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SPECIFICATION IMPROVEMENTS FOR ENHANCED CONSTRUCTABILITY

by

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Research Report Number 1149-2

Research Project 3-6-88/0-1149

Investigation of Highway Project Constructability Improvement

conducted for

Texas State Department of Highways and Public Transportation

by the

CENTER FOR TRANSPORTATION RESEARCH

Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

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PREFACE

A variety of barriers continue to hinder the constructability of highway projects, including both administrative and technical project specifications. This report examines the nature and extent of problems that specifications pose to contractors in the execution of highway construction contracts. The function, content, and format of SDHPT project specifications are questioned and analyzed in the context of facilitating both efficient project management and construction practices.

ABSTRACT

Specific problems with highway specifications that hinder constructability are identified and analyzed. Problem frequencies are represented in cross classification tables, considering affected project element, problem type, and apparent causal factor. A process for periodically updating specifications is presented and critiqued.

KEY WORDS: specifications, highways, constructability, communications, information management, project management, construction, tolerances

SUMMARY

Project constructability is keenly affected by the quality of specifications. This report explores the nature of specification-related obstacles to good constructability practice for highway projects. In accomplishing this objective, a multitude of problems were identified, relevant problem details 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. Highway specification problems are communicated through a series of Hierarchy of Objective Technique (HOT) diagrams. In addition, a procedure is proposed for the periodic updating of standard highway specifications.

IMPLEMENTATION STATEMENT

A small number of constructability problems caused by specifications are detailed in this report. Some are more serious or costly than others, and a few, it may be argued, represent personal preferences. It is recommended that the Department review these findings thoroughly and determine whether changes to the standard specifications are desirable.

The findings of this study also indicate that the SDHPT already has in place a reasonably effective procedure for periodically updating and improving project specifications, a procedure that involves the contracting community. However, this procedure can be enhanced with a more pro-active approach to determining contractor constructability problems. Included in this report is a comprehensive listing of potential specifications-driven contractor constructability problem types. This listing may be useful in ensuring a more complete and effective review of specifications in the future.

TABLE OF CONTENTS

CHAPTER I. INTRODUCTION

This research project addresses highway project constructability concerns related to specifications. It is one aspect of a highway project constructability study that is being funded by the Texas State Department of Highways and Public Transportation (SDHPT).

The highway project constructability study has been delineated into a number of critical issues for investigation. A study on the issue of pre-construction highway project planning and design was completed in 1988. It served as a pilot study of highway constructability and although no formal report was published, the feasibility of the research methodology was established. In particular a system for logically reviewing constructability concerns was developed. The essence of the findings together with a broad overview of constructability has been published in Highway Constructability Guide (Hugo et al, 1989) which is intended for the information of senior personnel of the Divisions and Districts of the Texas State Department of Highways and Public Transportation.

Concurrently with the pilot study, a study was undertaken of specification improvements that would enhance constructability. This research report completes the study on the issue of specifications.

OBJECTIVES OF RESEARCH

The prime objective of the study was to enhance constructability by improving specifications. In order to achieve this, the following tasks were identified:

(1) Determine specific problems with specification items and categorize these under appropriate problem types.
(2) Determine the most significant problem types of the specification items with the use of cross classification tables.
(3) Propose recommendations to correct each problem contained in the specification problem information base (SPIB).
(4) Determine the potential causal constructability factors for each problematic specification item contained in SPIB.
(5) Critique and propose recommendations for improving the specification rewrite and updating process.

By achieving this objective, fewer problems could be expected in the future, and the problems that do occur should be able to be solvable in an efficient and productive manner.

OUTLINE OF RESEARCH REPORT

The remainder of the research report has been organized as follows:

Chapter II consists of a literature review of constructability and specifications. The definition and benefits of constructability are presented, as well as barriers to its implementation. The explanation of the Construction Industry Institute (CII) Constructability Concepts File is also included in this section. The review of specifications consisted of determining the role of specifications and the different types of specifications that exist. A particular Federal Highway Administration payment guideline for performance specifications was also investigated. Finally, common problems with specifications were identified along with ways to eliminate the problems.

Chapter III contains a description of the methodology employed for conducting the research. A flow chart that shows clearly and succinctly the research methodology used, is presented in the chapter. The methods and tools used for data collection are also discussed. The purpose and the methods of data analysis along with a discussion of the items used in conducting the analysis, concludes the chapter.

Chapter IV presents the Specification Problem Information Base (SPIB), which contains problem items and comments with the specification manual. This chapter was used as the basis for analysis of the research findings.

Chapter V presents an analysis of SPIB. Two methods of analysis were utilized, namely cross classification tables and Hierarchy of Objective Techniques diagrams.

Chapter VI describes the process used by the SDHPT to review and update the specification manual. Areas that are discussed include:

(1) reasons for rewrite of specification manual,
(2) specification updating on a project by project basis,
(3) development of new specification manual,
(4) organizational approach,
(5) incorporation of changes,
(6) testing of new specifications, and
(7) work and proceedings of task forces.

Finally, Chapter VII presents the conclusions and recommendations of the research study on specifications.

CONCLUDING REMARKS

It is important to understand that specifications represent the official contractual description of interalia processes, methods, materials plant and equipment, that are considered necessary to complete a facility to a prescribed quality. As such, the official specifications of an institution such as the SDHPT are only revised at intervals of five to ten years. The importance of this study is therefore apparent and if constructability enhancement is considered in the present and future SDHPT specification reviews, the main purpose of this study will have been accomplished.

CHAPTER II. CONSTRUCTABILITY AND SPECIFICATIONS: LITERATURE REVIEW

The literature review was done to provide a foundation for the research. Aspects of both constructability and specifications were considered in order to show that specifications can contribute to the enhancement of constructability.

CONSTRUCTABILITY

Constructability may be defined as a measure of the ease or expediency with which a facility can be constructed (Hugo et al, 1989). Constructability is enhanced by the optimum use of construction knowledge and experience in planning, design procurement, and field operations in achieving overall project objectives (Construction Industry Institute, 1986).

Perhaps because constructability is by nature multidisciplinary and multicontextural, it means different things to the various participants in a project. To the project owner, constructability affords the opportunity, on construction projects, for achieving greater efficiency, with resulting lower cost, reduced schedule, or improved quality. To the designer, it is the understanding of the methods and constraints of the actual construction required to execute the design being made. To the constructor, it is a combination of effort required to implement the design most efficiently and the opportunity to minimize resource effort and expenditure.

The Construction Industry Institute (CII) has identified a number of constructability concepts applicable to the different phases of a project. Briefly, these concepts address project execution planning; conceptual project planning; specifications; contracting strategies; schedules; and construction methods, including those concerning preassembly, site layouts, design configurations, accessibility; and adverse weather (Constructability: A Primer, 1986). However, while constructability enhancement has been studied and applied to many segments of the industrial construction industry, it has not been researched in the context of highway construction.

Constructability is indeed already practiced to some extent by design engineers of the Department, although it perhaps has not been formally defined and thought of as a primary factor in highway design. While the bulk of constructability research to date has focused on industrial or commercial construction projects, most concepts are also applicable in the highway sector, and highway project costs and durations may be reduced when attention is directed toward more effective constructability.

With the effective implementation of constructability, many benefits can be realized on a project. The two most important benefits that can result are cost savings and schedule improvements. Other benefits include an increase in the quality of the work being performed, a reduction in the amount of labor manhours needed, and an increase in the accuracy of the estimates (CII 1987(a)). Thus, if constructability enhancement can be accomplished, projects will enjoy numerous advantages.

However, the implementation of constructability enhancement is not always easy because many barriers exist. Two types of barriers present problems to constructability. They are barriers to design-construct integration and barriers to technology development and implementation (CII 1987(a)).

The barriers to design-construct integration include:

(1) resistance by owners,
(2) resistance by constructors,
(3) resistance by engineers,
(4) limited training,
(5) infrequent use of incentives,
(6) contractual barriers,
(7) traditions, and
(8) shortage of time.

The barriers to technology development and implementation include:

(1) poor communication,
(2) industry fragmentation,
(3) limited research funding, and
(4) attitudes.

These barriers must be overcome for constructability to be implemented properly and effectively.

CONSTRUCTABILITY CONCEPTS FILE

The Concepts File is a publication based on the findings of research programs directed by the Construction Industry Institute (CII) Constructability Task Force. Thirteen concepts are contained in the file, along with sample applications of each. The concepts are divided into two groups based on their relation to a phase of construction. The two groups are the conceptual planning phase and the design and procurement phase. The Concepts File is not a "cook book," but it allows individuals to take advantage of the lessons learned by others and apply them in their organizations. "The primary purpose of the Concepts File is to stimulate thinking about constructability and how to make it work" (CII 1987(b)).

The conceptual planning phase involves the definition of functional and performance requirements, the evaluation of project feasibility, and the studying of criteria for preliminary engineering. The concepts contained in this phase are (CII 1987(b)):

Concept I-1: Constructability programs are made an integral part of project execution plans.

Concept I-2: Project planning actively involves construction knowledge and experience.

Concept I-3: Early construction involvement is considered in development of contracting strategy.

Concept I-4: Overall project schedules are construction sensitive.

Concept I-5: Basic design approaches consider major construction methods.

Concept I-6: Site layouts promote efficient construction. The design and procurement phase tends to concentrate its efforts on drawings, specifications, purchase orders, and schedules. The concepts contained in this phase are (CII 1987(b)):

Concept II-1: Design and procurement schedules are construction sensitive.

Concept II-2: Designs are configured to enable efficient construction.

