold-plating.

Each SPIB entry was analyzed for its apparent causal factor for the purpose of gaining additional insight into problem prevention. The list of apparent causal factors considered is presented in Appendix II. Major headings include project scoping, resources, processes and methods, controls, information and communication, innovation, and project environment. Each of these headings is further broken down into subfactors as indicated.

The analysis of apparent causal factors is summarized in cross-classification tables similarly to the problem types shown in Table 3. Table 4 pre-

TABLE 3. Elements of Highway Construction Related to Problem Types

Problem types (1)	Earthworks (2)	Pavement (3)	Drainage (4)	Bridges/ structures (5)	Other (6)	Total elements (and percent of total) (7)
Communication deficiency						
Inconsistent interpretation	1	3	—	1	1	6 (9.40)
Information deficiency						25 (39.00)
Irrelevancy/noncurrentness	4	5	—	1	—	10 (15.60)
Lack of definitiveness	—	6	1	1	2	10 (15.60)
Inconsistency	—	3	—	2	—	5 (7.80)
Functionality	—	—	—	—	—	—
Gold-plating	1	6	—	7	2	16 (25)
Practicality						17 (26.60)
Unrealistic tolerances/ impractical requirements	3	7	—	3	—	13 (20.30)
Inflexibility	—	—	—	1	—	1 (1.60)
Impractical measurement/ payment methods	—	1	2	—	—	3 (4.70)
Total	9	31	3	16	5	
Percent of total	(14.10)	(48.40)	(4.70)	(25)	(7.80)	64 (100)

Note: Items may relate to more than one element.

TABLE 4. Elements of Highway Construction Related to Causal Factors

Apparent causal factors[a] (1)	Earthworks (2)	Pavements (3)	Drainage (4)	Bridges/ structures (5)	Other (6)	Total elements (and percent of total) (7)
Project scoping						
Facility characteristics (A2)	2	9	—	6	2	19 (29.7)
Resources						
Materials (B2)	—	1	—	3	—	4 (6.3)
Processes						
Construction (E3)	2	3	—	2	—	7 (10.9)
Controls						
Cost and financial control (D2)	—	1	2	—	—	3 (4.7)
Information and communication	—	—	—	—	—	31 (48.4)
Documentation						
Relevancy/ currentness (E6)	4	5	—	1	—	10 (15.6)
Definitiveness/ completeness (E4)	—	6	1	1	2	10 (15.6)
Consistency (E3)	—	3	—	2	—	5 (7.8)
Interpretation						
Consistency (E3)	1	3	—	1	1	6 (9.4)
Total	9	31	3	16	5	
Percent of total	14.1	48.4	4.7	25	7.8	64 (100)

[a]Only primary factors have been considered.

TABLE 5. Cross Classification: Primary and Secondary Factors Related to Problem Types

Problem types (1)	Project[a] (primary factor) (2)	Scoping[a] (secondary factor) (3)	Resource[b]		Processes[c]		Controls[d]		Information/ Communication[e]		Environmental systems[f] (secondary factor) (12)	Total (and percent of total) (13)
			Primary factor (4)	Secondary factor (5)	Primary factor (6)	Secondary factor (7)	Primary factor (8)	Secondary factor (9)	Primary factor (10)	Secondary factor (11)		
Communication deficiency												
Inconsistent interpretation	—	4	—	1	—	3	—	1	6	—	2	17 (11)
Information deficiencies	—	—	—	—	—	—	—	—	—	—	—	60 (40.6)
Irrelevancy/ noncurrentness	—	3	—	4	—	4	—	2	7	—	1	21 (13.5)
Lack of definitiveness	—	4	—	4	—	—	—	6	10	—	—	24 (15.5)
Inconsistency	—	5	—	2	—	2	—	1	5	—	—	15 (9.7)
Functionality adequacy												
Gold-plating	8	9	3	5	3	9	—	—	—	1	—	38 (24.5)
Application Practicality:	—	—	—	—	—	—	—	—	—	—	—	40 (26.5)
Unrealistic tolerances/ impractical requirements	9	2	—	4	2	8	—	7	—	—	—	30 (20.6)
Inflexibility	—	—	—	—	1	1	—	—	—	—	—	2 (1.3)
Impractical measurement/ payment methods	—	3	—	—	—	—	3	—	—	—	—	6 (3.9)
Totals	17	30	3	20	6	27	3	17	28	1	3	155 (100)
Primary factors as a percent of total factors	29.8	—	5.3	—	10.5	—	5.3	—	49.1	—	—	57 ( )

[a]Cumulative factor total = 47; percent of total primary and secondary factors = 30.3.
[b]Cumulative factor total = 23; percent of total primary and secondary factors = 14.8.
[c]Cumulative factor total = 33; percent of total primary and secondary factors = 21.3.
[d]Cumulative factor total = 20; percent of total primary and secondary factors = 12.9.
[e]Cumulative factor total = 29; percent of total primary and secondary factors = 18.7.
[f]Cumulative factor total = 3; percent of total primary and secondary factors = 2.
Note: Items may relate to more than one element.

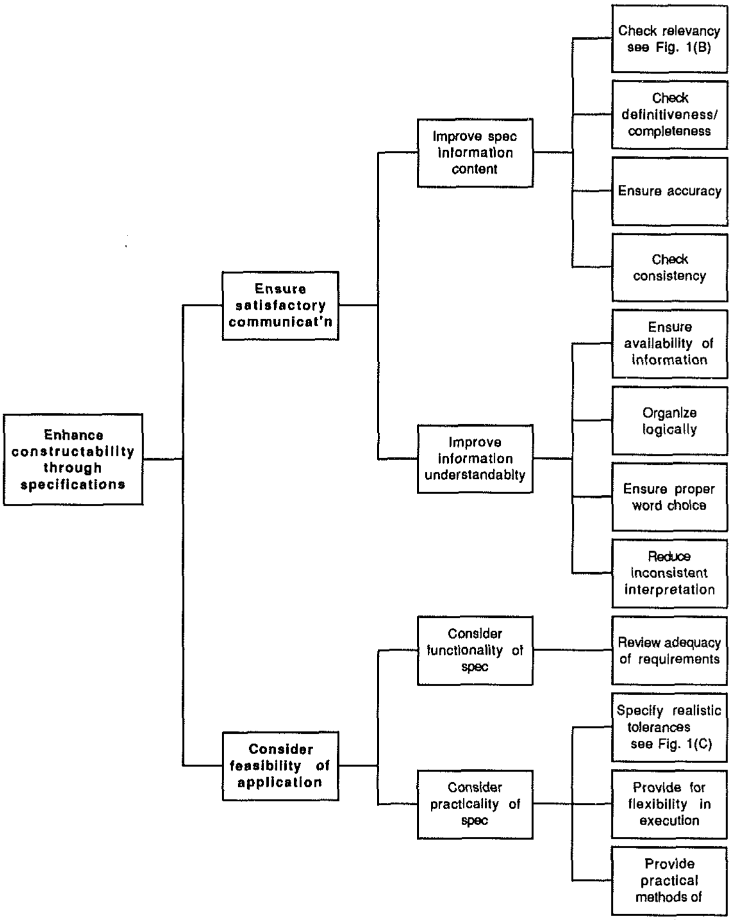

FIG. 1. (*a*) HOT Diagram for Enhancing Highway Constructibility through Specifications

sents highway elements and factors, while Table 5 presents problem types and factors. Both primary and secondary factors have been included in Table 5, while only primary factors were considered in Table 4. These analyses suggest that both pavement and bridge/structure specification problems are most influenced by project scoping/facility characteristics, and that both practicality-related and functionality specification problems are also driven primarily by project scoping. Overall, the most common primary apparent causal factor affecting the constructibility of specifications is information and communication, followed by project scoping.

The hierarchy of objectives technique (HOT) is another insightful method of analysis for exploring both high-order and low-order managerial or technical objectives (Fisher 1989). Similar to the functional analysis system technique (FAST) for diagramming of value engineering, HOT diagrams focus on objectives (rather than functions) and offer a particularly effective way