Concept II-3: Design elements are standardized.

Concept II-4: Construction efficiency is considered in specification development.

Concept II-5: Module/preassembly designs are prepared to facilitate fabrication, transport, and installation.

Concept II-6: Designs promote construction accessibility of personnel, material, and equipment.

Concept II-7: Designs facilitate construction under adverse weather conditions.

It is apparent that Concept II-4 is of particular interest to this research study because it corresponds with the objective of the research. This concept is concerned with the role of construction input in the development of specifications. Fabrication and construction efficiencies are greatly facilitated when constructability helps to produce specifications that are clear and complete. Several other considerations affect specification development along with constructability, such as reliability, maintainability, etc, but the most important one is constructability (CII 1987(b)).

Through certain specification improvements, construction efficiency can be greatly advanced. Thus, constructability is enhanced if (CII 1987(b)):

— The underlying guide specifications offer clear-cut options.

— Specification development within a project is done as a distinct project activity.

— Sufficient time is allowed and the right people are involved to develop good project specifications.

— Project specifications are consistent with job requirements, reflect current technology, and reflect the owner's intent for quality.

— Clarity is sought as one of the prime characteristics of a good specification.

— A single construction specification covers all appropriate aspects of a single subject or component.

— The cost saving potential of "or equal" specifications is balanced against the risk involved.

— Specifications are current.

Therefore, if emphasis is placed on improving specifications, constructability can be greatly enhanced.

ROLE OF SPECIFICATION

The following are typical definitions of specifications:

"A specification is a precise statement describing the characteristics of a particular item" (CSI 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). To this one should add that specified material is of the utmost importance, particularly in highway construction.

"Specifications are the written, technical, engineered portion of the construction contract documents" (ASCE 1988). Thus, specifications can be defined in many different ways with the same essential meaning. Likewise, the purposes of specifications are as widespread as their definitions. The following is a list of some purposes of specifications.

(1) Specifications are a guide for bidders in preparing their cost estimates upon which their proposals are based (Jellinger 1981).
(2) Specifications convey from the design engineer to the contractors specific technical information so that the required materials can be provided and construction can be performed and monitored. They describe the type and quality of materials, methods of construction, testing requirements, design submittals, and general requirements (ASCE 1988).
(3) Specifications form part of the agreement between the contractor and the owner. They are a book of instructions (Jellinger 1981).
(4) Specifications serve as the written record of construction instructions to the courts when specifications are in conflict with results (CSI 1985).

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

Standard specifications (such as those used in highway construction) are often extended and made structurally more complex with the attachment of special provisions and special specifications. These are specifications which supplement or modify the standard specifications and which 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 item. 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.

It is apparent that for specifications to fulfill their purpose, there are some basic requirements that must be met. These requirements are (Bockrath 1986):

— technical accuracy and adequacy,

— definite and clear stipulations,

— fair and equitable requirements, and

— format such as to permit easy use during operations—careful preparation to the end so they will be legally enforceable

If these requirements are satisfied, the specifications should adequately serve their purposes.

TYPES OF SPECIFICATIONS

There are four major types of specifications: guide, descriptive, performance, and proprietary. Project specifications will usually employ more than one type of specification. The types used will depend on the intended purpose of the specification.

Guide specifications are essentially outline specifications with blank spaces to be filled in with information peculiar to a particular project (Jellinger 1981). They are used by specification writers to aid them in their work. There are four types of guide specifications: commercial, industry, government agency, and the specifier's own (Simmons 1986). Commercial guides are guides like "Masterspec" and "Spectext" which are sold by companies. Industry guides are produced by product manufacturers and tend to favor the producer over its competition. Government agencies have developed guide specifications for their work, and the guides must be used when working for them. The specifier's guides are usually office guides which have been developed from previous projects (Simmons 1986). The use of office guides over other guides results in:

— increased efficiency,

— reduction of repetitive work,

— reduction of errors, and

— uniformity between projects.

Thus, guide specifications help to develop effective project specifications.

A descriptive specification is a detailed written description of the required properties of a product, material, or piece of equipment, and the workmanship required for its proper installation (CSI 1985). Descriptive specifications describe how the end result is to be accomplished. The burden of performance is assumed by the specifier when this type of specification is used. As projects become more complex, the descriptive specification is being used less because the writing process becomes very lengthy and tedious (CSI 1985). A descriptive specification is essentially a recipe for completing a project.

A performance specification states the required results with criteria for verifying compliance but without unnecessary limitations on the methods for achieving the required results (CSI 1985). This type of specification gives a contractor the initiative for selecting methods to accomplish the desired result (ASCE 1988). "Under a pure performance specification, the contractor accepts responsibility for design, engineering, and performance requirements, with general discretion as to how to accomplish the goal" (Sweet 1985). A performance specification is used mostly on large-scale industrial projects or in specialized work (Sweet 1985). The performance specification places a burden on the contractor requiring him to be a specialist, but it gives him the freedom to determine how he will complete a project to accomplish the prescribed goal. To phrase it simply, a performance specification describes the end result.

A proprietary specification identifies the desired products by manufacturer's name, brand name, type designation, model number, or other unique characteristics. Also, a specification is considered proprietary when the specified product is available from only one source, even if a manufacturer's name is not stated (CSI 1985). The proprietary specification usually increases the contract cost because it limits the contractor's ability to use material or equipment that may be just as good as the ones specified and cost less (Sweet 1985). The other disadvantages of these specifications are:

— Elimination of competition.

— Requiring products with which the contractor may have had little or bad experience.

— Favoring certain products and manufacturers over others.

However, several advantages are offered by using proprietary specifications. They are (CSI 1985):

— Close control of product selection.

— Preparation of more detailed and complete drawings based on precise information obtained from manufacturer's data.

— Decreases the overall length of the specification and reduces production time.

— Simplifies bidding by narrowing competition and removing product pricing as a major variable.

A proprietary specification is also referred to as a manufacturer's specification or a purchase description specification.

CRITIQUE OF SPECIFICATION TYPES

If the different types of specifications are considered it is apparent that::

(1) The intended purpose of the specification will determine which type is used in a particular instance.

(2) Each type of specification has its advantages and disadvantages.

(3) Guide specifications are probably most useful where specifications have been standardized and are available for a wide range of uses, each with varying parameters for the respective specification items. The onus is then on the user to complete the specification according to specific needs. When the end result cannot be adequately defined, descriptive specifications are generally used. Likewise, when new products or processes are required and it is desirable for the contractor to provide creativity for the development, performance specifications are used (ASCE 1988). Bidding is more difficult with performance specifications because of the unknowns associated with developing a process, however, innovation highly favors performance. Descriptive specifications have an advantage with design control since each aspect of design is specified. Cost advantage varies, but for complex projects, performance specifications result in a lower total cost because the contractor is not restricted to a specific procedure. Testing and inspection is more difficult with performance specifications (ASCE 1988).

Descriptive specifications are the most commonly used type, but the advantages and disadvantages of each type must be examined when selecting the best one to use on a particular project.

The FHWA 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 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 and is affected by shifts in the arithmetic mean and by the standard deviation. Analysis of each test parameter will be based on an 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 (U.S. DOT-FHWA 1985).

SPECIFICATION PROBLEMS: TYPES AND CAUSES

For specifications to be successful, they must provide enough detail for construction to proceed in a timely, efficient manner and conclude within the intended design scope. However, construction technology is constantly changing which complicates the specification preparation process and creates risk. In order to minimize the risk, aspects of specification preparation, interpretation, and implementation that have created the most problems have been identified by Nielsen and others. These are:

(1) The allowance of substitutions. Many specification writers describe desired characteristics for a product by using a brand name. However, to assure competition, the phrase "or equal" is placed after the brand name of the product. The main problem that arises is determining whether a proposed substitute is "equal" (CII 1987 (b)).

(2) Tight tolerances and defective specifications. Tight tolerances deals with the amount of leeway a contractor is given for the compliance of the specifications. The resulting problem is in determining how much performance deviation is still considered to be legally acceptable under the contract. Defective specifications are those that are not reasonably constructable. Problems result because the performance of the contractor can become more expensive and time consuming than anticipated (CII 1987 (b)).

(3) Phrasing ambiguities. Misunderstandings, disputes, and claims arise from differences of opinion of the meaning of certain words and phrases in contract documents. Contributing reasons for the problems are that construction is complex and contract documents are usually voluminous. Ambiguities tend to always exist, even with highly qualified specification writers (Smith 1981).

(4) Conflicts between specifications and plans and other specifications. When this occurs, it demonstrates the presence of an unclear total scope of work and a lack of coordination in document preparation. The conflicts cause a problem with the order of precedence of documents if it has not been predetermined. A court will usually be needed to solve the conflict (Nielsen 1981).

(5) Inaccurate data. Specifications are filled with technical data upon which the contractor relies. If the data is not accurate or specific information is lacking, disagreements and guesswork will occur in the field, and faulty work will result (Nielsen 1981).

(6) Inspection requirements. If the design professional is overzealous or inadequate with his inspection, problems can result with the work process and the finished product. When a contractor is held to a higher standard of performance than is required by a reasonable interpretation of the specifications, he is entitled to recover his additional costs. Likewise, the owner's right to inspect the work at any time

during the contractor's performance may not be exercised in a way that unduly interferes with efficient performance (Nielsen 1981).

(7) Safety and health requirements. The proliferation of safety and health issues on the construction site has occurred in recent years. The major issue is the specification writer's responsibility with regard to incorporating safety into the project design (CII 1987 (b)). Another concern is the compliance with local building codes and ordinances which are enacted to protect the safety of the public. If specifications do not comply with code requirements, the legal exposure of the design professional is under question (Nielsen 1981).