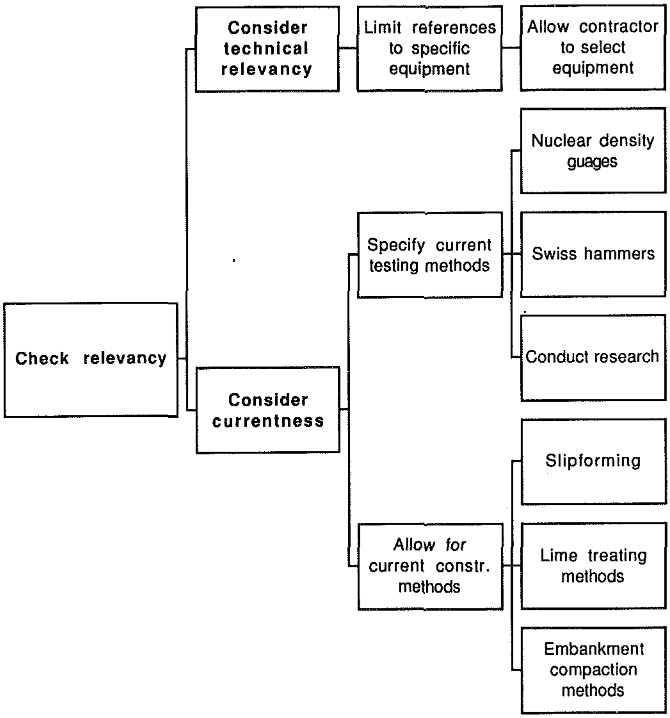

FIG. 1. (*b*) Continued from Fig. 1(*a*)—"Check Relevancy"

of communicating the complex and detailed hierarchy of objectives supportive of improved specifications for constructibility. Figs. 1(*a–c*) presents the HOT diagrams developed from the data collected in this research. Diagram interpretation is rather simple. High-order objectives are listed on the left side of the diagram, and low-order objectives or tactics are listed on the right side. As one reads from left to right the diagrams address "how," or the manner of achieving objectives. The "why," or motivation for objectives or tactics, is provided as one reads from right to left. HOT diagrams have proven to be a very effective device for eliciting, structuring, and communicating knowledge.

Additional significant, specific findings from this research are as follows:

1. In many circumstances, it can be argued that tolerances for temporary work should be looser than those for the permanent facility. In general, tolerances should be determined by parameters of the job and should be consistent with both construction methods and testing procedures.
2. Experienced engineers tend to not enforce unrealistic tolerances. Less experienced engineers often lack the judgement to know when or when not to enforce specified yet unrealistic tolerances. One senior engineer stated that "gold plating generally results from job fear and is an attempt to avoid peer criticism."
3. In counteracting variable inspector interpretations due to lack of experience, training programs have been effective. These lead to greater consistency

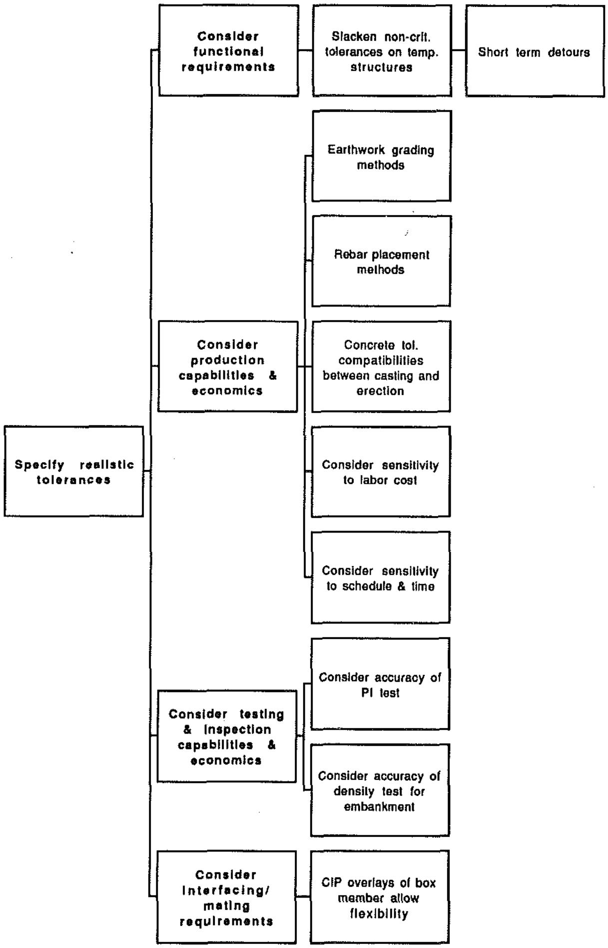

FIG. 1. (*c*) Continued from Fig. 1(*a*)—"Specify Realistic Tolerances"

and uniformity in the interpretation of specifications and inspection procedures. As part of their training, inspectors should be rotated through several highway field districts to ensure statewide uniformity in specification interpretation.