To reiterate, the common problems of specifications are:

(1) the allowance of substitutions,
(2) tight tolerances and defective specifications,
(3) phrasing ambiguities,
(4) conflicts between specifications and plans,
(5) inaccurate technical data,
(6) inspection requirements, and
(7) safety and health requirements.

Before considering how to counteract specification related problems, it is necessary to consider some of the reasons why they occur. A few reasons are summarized as follows:

(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;
(8) inadequate design fees leading to rushed work, inadequate analyses of alternatives, and minimal checking or reviews; and
(9) human fallibility.

Thus, all the above aspects of specifications have to be examined when considering specification related problems and ways to solve them.

ELIMINATION OF PROBLEMS

In order for specifications to be effective and efficient, attention must be directed to the minimization of the problems stated above. Problems associated with specifications must be corrected so documents can serve the needs of the end user in the field. It is apparent that there are a few simple things that can be done to help eliminate specification problems.

* Clarity and conciseness of specifications can eliminate many problems. It is essential that specifications employ the correct use of words and grammar in properly constructed sentences and paragraphs. The word expressing the exact intention should be repeated as often as is necessary to make the meaning clear. Also, words and terms that are clearly understandable should be selected. The use of short sentences with structures in simple declarative statements should be employed in specification writing. Thus, specification problems can be reduced by avoiding long sentences, obscure terms, and unnecessary wording (Walker 1979).

* Specifications should be tailored to the specific job that is being performed. Inapplicable standard specifications should not be used simply to avoid the effort of preparing proper specifications. If updated, appropriate standard specifications exist, they should be utilized because standard forms are more easily understood. However, the standard specifications must be modified to coincide with the needs of the particular job, and this modification is sometimes done with special provisions. This will help to reduce the problems of poor inappropriate specifications (Jellinger 1981).

* Coordination of specifications is very critical to the reduction of problems. Specifications cover information related to materials and workmanship, and their purpose should not overlap the purposes of other contract documents. Duplication of information should be avoided because it leads to contradictions which cause legal problems and extra costs. Likewise, specification sections must be coordinated with each other to avoid any discrepancies in the contained information. Thus, contract documents must complement each other in order to reduce problems of delays and increased costs (Jellinger 1981).

* Ensure proper use and interpretation of specifications by inspectors. No matter how much effort is placed into writing good specifications, there will always be field conditions that vary from the assumed design conditions. Many adjustments will have to be made, which will best be accomplished by a well qualified inspector. If incompetent inspectors are used, many construction problems will result because the inspectors will impose

excessive requirements to protect themselves. In order to improve the inspection process, several recommendations have been made:

— higher salaries for inspectors,

— a minimum of two years formal education for inspectors,

— more in-house continuing education training programs,

— certification or licensing of inspectors,

— improvement in quality of the inspector's supervisors,

— education of clients to the need for funds to support inspection,

— improving the quality of the plans and specifications, and

— the owner to provide inspection, not the contractor.

Thus, through an improved inspection process, specifications can be better implemented (Fisk 1981).

DEVELOPING SPECIFICATIONS SUPPORTIVE OF CONSTRUCTABILITY

According to Bockrath (1986), desirable characteristics of good specifications include the following:

— technical accuracy and adequacy,
— definite and clear stipulations,
— fair and equitable requirements,
— usable format, and
— legal enforceability.

As the basis for the authors' own research, a more detailed structure of desirable attributes or characteristics of specifications which are supportive of constructability was developed. This is given in Table 2.1. Major or primary headings relate to either the effectiveness of communication of the specification, content of the specification, functionality of the specification, or practicality of the specification. Sub-attributes related to communication include availability/accessibility and understandability. Sub-attributes related to content include relevancy (both technical and currentness), definitiveness/ completeness, accuracy, and consistency. Functionality of specifications may relate to inadequacy 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 2.1 to give clearer meaning to these terms. Once established, these desirable characteristics of specifications were subsequently used in identifying and classifying specification problems. A database of problems was then structured.

OVERVIEW

The literature review provided information about constructability and specifications lending support to the research study. From the information collected, it was demonstrated that improving specifications can contribute to the enhancement of constructability. The following chapter discusses the methodology employed to enhance constructability through specification improvements.

TABLE 2.1. ATTRIBUTES OF SPECIFICATIONS SUPPORTIVE OF CONSTRUCTABILITY

DESIRABLE ATTRIBUTE	DESCRIPTION	POOR CONDITION
	MANNER OF COMMUNICATION	
Information Availability	Readily available information	Referenced specifications not included or commonly found
Organization	Rationally structured or sequenced; Effectively packaged	Unnatural, non-intuitive structure or sequence of specs; Repetitive
Proper Word Choice	Clear, common, incisive technical language without generalization; Avoidance of problem words or phrases	Verbose, wordy; Use of uncommon terms; Interpretation problems due to poor wording
	SPECIFICATION CONTENT	
Relevancy/ Technical Applicability	On point Meaningful Appropriate Useful Information	Useless Information; Non meaningful tests or methods of measurement or payment; Irrelevant verbage
Relevancy/ Currentness	Referenced technology is current	Referenced 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 or plans or other specs
	SPEC FUNCTIONALITY	
Functionality/ Adequacy	Functional Sufficient Non-excessive	Gold-plated or super-adequate; Sub-adequate or technically inadequate; In excess of needs
	SPEC PRACTICALITY	
Practicality	Realistic Reasonably executable Realistic tolerances Measurable or biddable quantities	Unstated tolerances; Unrealistic tolerances; Impractical methods of measurement or payment

CHAPTER III. RESEARCH METHODOLOGY

The literature review confirmed that constructability needs to be considered in all aspects of design, procurement, and construction. It is apparent that constructability is especially important in the writing of specifications since specifications are intimately concerned with design, procurement, and construction. With the establishment of a good constructability program, the specification writing process can be greatly facilitated. Also, by considering constructability, better, more coherent specifications can be written, thus providing better quality and cost efficiency for the end product.

RESEARCH METHODOLOGY FLOW CHART

A flow chart, shown as Figure 3.1, graphically illustrates the procedures employed in conducting the research. Each box represents a logical step in the research process which culminated with a final report to the Texas State Department of Highways and Public Transportation.

The first step of the process was the steering committee scoping which started with a meeting on December 11, 1987. The meeting allowed for the statement of objectives of the highway project constructability study, as well as a discussion of the topics that influence highway constructability. The topics that subsequently were identified to form part of the study are:

(1) planning and design guidelines for enhanced highway construction,
(2) specification improvements for enhanced highway constructability,
(3) effective communication of constructability,
(4) selection, processing and management of materials,
(5) constructability enhancement through innovation,
(6) facilitating construction under traffic,
(7) facilitating future expansion and upgrade,
(8) optimal utilization of plant and equipment,
(9) optimal risk/responsibility allocation, and
(10) constructability program implementation.

The decision to embark on the specification study was based upon an evaluation of the relative criticality of the topics, which selected specifications as being of major importance. This was further endorsed by the present revision of specification which is being undertaken by the Department.

A questionnaire (see Appendix A) that contained the basic critical issues as well as subtopics of the issues was distributed to the steering committee members for their evaluation. The questionnaire allowed for the addition of new problem issues and provided for the prioritization of topics included in the research study.

Upon completion and evaluation of the questionnaires, expert sessions were held to elaborate on information and gather new ideas related to specifications. At the beginning of an expert session, the scope of the research project was explained to the participants. Then, ideas were solicited from the participants under the critical topics associated with specifications. The ideas were either general comments or specification Items with a problem. The data were then grouped under specific problem types for analysis.

Interviews with attendees of expert sessions were conducted in order to clarify and elaborate on the information that was collected at the expert sessions. The interviews also allowed for the solicitation of new ideas and additional problems.

Additional interviews were scheduled with a diverse group of individuals who perform work for the Highway Department. These interviews allowed for the elaboration of established problem specification Items as well as the solicitation of additional problem Items and comments.

An assessment of all of the interviews was performed to assure a diverse sampling of individuals. The type of work that the interviewees perform and the locations where they work were analyzed to ensure a complete mix of interview respondents.

The data that were collected from the expert sessions and interviews were incorporated into a "Specification Problem Information Base" (SPIB) for analysis. SPIB was organized according to specific problem types that occur with specifications. Classified under these problem types are appropriate specification Items and general comments. The format of the specification Items was to list the specific problem and issues with a recommended solution as well as the important constructability factors that were causing the problem.

Concurrently, the Department was reviewing the 1982 Specification Manual. In this process they had solicited comments about specification problems from department personnel, contractors, and suppliers. These comments were scrutinized. Most of the comments dealt with specific problem Items, and the comments were sorted according to the quality of the information and the cost of the Item in the Department's scheme of total work. The good comments that were applicable to constructability, were incorporated into SPIB under the appropriate problem types.

The proceedings of the Department's specification task forces' meetings were also analyzed along with an observation of their functioning. By attending their meetings, their review procedures could be evaluated, and recommendations for future changes could be made.

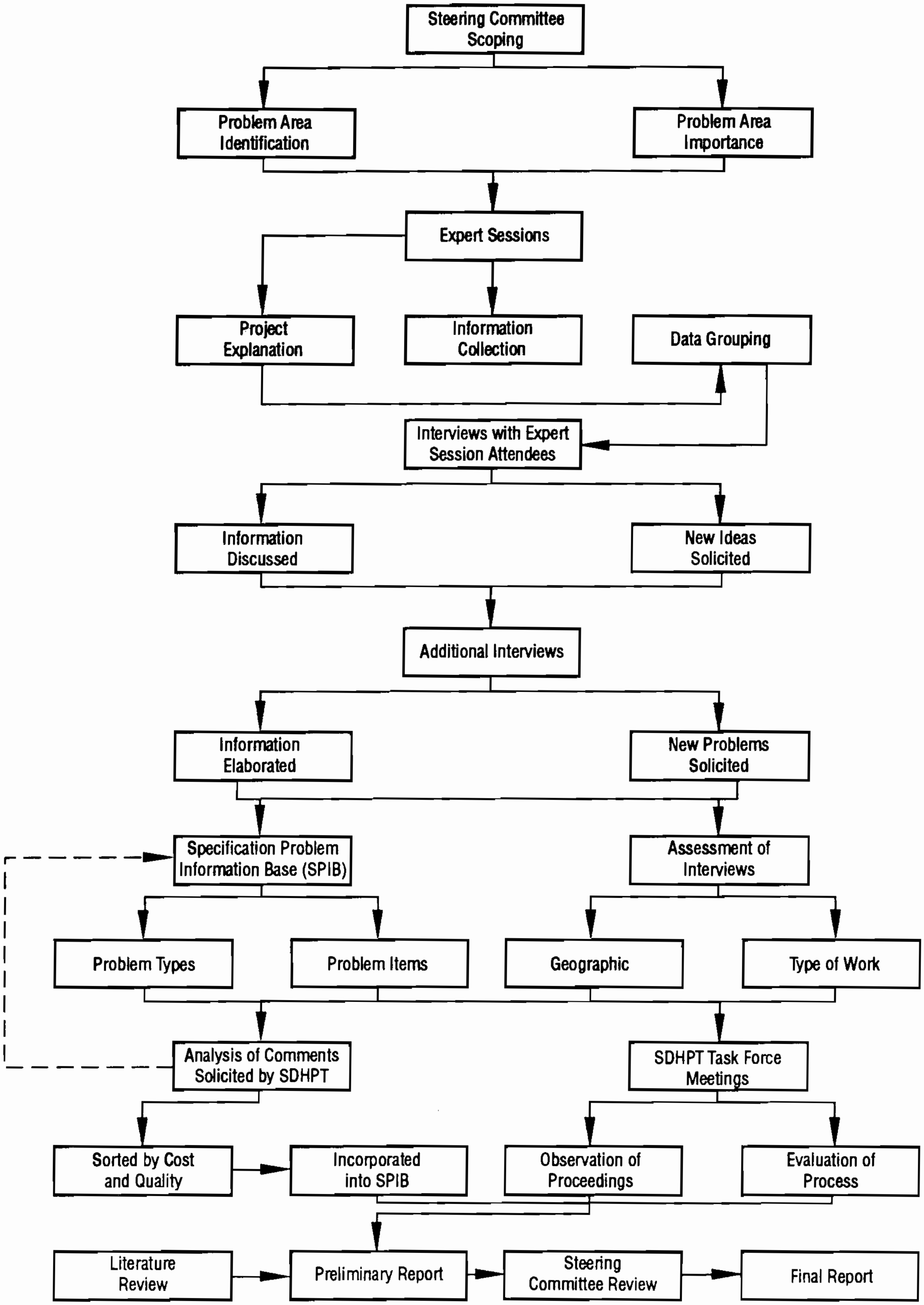

Figure 3.1. Research methodology flow chart.

The literature review which covered the appropriate aspects of both constructability and specifications provided a detailed understanding of both constructability and specifications. Also, this review supplemented the original material collected for this report.

It is anticipated that the draft of the report will be reviewed by the Steering Committee and copies will also be made available to the Department's specifications task forces. Aspects of the research methodology are discussed in greater detail, below.

DATA COLLECTION METHODS AND TOOLS

Several different methods were used to collect the needed information for the research study. These included questionnaires, expert sessions, interviews, and comments solicited by the Department. Each is briefly discussed below. However before doing so, a few words about data collection tools are appropriate.

The data collection tools were structured to gather information for SPIB. As the research study progressed and more information was gathered and understood, the tools became more detailed and focused particularly toward the end of the research study. The tools that were used were a questionnaire of critical constructability issues, an outline of data placed under problem areas, and an outline of specification Items categorized under specific problem types.

QUESTIONNAIRES

The first method used for the collection of data was a questionnaire that was sent to the members of the steering committee. This questionnaire contained critical issues of the highway project constructability study along with subtopics of the major issues. For this particular study only the issue of specifications was dealt with. The questionnaire, the first data collection tool, allowed for the establishment of major problem types that were occurring with specifications (see Appendix A for copy of questionnaire). The questionnaire respondents were asked to expand upon the listing of problems under specifications by identifying additional subtopics. After the additional subtopics were listed, each respondent ranked the subtopics with respect to its importance to specifications. The ranking system that was used is as follows:

A — most meaningful to the study;

B — very meaningful to the study; and

C — only moderately or marginally meaningful to the study.

Once all of the questionnaires had been returned, the rankings were assigned numbers so that the individual responses could be averaged. "A" was given a value of 3, "B" a value of 2, and "C" a value of 1 (see Appendix B for listing of subtopics and average rankings). The averages of the rankings allowed for a determination of the most important issues related to specifications.

The major problem areas that were determined from the questionnaire were used to develop an outline of appropriate data about specifications.

EXPERT SESSIONS

Another method of data collection was expert sessions. Two expert sessions were held in order to gather information and specific examples on the critical issues of specifications. The expert sessions were a good forum for contractors and Department personnel to get together and discuss pertinent problems with the specifications. The sessions allowed attendees to build on each other's comments which provided more in depth and useful information. The two expert sessions were held on January 21, 1988, and April 22, 1988, in Austin and Dallas, respectively. The information obtained at these sessions was very helpful in producing an outline which could be used when subsequently conducting interviews and formed the basis for the material contained under the problem areas (see Appendix C for outline).

INTERVIEWS

Several interviews were conducted to supplement and elaborate on the information gathered at the expert sessions. Also, the interviews allowed for the solicitation of additional information from a wide variety of individuals. The interviews provided a forum for one on one interaction which allowed for more candid responses and open discussions. The information obtained from the initial interviews helped to expand the outline of data that was developed from the expert sessions. Later, the structure of the outline was refined to include problem types and specific specification Items under each problem type. Hence, an outline of specification Items categorized under specific problem types was developed from the information contained in the previous outline. The new outline of specification Items was used on the remainder of the interviews with only updates changing its form (see Appendix D for outlines). This new outline presented a better format for the collection of meaningful and useful information.

When the interviewing was completed, a poll was taken for each specific Item to determine how many interviewees agreed or disagreed with the statements being made. The degree of consensus served as validation or otherwise of the statements that had been made.

TASK FORCE DATA COLLECTION

Three methods were used to collect information through interaction with the Department's specification task forces. These were respectively, the attainment of the 700 comments solicited by the task forces, observation of task forces' meetings, and discussions with Ms. Peggy Chandler.

In order to obtain the 700 comments, the Department had sent a letter and a form for comments to Department personnel, contractors, and suppliers (see Appendix E for the letter and form used). The respondents were asked to provide information on current specifications, special specifications, and special provisions in the form of revisions, additions, or comments. Also, a separate submission was required for each specification Item.

The comments were first sorted by cost according to the Department's top costing specification Items for their work. Those that contained specification Items on which the Department spent the most money were further sorted according to the quality of the information that was presented. The comments were then placed into three categories which were good comments, average comments, and poor comments or repeat comments. Nine percent of the top costing Items were selected as good comments, and two percent of the 700 comments were classified as good. Only the problem Items that were considered to be good comments were included with the rest of the problem Items. Accordingly, fourteen of the 700 comments were selected for inclusion into SPIB.

Another method of data collection was the observation of the task forces' meetings. These meetings were attended in order to gain insight of the processes being used by the task forces for the rewrite of the specification manual. The general functioning of their meetings as well as the steps being used to rewrite the specification manual were critiqued in order to provide constructive criticism for future rewrites.

To further supplement the information obtained by attending the task forces' meetings, discussions were held with Ms. Peggy Chandler. During these meetings, much information was gathered concerning the specification review and updating process. A bar chart showing the development process of the new specification manual was obtained with an explanation of each stage of development. Other information obtained from these discussions included the reasons for the rewrite of the specification manual, the updating of specifications on a project by project basis, the incorporating of changes, and the testing of new specifications. Thus, the interactions with the task forces and Ms. Peggy Chandler provided direct data for SPIB, as well as supportive information for the research study.

LITERATURE SEARCH

A literature search was continued throughout the study as a method of data collection in order to discover more detailed information about constructability and specifications. The literature review included such information as the definition and barriers of constructability as well as the role, types, and problems of specifications. The materials used for the literature review consisted of books, journal articles, and various manuals and documents.

All of the above mentioned methods of data collection contributed to the successful completion of the study and detailed presentation of the report.

PROFILE OF INTERVIEWEES

The individuals used for the purpose of data collection consisted of a wide variety of construction professionals. Included in the list of interviewees were SDHPT personnel, contractors, material suppliers, consultants, and a representative from the attorney general's office. Table 3.1, interview itinerary, provides a complete listing of the individuals interviewed for the research study. Along with the names of the individuals, the interview itinerary contains the company the individual is affiliated with and the city where the company is located. Also, the itinerary includes the dates and times of the interviews and their durations in hours.