4. Some inspector decisions can have a drastic effect on contractor costs. For example, difficult yet cost-sensitive inspector decisions relate to weather conditions suitable for seal-coat placement, suitability of fill material, weight of compaction rollers to be used, and tolerances for rebar placement. A reference with inspection guidelines may be worth developing. In addition to inspectors, contractors would benefit from greater knowledge of owner expectations and inspector interpretations.

5. Specifications should be written to encourage use of local materials to the greatest extent possible. This requires that the specification address both material variability and a variety of cost-effective material stabilization methods. Dramatic savings in contractor fuel costs may be accrued.

6. Prescriptive specifications are based on the fallacy that specifications can always be kept current for frequently changing construction equipment. To the greatest extent possible, highway departments should not specify what methods or equipment contractors are to use.

7. For some specification items, it has been suggested that pay practices be based on the percentage of tests that pass (within stipulated limits). However, little common agreement has been found here. Appendix III contains a brief discussion of a related Federal Highway Administration procedure.

8. Specified time limits for time-sensitive construction processes such as concrete placement or curing should be flexible enough to accommodate the various conditions that may apply.

End-Result Specifications

For the most part, the use of end-result specifications remains a controversial practice. Under many circumstances or for many project elements, contractor performance under end-result specifications is difficult, if not impossible, to inspect or approve due to the level of existing testing/inspection methods or technology. Pros and cons for the use of end-result specifications that have surfaced from this and other research are given as follows.

Pros

1. Innovation is encouraged and rewarded. Contractors are free to select cost-effective methods and to use equipment in a cost-effective manner.

2. Wide variations in equipment characteristics and continuing advances in equipment technology are less problematic to the specifications writer.

3. Material variability is accommodated.

4. Quality-assurance/quality-control (QA/QC) efforts (and thus manpower requirements) by the highway department are reduced.

5. Performance penalties can be used to promote fairness and more clearly define contractor performance risk.

Cons

1. Specifications are limited by the engineer's ability to describe the desired end product and to provide a means of measuring the quality of this end product (Blaschke 1989). Significant development of nondestructive testing methods is needed.

2. Contractor prequalification may be necessary to ensure that only skilled, responsible contractors are awarded contracts.

3. Bidding may be difficult due to uncertain construction methods that may exist at the time of bidding.

4. Quality performance is limited by the contractor's ability to appropriately supplement his own organization with additional skills necessary for quality assurance monitoring (Blaschke 1989).

5. Performance penalties are often excessive.

Periodic Specification Updating

The process of periodically reviewing and updating standard specifications is critical to project success and can benefit from some of the lessons learned in this study on constructibility. Fig. 2 suggests one approach to this process,

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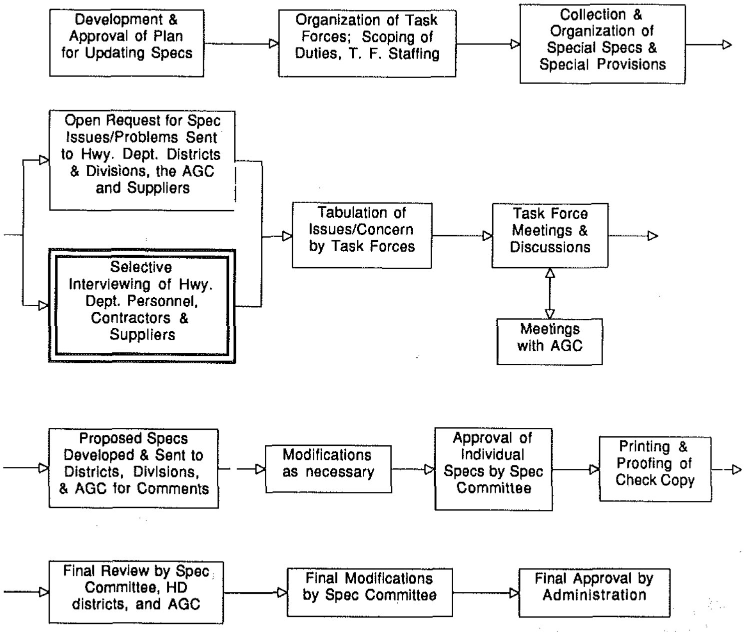

FIG. 2. Suggested Procedure for Updating Standard Highway Specifications

which is primarily executed by a number of quasi-independent task forces focused on particular elements of highways (such as earthworks, pavements, or structures).