The names of the persons interviewed were primarily obtained from two sources. The first source was the expert sessions. A few attendees of each expert session were selected to be interviewed. The second source was the Associated General Contractors (AGC). The local AGC chapters of various Texas cities were contacted and asked to supply a list of contractors that perform work for the Department. From these lists, contractors were selected and called to set up interviews. Once the research project had been explained to them, every contractor that had been contacted was willing to participate with the research study.

An analysis of the interviewees was conducted to ensure a diverse spread of participants. First, the companies they work for were examined based on the type of work that is performed and the size of the company. The type of work that each company performs for the Department was examined carefully to ensure that every aspect of highway construction was represented fairly among the participants. The size of the company was based on two factors, the volume of work that is produced in a year and the number of employees that the company possesses. These factors were determined for each company to ensure that large, medium, and small companies were represented proportionately in the research study. The volume of work for a company ranged from $5 million to $160 million, and the number of employees ranged from 50 to 750. This information on type of work and size of company is summarized in Table 3.2, interview data.

Second, a geographic analysis was conducted to ensure a diverse spread of locations of work and types of respondents. Table 3.3 illustrates in matrix form the areas where work is performed by the interview respondents and the type of companies that have participated in the study. The numbers used in the matrix correspond to the numbers assigned to the various companies in Table 3.2. Table 3.3 is divided into two sections, urban areas of work and rural areas of work. The urban section shows

TABLE 3.1. INTERVIEW ITINERARY

DATE	TIME	PLACE	NAME	COMPANY	LENGTH
1/21/88	9:00am	AUSTIN	EXPERT SESSION	10 SDHPT & 5 CONTRACTORS	5.5 hrs.
2/26/88	9:30am	SAN ANTONIO	FRED HILGERS	SDHPT	1.8 hrs.
2/26/88	2:00pm	SAN ANTONIO	PHIL PARKER	PARKER BRIDGE CO.	2.0 hrs.
3/10/88	2:00pm	FREDRICKSBURG	KEITH KELLER	ALLEN KELLER CO.	1.8 hrs.
3/14/88	1:00pm	SAN ANTONIO	WILLIAM ALLAN	ALLAN CONSTR. CO.	4.0 hrs.
3/22/88	2:00pm	AUSTIN	RICHARD BARTH	J.D. ABRAMS INC.	1.8 hrs.
4/22/88	9:00am	DALLAS	EXPERT SESSION	12 SDHPT & 6 CONTRACTORS	4.0 hrs.
5/10/88	10:30am	AUSTIN	PEGGY CHANDLER	SDHPT	1.0 hrs.
6/23/88	10:00am	WACO	JOHN MILLER	YOUNG BROTHERS INC.	2.3 hrs.
7/19/88	9:45am	AMARILLO	CHARLES SCHMIDT	AMARILLO ROADS INC.	2.5 hrs.
7/19/88	2:00pm	AMARILLO	WAYNE SAUNDERS	J. LEE MILLIGAN INC.	2.0 hrs.
7/20/88	8:30am	AMARILLO	RAYMOND CHOW	GILVIN, TERRILL INC.	1.0 hrs.
7/20/88	3:00pm	AMARILLO	MARK FULLER	L.A. FULLER & SONS INC.	1.5 hrs.
8/02/88	9:00am	DALLAS	RANDY ROGERS	ROGERS & CLACK INC.	1.2 hrs.
8/02/88	1:00pm	FT. WORTH	DON CROSS	SUNMOUNT INC.	2.5 hrs.
8/03/88	11:00am	DALLAS	JAMES MELHORN	APAC OF TEXAS	1.0 hrs.
8/03/88	1:30pm	FT. WORTH	DWIGHT SMITH & TOM LEAVERTON	AUSTIN PAVING INC.	1.5 hrs.
8/17/88	9:00am	EL PASO	FRANCISCO ESPARZA	J.A.R. CONCRETE INC.	1.7 hrs.
8/17/88	10:45am	EL PASO	JOE ROSALES	J.A.R. CONCRETE INC.	0.8 hrs.
8/17/88	3:00pm	EL PASO	LESTER HANSEN	HANSEN CONSTR. CO.	1.5 hrs.
8/18/88	10:00am	EL PASO	GLENN GUY	G.E. GUY INC.	2.0 hrs.
8/18/88	2:00pm	EL PASO	CHUY GONZALES	EL PASO SAND	1.0 hrs.
8/26/88	10:00am	AUSTIN	PEGGY CHANDLER	SDHPT	1.0 hrs.
9/12/88	10:15am	AUSTIN	TASK FORCE #1	SDHPT	1.8 hrs.
9/20/88	10:00am	AUSTIN	TASK FORCE #4	SDHPT	2.0 hrs.
9/26/88	10:30am	AUSTIN	TASK FORCE #2	SDHPT	1.5 hrs.
11/16/88	9:00am	AUSTIN	GRADY CLICK	ATTORNEY GENERAL	1.5 hrs.

TABLE 3.2. INTERVIEW DATA

COMPANY	TYPE OF WORK	VOLUME OF WORK	# OF EMPLOYEES
1 District 15	Everything	$160 million	150
2 Parker Bridge Co.	Bridge & Drainage Structures	$5 million	60
3 Allen Keller Co.	Excavation, Base Work,& Structures	$15 million	125
4 Allan Constr. Co.	Everything except concrete pavement	$25 million	250
5 J.D. Abrams Inc.	Everything except concrete pavement	$100 million	750
6 Young Brothers Inc.	Everything except concrete pavement	$40 million	500
7 Amarillo Roads Inc.	Everything except concrete pavement	$15 million	200
8 J. Lee Milligan Inc.	Pavement & Structures	$10 million	120
9 Gilvin, Terrill Inc.	Everything	$15 million	150
10 L.A. Fuller & Sons Inc.	Base Work, Asphalt, Pavement, & Structures	$10 million	75
11 Rogers & Clack Inc.	Structures, Pavement, & Underground Work	$20 million	200
12 Sunmount Inc.	Everything	$15 million	100
13 APAC of Texas	Pavement	$75 million	50
14 Austin Paving Inc.	Excavation, Pavement, Base, Work, Signalization, & Stabilization	$100 million	500
15 J.A.R. Concrete Inc.	Concrete Pavement	$7 million	60
16 Hansen Constr. Co.	Excavation & Grading	$5 million	50
17 G.E. Guy Inc.	Bridge & Drainage Structures	$5 million	75
18 El Paso Sand	Asphalt Pavement	$50 million	350

TABLE 3.3. INTERVIEW GEOGRAPHIC MATRIX

Locations of Work	Interview Respondents: SDHPT	Contractor	Material Supplier	Consultant
Urban				
El Paso		5, 13, 16, 17, 18	5, 13, 18	16, 17
Amarillo		5, 7, 8, 9, 10, 13	5, 8, 9, 13	
Lubbock		4, 5, 7, 9, 18	5, 9, 18	
Wichita Falls		5, 7, 9	5, 9	
Ft. Worth		4, 5, 11, 12, 13, 14, 15	5, 12, 13, 14	
Dallas		4, 5, 11, 12, 13, 14, 15	5, 12, 13, 14	
Waco		5, 6, 13	5, 6, 13	
Austin		3, 4, 5, 6, 13, 14, 15	5, 6, 13, 14	
San Antonio	1	2, 3, 5, 13	5, 13	
Houston		5, 12, 13, 14	5, 12, 13, 14	
Rural				
West		3, 4, 5, 9, 13, 16, 17, 18	5, 9, 13, 18	16, 17
Northwest		4, 5, 7, 8, 9, 10, 13	5, 8, 9, 13	
Northeast		11, 12, 13, 14, 15	12, 13, 14	
Central	1	2, 3, 4, 5, 6, 13, 14, 15	5, 6, 13, 14	
South	1	2, 13	13	
Coastal		12, 13, 14	12, 13, 14	

the cities where the companies perform the majority of the work for the Department, and the rural section shows the geographic regions of the state where the work is being performed by the companies. As can be seen from the matrix, the areas of work tend to be evenly distributed throughout the state while the majority of the interview respondents are contractors and material suppliers. Hence, the sampling of interviewees resulted in a diverse spread of respondents for the research study.

PURPOSES OF DATA ANALYSIS

Data analysis is a very critical part of any research study. Collected data have to be presented in an organized format so that they can be interpreted and understood. Once the organized format has been achieved, the data can be analyzed to satisfy the purposes of the research study. This particular research study had several purposes of data analysis.

One purpose of data analysis was to determine the primary potential causal constructability factors for the problem specification Items that were established. For each specification Item that is contained in SPIB, potential causal constructability factors were listed to determine potential causal relationships between problems and related attributes. This information was tabulated to determine the primary factors and where the emphasis should be placed in correcting the problems. Other reasons for analysis included the determination of the major problem types associated with specifications and the determination of the most problematic elements of highway construction, as well as their frequency of occurrence with problem specification Items. The problem types were established from the questionnaires given to the members of the steering committee. From the analysis performed, the problem types causing the greatest impact could be determined and studied. Likewise, the elements of highway construction causing the most problems could be identified from the data analysis. The data analysis also allowed the observation of the frequency of occurrence of different problem types with the related elements of highway construction. This identification allows for future effort to be concentrated in those areas of construction with the most problems.

Another purpose of the data analysis was to determine why the problems occur and how they could be solved. This was the most difficult part of the analysis, and it required the most effort and thought. Once this effort was solved, the main objective of the research was complete. After all problems had been critiqued in terms of constructability, the analysis would form the basis of reviewing the standard specification specifically from the constructability enhancement point of view.

METHODS OF DATA ANALYSIS

Two main methods of data analysis were used to satisfy the purposes of the research study. These methods included cross classification tables and HOT diagrams. The methods are briefly discussed below and expanded on further in Chapter V.

Three cross classification tables were used to determine the important potential causal constructability factors, the important problem types, and the important elements of highway construction. The cross classification tables displayed these factors' relative importance to each other on a matrix type of a grid. Simply by looking at the tables it could be seen where the greatest concentration of specification Items occurs. By observing the grid nodes with the greatest concentration, the factors requiring the most emphasis for study could be noted. After the critical factors had been determined, the areas with the greatest amount of problems were looked at first to quickly reduce the vast amount of problematic issues.

The other method of data analysis that was used was a HOT diagram. A HOT diagram is a Hierarchy of Objectives Technique which was used to investigate the concern of constructability associated with specification Items (Fisher 1989). The logic used in a HOT diagram is that the question "how?" is asked as one moves from left to right through the diagram, and the question "why?" is asked as one moves from right to left through the diagram. This technique helped to determine why problems occur with the specifications and how the problems can be solved. Thus, the methods used for data analysis proved to be very effective at discovering what specification improvements are needed and how they can be made so constructability can be enhanced.

The method was evolved from the adaptation of the Analysis System Technique (FAST) which Brown proposed in his pilot study on constructability (Brown 1988).

STRUCTURE OF SPECIFICATION PROBLEM INFORMATION BASE (SPIB)

The structure of the Specification Problem Information Base (SPIB) evolved out of a need to present the information obtained in an organized and useful format to facilitate the analysis. It was based on seven elements:

(1) The Item number and where applicable, the related Article; the title of the specification which is under scrutiny. For sake of simplicity, specific Articles of specification Items were considered to be included when referring to the Item.

(2) A brief problem statement, written to clarify the specification's particular problem under the general problem type heading.

(3) Issues and comments, obtained from sources mentioned previously, explaining why the problem exists.

(4) A recommendation suggesting of how the problem, associated with the specification Item, may best be solved.

(5) A listing of the three most critical potential causal constructability factors affecting the Item. This list shows which factors are causing the problem for the specification Item and where the emphasis should be placed in seeking a solution for the problem.

(6) A reference to the degree of consensus between the interviewees who commented on the particular Item. This also served to indicate the number of people with whom the Item had been discussed. Where this discussion has been omitted, it means that the specification Item was obtained from the 700 comments solicited by the Department.

(7) A section for additional comments which contains any gathered information that supplements the material previously mentioned for the Item.

To reiterate, the structure of a specification Item contained in SPIB contains these elements:

(1) item number and title of specification,
(2) problem statement,
(3) issues and comments,
(4) recommendation,
(5) potential causal constructability factors,
(6) degree of consensus, and
(7) additional comments.

Where information was collected that did not specifically relate to a specification Item, it was placed in SPIB as a general comment. These general comments were placed under the appropriate problem types to supplement the information presented with the specification Items. Thus, the information contained in SPIB provides an organized format for easy interpretation.

PROBLEM TYPES

As pointed out earlier, the Specification Problem Information Base (SPIB) with 57 entries or records emerged from lengthy discussions with highway department and contractor personnel and from review of data collected by highway department task forces established for the purpose of updating the standard specification. In all, 24 highway department personnel and 29 contractor personnel were interviewed or participated in group discussions over a seven month period for the purpose of identifying constructability 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 regardless of severity or frequency.

Initially five problem types were established during the process of collection and analysis of the information contained in SPIB. These were:

* information deficiencies,
* communication deficiencies,
* gold-plated designs, specifications, etc,
* unrealistic tolerances and/or requirements, and
* impractical methods of measurement and payment.

These problem types are defined in greater detail in the following paragraphs.

(1) Information and communication deficiencies:

Information deficiencies of necessity lead to communication deficiencies. However communication deficiencies can also result in the process of interpreting the given information. In fact, the two aspects are strongly related. Poorly communicated specifications relate primarily to problems of interpretation or understanding due to those Items whose information is not presented in the best manner for easy comprehension or interpretation. Problems may also occur because the Item contains incomplete information or is worded incorrectly, or is inconsistent with other Items or ambiguous.

Specifications which are often inconsistently interpreted include Items that are not always interpreted in the same manner due to information deficiencies. An Item could also be causing a problem because of the terminology contained in it or simply because of poor wording. Problems also arise because different people have different experiences, and they tend to interpret things differently given any leeway for personal judgment.

Specifications with reference to obsolete construction methods, materials, equipment, and products have been classified under information deficiencies as "irrelevant information." This also applies to those Items that contain anything outdated or which do not refer to the latest equipment. Problems of this type can easily be corrected by simply removing or correcting the relevant information by referring to current information.

(2) Gold-plated specifications:

Gold-plated specifications are those which specify more than what is actually needed for functionality or maintenance or both. Problems occur because the Items specify excessive finishing, curing, or design. If the function of the finished product were to be examined more closely, there would be fewer gold-plated specifications.

(3) Unrealistic tolerances or requirements:

Problems of this type arise when it is difficult to achieve prescribed standards in a specific Item on a regular basis. This relates inter alia to materials, construction practices, and surface finishes. Naturally decisions regarding tolerances have to be taken with due regard to functional requirements stemming from the intended purpose of the finished product.

(4) Impractical methods of measurement and payment:

Problems of this type stem from Items that do not have an efficient or accurate payment method. Problems may arise because of the large number of payment Items or because the payment is insufficient, since more Items or work are needed than have been specified.

In conducting the final research analysis, the various problem types were classified under four major headings related to constructability and discussed earlier in Chapter II, namely:

* communication deficiencies,
* information deficiencies,
* functional exorbitance, and
* practicality limitations.

These problems relate to the main features of specifications, namely what needs to be done, what functional requirements are related to the product and what the ability is to execute the instruction.

In Chapter IV each of the problems is discussed in detail.

POTENTIAL CAUSAL CONSTRUCTABILITY FACTORS

Potential causal constructability factors were determined for every Item contained in SPIB for the purpose of data analysis. The constructability factors that were chosen for an Item were determined by seeing which factors appeared to be causing the problem associated with the specification Item. Only the three factors impeding constructability the most, were identified. Once the factors had been determined, they were used in the cross classification tables to help with the analysis of the research study. In this way it was possible to determine to what extent constructability could be enhanced by making specification improvements.

Six major categories of constructability factors were established for the purposes of this research study. The categories are project scoping, resources, processes and methods, controls, information and communication, innovation and environmental systems. Each major category was broken down into more detailed factors which were stated along with the associated major category for each Item contained in SPIB. However, due to the large number of constructability factors, only the major categories were used for the purpose of analysis. Table 3.4 gives a complete listing of the constructability factors which were considered in the compilation of SPIB.

Chapter IV contains the SPIB, which presents the essence of the data collected for analysis and subsequent synthesis, which is discussed in Chapter V.

TABLE 3.4. CONSTRUCTABILITY FACTORS

A. Project Scoping
  1) Operational requirements
  2) Facility characteristics: Structural Composition, Complexity, Scale, Size, Owner Preferences and Specifications
  3) Budget constraints
  4) Time Constraints: Schedule Objectives and Limits

B. Resources: Availability, Variability, Suitability, Intrinsic Attributes
  1) Manpower
  2) Material
  3) Machines

C. Processes/Methods/Subprocesses Pertaining to:
  1) Planning and Design
  2) Procurement and Bidding
  3) Construction
  4) Maintenance

D. Controls
  1) QA/QC, Testing and Inspection
  2) Cost and Financial Controls
  3) Schedule Controls/Productivity Measurement

E. Information/Communication
  1) Documentation/Transmission/Iinterpretation
  2) Availability; Source; Accuracy
  3) Consistency/Compatibility/Ambiguity
  4) Clarity/Conciseness/Completeness
  5) Timeliness and Frequency
  6) Relevance

F. Innovation
  1) Awareness of Prompters: Recognition of Need
  2) Motivation and Freedom to Innovate; Related Constraints
  3) Capability to Innovate; Needed Resources and R&D
  4) Support or Lack of Champion

G. Environmental Systems
  1) Site: Topography, Geotechnics, Water, Accessibility
  2) Weather
  3) Infrastructure/Traffic
  4) Political/Legal/Regulatory
  5) Macroeconomic/Financial/Sociological

CHAPTER IV. SPECIFICATION PROBLEM INFORMATION BASE (SPIB)

This chapter contains the Specification Problem Information Base (SPIB) which was structured as set out in Chapter III. Before presenting the specifics of the database a few introductory remarks need to be made.

The information presented in SPIB shows problem items and areas of specifications that need to be reviewed or improved in order to enhance constructability. The recommendations that are presented in SPIB stem from interviews, discussions, task forces' meetings, etc. Table 4.1 contains topics used in categorizing the various aspects of SPIB according to matters discussed earlier in the report.

The feasibility of the recommendations suggested by the respondents, may still have to be established or confirmed by the respective SDHPT divisions. This is particularly important for those recommendations which may influence long-term maintenance or durability. Also, the degree of consensus of opinion indicated for most items reflects the extent to which support was apparent for the respective item. This should be taken into account when considering the implementation of recommendations or the necessity for further investigation. Likewise, the trend of the recommendations toward the creation of an end result specification, should also be considered.