Initially, attention of the task forces is directed toward special specifications and special provisions which (as discussed previously) have evolved on projects since the last review of the standard specifications and are considered for adoption as new standard specifications. Early efforts are also devoted to written solicitations for input and constructive criticism from highway department regional districts and staff divisions, as well as from contractor organizations and material suppliers. In addition, this research indicates that such open-ended solicitations can be effectively supplemented with selective interviewing of knowledgeable individuals, focused on very specific issues.

In fact, it is suggested that each of the desirable specification attributes listed in Table 2 be thoroughly addressed in an interview setting. By prompting respondents with general problem types, such interviews may serve as an effective mechanism for determining the complexities of issues or for exposing problems that might otherwise go unnoticed. Following the identification of problem areas and the collection of ideas, comments are screened and lengthy debates may be necessary. New or revised specifications should be reviewed for acceptability against various criteria (such as durability and life-cycle costs) and checked for consistency with other specifications.

Conclusions and Recommendations

This research has led to the following conclusions and recommendations:

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1. Specification problems are common for a multitude of reasons. The structure of desirable attributes of specifications (and corresponding problems types) presented is complex, yet of great value in the insight it affords. The day-to-day professional activities of specification writers should include consideration of these attributes in a rigorous and systematic manner.

2. Highway specifications appear particularly problematic with respect to "gold-plating," tolerances, definitiveness, and currentness. In general, facility function and significance or criticality should drive project requirements. Additional communication between designer and constructor on achievability of tolerances is needed.

3. Pavement and bridge/structures specifications deserve particular scrutiny.

4. Common apparent causal factors that lead to problems include information, communication, and project scoping.

5. Good specifications must be matched with effective inspector training programs if specification interpretation and enforcement are to be successful.

6. Specifying current or up-to-date methods for construction or testing will continue to be a challenge. Modern information systems must incorporate a capability for tracking the timeliness of such requirements.

7. The promise of end-result/performance type specifications, for the most part, is not yet a reality. Additional research is needed in testing and inspection procedures and technologies supportive of this approach. In general, the industry is badly in need of more expedient methods for quality-control testing.

8. Periodic updating of specifications should include an aggressive plan for personal interviewing of knowledgeable parties and should address each of the desirable specification attributes in detail.

9. Additional statistical research is needed into the causes of specification-driven project problems.

Highway constructibility is a worthy endeavor deserving of increased attention. This is particularly true in the context of specifications, which are becoming both more voluminous and technically complex. Highway project costs, durations, and disputes will only be reduced when project planners and designers focus greater attention on detrimental obstacles to contractor efficiency and cost-effectiveness. Engineers must become more sensitive to the effectiveness of their communication skills, both oral and written.

Appendix I. Sample SPIB Entries

3.7 Item 131.2, 132.2, 246.2, 249.4, and 274.2:

Plasticity Index (PI)

Borrow, embankment, foundation courses, flexible base, flexible base delivered, and cement-stabilized base.

I. Problems:

C. Specification has unrealistic tolerances/requirements. Unrealistic tolerances for application of PI test results.

Issues and Comments:

The PI test procedure is not very accurate, yet test results tend to be strictly interpreted. It is very hard to obtain a representative sample to work with. Consistent results are difficult to obtain because it is a very subjective test.

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Recommendation:

Allowable tolerances of the PI test should be reflective of the accuracy of the test method itself.

II. Elements of Highway Construction

A. Earthworks.

B. Pavement.

III. Factors

A. Project scoping:

(2) facility characteristics: owner preferences and specifications.

B. Resources: availability, variability, suitability, intrinsic attributes.

(2) material.

D. Controls:

(1) QA/QC, testing and inspection.

Degree of Consensus:

Ten out of 10 agree that the tolerances for the PI test are too light.

Additional Comments:

a. Different labs can test the same material and produce different test results. A new test method needs to be developed to take out the inconsistent human factor.

b. Liquid limit has been found to be a better test for control purposes.