SPECIFICATION PROBLEM INFORMATION BASE

Details of SPIB are set out below. A summary is given in Table 4.2. All of the quoted material is from the SDHPT's Standard Specifications for Construction of Highways, Streets and Bridges (SDHPT 1982). Readers should refer to this for more details about the respective Items. In the text the driving factor, apparently impeding constructability the most, has been indicated by an asterisk (*). These factors are considered to be Primary factors. Other factors are accepted to be Secondary factors.

OVERVIEW

The problem types, problem specification Items, and apparent causal constructability factors were presented in an organized format in the SPIB. This database was designed to enable an analysis to be carried out in order to determine the extent of the problem and formulate proposals for dealing with it. An extract of the findings in the SPIB is given in Table 4.2. This relates problem types to Items. The analysis of the SPIB and a discussion of the findings is contained in the following chapter.

TABLE 4.1. TOPICS USED FOR CATEGORIZING VARIOUS ASPECTS OF SPIB

I. PROBLEM TYPES

A. information deficiencies
B. communication deficiencies
C. unrealistic tolerances/requirements
D. gold-plated designs, specifications, etc
E. unsatisfactory methods of payment

II. ELEMENTS OF HIGHWAY CONSTRUCTION

A. earthworks
B. row and utilities
C. geometrics/alignment
D. pavement
E. drainage structures
F. bridges/structures
G. lighting & signing
H. incidental construction

III FACTORS

A. Project Scoping
1) operational requirements
2) facility characteristics: structural composition, complexity, scale, size, owner preferences and specifi-cations
3) budget constraints
4) time constraints: schedule objectives and limits

B. Resources: Availability, Variability, Suitability, Intrinsic Attributes
1) manpower
2) material
3) machines

C. Processes/Methods/Subprocesses Pertaining to:
1) planning and design
2) procurement and bidding
3) construction
4) maintenance

D. Controls
1) QA/QC, testing and inspection
2) cost and financial controls
3) schedule controls/productivity measurement

E. Information/Communication
1) documentation/transmission/interpretation
2) availability; source; accuracy
3) consistency/compatibility/ambiguity
4) clarity/conciseness/completeness
5) timeliness and frequency
6) relevance/currency

F. Innovation
1) awareness of prompters: recognition of need
2) motivation and freedom to innovate; related constraints
3) capability to innovate; needed resources and R&D
4) support or lack of champion

G. Environmental Systems
1) site: topography, geotechnics, water, accessibility
2) weather
3) infrastructure/traffic
4) political/legal/regulatory
5) macroeconomic/financial/sociological

TABLE 4.2. SUMMARY OF FINDINGS IN SPIB RELATING PROBLEM TYPES TO ITEMS

PROBLEM / ITEM / TITLE

==

I. <u>PROBLEM</u>

A. <u>INFORMATION DEFICIENCIES:</u>

1.1
Inconsistency between specification Items
ITEM 274.8 - Cement Stabilized Base (Penalty for Deficient Base Thickness)

1.2
Insufficient information regarding quantity of tack coat
ITEM 340.6 - Hot Mix Asphaltic Concrete Pavement (Construction Methods - Tack Coat)

1.3
Insufficient information regarding type of usable aggregate
ITEM 340.2 - Hot Mix Asphaltic Concrete Pavement (Materials)

1.4
Insufficient information regarding material properties
ITEM 249.3 - Flexible Base (Delivered)

1.5
Insufficient information regarding method of operation
ITEM 340.4 - Hot Mix Asphaltic Concrete Pavement (Equipment)

1.6
Item not comprehensive enough to ensure enforcement
ITEM 340.6 - Hot Mix Asphaltic Concrete Pavement (Construction Methods - in-place density)

1.7
Insufficient information regarding material composition - definition required
ITEM 249.4 - Flexible Base [Delivered] (Grades)

1.8
Irrelevant documentation (information regarding obsolete equipment)
ITEM 260.4 - Lime Treatment for Materials in Place (Construction Methods)

1.9
Irrelevant documentation (information regarding questionable liming methods)
ITEM 264.2 - Hydrated Lime and Lime Slurry (Type A, Hydrated Lime)

1.10
Irrelevant documentation (information regarding obsolete equipment); incomplete information regarding modern equipment)
ITEM 360.4 - Concrete Pavement

1.11
Incomplete information regarding latest test methods
ITEMS 420 & 421 - Concrete Structures and Concrete for Structures

TABLE 4.2. SUMMARY OF FINDINGS IN SPIB RELATING PROBLEM TYPES TO ITEMS (CONTINUED)

1.12
Contains outdated information regarding bridge construction methods
ITEM 421 - Concrete for Structures

1.13
Contains outdated information regarding obsolete tests
ITEM 300 - Asphalts, Oils and Emulsions

1.14
Contains irrelevant outdated information regarding compaction control
ITEM 132.2 - Embankment

1.15
Apparently contains inconsistent information regarding aggregate blending
ITEM 340.2 - Hot Mix Asphaltic Concrete Pavement (coarse aggregate for skid resistant surface)

1.16
Non-current information regarding types of lime
ITEM 264.2 - Hydrated Lime and Lime Slurry

==

I. <u>PROBLEM:</u>
B. <u>COMMUNICATION DEFICIENCIES</u>:

2.1
Inconsistent interpretation of "principal unit of work" (terminology)
ITEM 1.40 - Working Day

2.2
Inconsistent interpretation of terminology - "unsuitable weather"
ITEM 316.1 - Seal Coat

2.3
Inconsistent interpretation by the engineer
ITEMS 110, 120, 130, 131 & 132 - Fill Material (excavation, borrow, and embankment)

2.4
Inconsistent interpretation of liquidated damages
ITEM 340 - Hot Mix Asphaltic Concrete Pavement

2.5
Inconsistent interpretation of usable aggregates
ITEM 340 - Hot Mix Asphaltic Concrete Pavement

2.6
Inconsistent interpretation due to ambiguity regarding tolerance
ITEM 425.4 - Prestressed Concrete Structures

TABLE 4.2. SUMMARY OF FINDINGS IN SPIB RELATING PROBLEM TYPES TO ITEMS (CONTINUED)

I. **PROBLEM:**
C. **UNREALISTIC TOLERANCES/REQUIREMENTS**

3.1
Unrealistic tolerances for aggregate selection
ITEM 340 - Hot mix Asphaltic Concrete pavement

3.2
Unrealistic tolerances for finished grade
ITEM 420.20 - Concrete Structures

3.3
Unrealistic tolerances for rebar placement
ITEM 440.7 - Reinforcing Steel

3.4
Unrealistic tolerances for subgrade preparation
ITEM 248.6 - Flexible Base

3.5
Unrealistic tolerances for subgrade finish before lime treatment
ITEM 260.4 - Lime Treatment for Materials in Place

3.6
No tolerances exist for concrete strength
ITEMS 360, 420 & 421 - Concrete Strength

3.7
Unrealistic tolerances for application of PI test results
ITEMS 131, 132, 246, 249 & 274 - Plasticity Index (Borrow, Embankment, Foundation Course, Flexible Base, Flexiblode Base Delivered, and Cement Stabilized Base)

3.8
Unrealistic tolerances for embankment densities
ITEM 132.2 - Embankment

3.9
Unrealistic casting and erection tolerances
ITEM 425 - Prestressed Concrete Structures

3.10
Unrealistic tolerances for aggregate exposure finished concrete
ITEM 427.7 - Surface Finishes for Concrete (Exposed Aggregate Finish)

3.11
Unrealistic tolerances for form depth
ITEM 360.3 - Concrete Pavement

TABLE 4.2. SUMMARY OF FINDINGS IN SPIB RELATING PROBLEM TYPES TO ITEMS (CONTINUED)

3.12
Unrealistic tolerances for finish
ITEM 425.4 - Prestressed Concrete Structures

3.13
Unrealistic tolerance for sand equivalent value
ITEM 292.2 - Asphalt Stabilized Base

3.14
Unrealistic requirement regarding placing of concrete (Department needs to review method of placing concrete)
ITEM 425.4 - Prestressed Concrete Structures

==

I. PROBLEM:
D. GOLD-PLATED DESIGNS, SPECIFICATIONS, ETC

4.1
Unnecessary finishing of rural roads (gold-plated)
ITEM 360.8 - Concrete Pavement

4.2
Gold-plated design of road shoulders
ITEMS 340 & 360 - Road Shoulders

4.3
Excessive painting (gold-plated)
ITEM 446.9 - Cleaning, Paint and Painting

4.4
Excessive curing times for follow-on work (gold-plated)
ITEM 420.22 - Concrete Structures

4.5
Excessive finishing for appearance (gold-plated)
ITEM 427.4 - Surface Finishes for Concrete

4.6
Gold-plated usage of railings
ITEM 450 - Railing

4.7
Indiscriminate use of diaphragms (gold-plated)
ITEM 422 - Reinforced Concrete Slab

4.8
Inflexibility of design and specification requirements
ITEM 440.7 - Reinforcing Steel

4.9
Gold-plated curing
ITEM 512.3 - Portable Concrete Traffic Barrier

TABLE 4.2. SUMMARY OF FINDINGS IN SPIB RELATING PROBLEM TYPES TO ITEMS (CONTINUED)

4.10
Gold-plated density requirements
ITEM 260.4 - Lime Treatment for Materials in Place

4.11
Gold-plated placing time
ITEM 360.6 - Concrete Pavement

4.12
Gold-plated aggregates
ITEM 340.2 - Hot Mix Asphaltic Concrete Pavement

4.13
Gold-plated placing time
ITEM 425.4 - Prestressed Concrete Structures

4.14
Gold-plated time element
ITEM 274.6 - Cement Stabilized Base

4.15
Gold-plated maintenance during construction
ITEM 7.12 - Contractor's Responsibility for Work

==

I <u>PROBLEM:</u>
E. <u>IMPRACTICAL METHOD OF MEASUREMENT AND PAYMENT</u>

5.1
Payment method unnecessarily complex
ITEM 477.6 - Safety End Treatment

5.2
Extent of items poorly defined
ITEM 502 - Barricades, Signs, and Traffic Handling

5.3
Number of applications not defined
ITEM 664 - Abbreviated Pavement Markings

5.4
Unnecessarily complicated payment method
ITEM 401.2 - Excavation and Backfill for Sewers

5.5
Contains undefined subsidiary work
ITEM 462.10 - Concrete Box Culverts

5.6
Simplify payment method by combining Items
ITEMS 260 & 262 - Lime Treatment for Materials in Place and Lime Treatment for Base Courses Methods

1.1 ITEM 274.8: CEMENT STABILIZED BASE (PENALTY FOR DEFICIENT BASE THICKNESS)

I. PROBLEM:
A. Specification has information deficiency: Inconsistancy between Items

ISSUES AND COMMENTS:

The procedure for determination of deficient thickness differs from that in Item 360.11.