4.11 Item 477.6: Safety End Treatment (Payment)

I. Problem:

D. Gold-plated designs, specifications, etc. Gold-plated placing time.

Issue and Comments:

"Any concrete not placed as herein prescribed within 30 min after mixing shall be rejected and disposed of as directed except as provided otherwise herein." The time period specified from batching to placing is not long enough. If 10 min were added to the time period, quality would not be affected, and less concrete would be wasted due to the restrictive time period.

Recommendation:

Air- or concrete-temperature ranges should be specified with corresponding maximum time periods for the batching to the placement of concrete. The use of an approved retarding agent in the concrete can permit the extension of the time periods by 30 min.

II. Elements of Highway Construction

D. Pavement.

III. Factors

A. Project scoping:

(2) facility characteristics: owner preferences and specifications.

B. Resources: availability, variability, suitability, intrinsic attributes;

(2) material.

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C. Processes/methods/subprocesses pertaining to:
(3) construction.

Degree of Consensus:
Two out of two agree that the time period allowed for placing concrete is not sufficient.

5.1 Item 477.6: Safety End Treatment (Payment)

I. Problem:
E. Specification with unsatisfactory method(s) of payment. Improper payment method.

Issues and Comments:
A practical method is needed to pay for safety end treatments. The current method is to pay for each individual safety end treatment, which requires a lot of estimating time due to the large quantity of items.

Recommendation:
Safety end treatments should be paid based on the cubic yards of concrete that are used with reinforcing steel as a subsidiary item. A statewide standard method of payment is needed. Also, payment could be made based on the linear feet of pipe, riprap, and pipe runners used. This will eliminate the problem of having a different pay item for each size of pipe.

II. Elements of Highway Construction
E. Drainage structures.

III. Factors
A. Project scoping.
(2) facility characteristics: owner preferences and specifications.
D. Controls.
(2) cost and financial controls.

Degree of Consensus:
Eight out of eight agree that a practical method of payment is needed to pay for safety end treatments.

Additional Comments:
a. In one district, precast pipe runners are used so riprap is not needed.
b. The method needs to be changed because much time is required by the estimator to handle the numerous take-offs.

Appendix II. Apparent Causal Factors

1. Project scoping:
   a. Operational requirements.
   b. Facility characteristics—scale, complexity, composition, and preferences.
   c. Budget constraints.
   d. Time constraints, schedule objectives and limits.
2. Resources—availability, variability, suitability, and intrinsic attributes:

   a. Manpower.
   b. Material.
   c. Machine.
3. Processes and methods:
   a. Planning and design.
   b. Procurement and bidding.
   c. Construction.
   d. Maintenance.
4. Controls:
   a. QA/QC, testing and inspection.
   b. Cost and financial controls.
   c. Schedule controls/productivity measurement.
5. Information/communication:
   a. Documentation/transmission/interpretation.
   b. Availability/source/accuracy.
   c. Consistency, compatibility, and ambiguity.
   d. Clarity, conciseness, and completeness.
   e. Timeliness and frequency.
   f. Relevance.
6. Innovation:
   a. Awareness of promptors—recognition of need.
   b. Motivation and freedom to innovate, related constraints.
   c. Capability to innovate needed resources, and research and development.
   d. Support or lack of champion.
7. Environment:
   a. Site—topography, geotechnics, water, and accessibility.
   b. Weather.
   c. Infrastructure/traffic.
   d. Political/legal/regulatory.
   e. Macroeconomic/financial/sociological.

Appendix III. Quality-Level Analysis

The Federal Highway Administration has developed a procedure to determine the acceptance level of a material for certain performance specifications. When specifications provide for material to be tested on a statistical basis, the material will be evaluated for acceptance accordingly. All test results for a specified lot of material will be analyzed by the quality-level-analysis/standard-deviation method to determine the total estimated percent of the lot that is within specification limits. Quality-level analysis is a statistical procedure for estimating the percent compliance to a specification. It is affected by shifts in the arithmetic mean and by the standard deviation. Analysis of each test parameter is based on the acceptable quality level (AQL) of 95.0 and a producer's risk of 0.05. AQL is the lowest percent of specification material that is acceptable as a process average. The producer's risk is the probability that when the contractor is producing material at AQL, the materials will receive less than a 1.00 pay factor. As an incentive to produce quality material, a pay factor may be obtained that is greater than 1.00, up to a maximum of 1.05 (*Standard* 1985).

Appendix IV. References

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