RECOMMENDATION:

The seventh paragraph of this Item should be changed to read "...and measurements which are less than the specified thickness by more than 1.50 inches will be considered as the specified thickness less 1.50 inches."

This change will eliminate the problem of not having three cores to average when the first core is deficient by more than 1.50 inches.
Also, the change will make the procedure for deficient thickness calculations the same as it is for Item 360.11, which is the original intent of the specifications.

II ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
A. project scoping
2) facility characteristics: specifications
D. controls
1) QA/QC, testing and inspection
E. information/communication
* 1) documentation
* 3) consistency

1.2 ITEM 340.6: HOT MIX ASPHALTIC CONCRETE PAVEMENT (Construction Methods - Tack Coat)
I. PROBLEM:
A. Specification has information deficiency: Insufficient information regarding quantity of tack coat

ISSUES AND COMMENTS:

The quantity of tack coat for HMAC is poorly communicated. This Item merely states: "The surface shall be given a uniform application of tack coat using asphaltic materials of this specification."

RECOMMENDATION:

Tack coat should become a separate bid Item be paid for by the gallon in case the inspector wants an extra coat placed. If a separate bid Item is not feasible, the quantity to be placed needs to be better defined. Too much discretion is given to the engineer as to how much tack coat is to be placed.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
D. controls
2) cost and financial controls
E. information/communication

* 1) documentation
* 4) completeness

DEGREE OF CONSENSUS:

6 out of 6 agree that the placement of tack coat is poorly communicated.

1.3 ITEM 340.2: HOT MIX ASPHALTIC CONCRETE PAVEMENT (Materials)

I. PROBLEM:
A. Specification has information deficiency: Insufficient information regarding type of usable aggregate

ISSUES AND COMMENTS:

Siliceous gravel is often unacceptable as coarse aggregate because of its mineralogical properties; yet this is not explicitly stated in the specifications.

RECOMMENDATION:

Siliceous gravel should be allowed on overlay jobs because it will have little affect on skid resistance since overlay work is redone every five years. The time period involved should not cause the material to lose its required skid resistance.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
B. resources: availability, variability, suitability, intrinsic attributes
2) material
E. information/communication
* 1) documentation
* 4) completeness

DEGREE OF CONSENSUS:

2 out of 2 agree that the type of usable aggregate is poorly communicated.

ADDITIONAL COMMENTS:

a) Siliceous gravel would be a good coarse aggregate if it did not polish easily making it poor for skid resistance.

b) In Waco, siliceous gravel is used only on border control work or requisitions.

c) The specification manual only allows the use of crushed gravel.

d) Siliceous gravel could become acceptable if steps are taken to counteract stripping.

1.4 ITEM 249.3: FLEXIBLE BASE (Delivered)
I. PROBLEM:
A. Specification has information deficiency: Insufficient information regarding material properties

ISSUES AND COMMENTS:

Binder material for aggregates needs to be better defined. Binder material should clearly exclude fines of sand or gravel particles which have very low plasticity indices. The purpose of fines is to bind material, and the binder needs to possess some cohesive properties. Small sand fines do not provide any cohesion between aggregates.

RECOMMENDATION:

A set of definitions for type A flexible base should be formulated and placed under this Item to clarify material properties. This should state that sand is siliceous and not a gravel aggregate.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
B. resources: availability, variability, suitability, intrinsic attributes
    2) material
E. information/communication
* 1) documentation
* 4) completeness

1.5 ITEM 340.4: HOT MIX ASPHALTIC CONCRETE PAVEMENT (Equipment)
I. PROBLEM:
A. Specification has information deficiency: Insufficient information regarding method of operation

ISSUES AND COMMENTS:

Problems have occurred over the proper operation of the spreading and finishing machine. The inspector needs to be knowledgeable of the travel speed, quantity of material on the augers, and the frequency of their operation to obtain a quality finish.

RECOMMENDATION:

The contractor should furnish a manual (provided by the manufacturer of the machine) which outlines the manner that the machine is to be operated in order to obtain the best possible finish. This will give the inspector the needed knowledge for him to properly perform his job.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
B. resources: availability, variability, suitability, intrinsic attributes
    1) manpower
E. information/communication
* 1) documentation
* 4) completeness

1.6 ITEM 340.6: HOT MIX ASPHALTIC CONCRETE PAVEMENT (Construction Methods - in-place density)

I. PROBLEM:

A. Specification has information deficiency: Item not comprehensive enough to ensure enforcement

ISSUES AND COMMENTS:

"If the in-place density of the mixture produced has a value lower than that specified and in the opinion of the Engineer is not due to a change in the quality of the material, production may proceed with subsequent changes in the mix and/or construction operations until the in-place density equals or exceeds the specified density." If field densities do not meet minimum plan requirements, there is no provision for any penalty to the contractor. Without either a monetary penalty or a removal requirement, the incentive for the contractor to meet minimum density requirements is lacking.

RECOMMENDATION:

A penalty should exist if minimum requirements are not met. Also, more definitive acceptance criteria would assist project personnel in deciding whether to accept it or require it to be removed.

II. ELEMENTS OF HIGHWAY CONSTRUCTION

D. pavement

III FACTORS

D. controls

2) cost and financial controls

E. information/communication

* 1) documentation

* 4) completeness

1.7 ITEM 249.4: FLEXIBLE BASE [Delivered] (Grades)

I. PROBLEM:

A. Specification has information deficiency: Insufficient information regarding material composition.

ISSUES AND COMMENTS:

When the material under consideration is iron ore topsoil, which is a red dirt that exhibits a chemical reaction when it is placed (it compacts and bonds together), problems occur with the amount of soil that is retained on the No. 40 sieve. Some instances have occurred where a large portion retained on the No. 40 sieve was siliceous gravel. In one instance the material was rejected 9 months after it was placed because it was not performing as intended. No provisions are contained in the specification to solve this problem.

RECOMMENDATION:

The specification should state that, for type C (grades 2 and 3) "Flexible Base Materials", the material retained on the No. 40 sieve should contain at least 90% iron ore. A soil cannot be considered iron ore unless there is a predominant amount of iron ore in it. A reasonable amount of foreign material can exist so long as the performance of the material is not degraded.

II. ELEMENTS OF HIGHWAY CONSTRUCTION

D. pavement

III FACTORS

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

2) material

E. information/communication

* 1) documentation
* 4) completeness

DEGREE OF CONSENSUS:

1 out of 1 agrees that the required soil composition is poorly communicated.

1.8 ITEM 260.4: LIME TREATMENT FOR MATERIALS IN PLACE (Construction Methods)

I. PROBLEM:

A. Specification has information deficiency: Relevancy of documentation (obsolete equipment)

ISSUES AND COMMENTS:

The lime subgrade specification contains extensive detail on the use of cutting and pulverizing machines and the work concerned with secondary grade, neither of which are relevant anymore.

RECOMMENDATION:

Machines exist today that have built-in depth control which allows the depth of grade and mixing to be easily checked and maintained. Up-to-date equipment needs to be specified and used.

II. ELEMENTS OF HIGHWAY CONSTRUCTION

A. earthworks

D. pavement

III FACTORS

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

3) machines

C. processes/methods/subprocesses pertaining to:

3) construction

E. information/communication

* 1) documentation
* 6) relevance

DEGREE OF CONSENSUS:

7 out of 7 agree that obsolete equipment is being specified.

1.9 ITEM 264.2: HYDRATED LIME AND LIME SLURRY (Type A, Hydrated Lime) (also see para 1.16)

I. PROBLEM:

A. Specification has information deficiency: Relevancy of documentation (irrelevant information regarding questionable liming methods)

ISSUES AND COMMENTS:

Dry lime is specified even though it is not allowed in most places because of dust control problems.

RECOMMENDATION:

Pebble lime, which is simply lime in the form of small pebbles, should be used to avoid messy slurries and dust hazards. Naturally, proper uniform mixing of the lime is essential.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
A. earthworks
D. pavement

III FACTORS
B. resources: availability, variability, suitability, intrinsic attributes
    2) material
E. information/communication
* 1) documentation
* 6) relevance
G. environmental systems
    4) regulatory

DEGREE OF CONSENSUS:

4 out of 4 agree that the best liming methods are not being used in many cases.

ADDITIONAL COMMENTS:

a) Environmental and traffic problems result when dry lime is used; however, there is no problem when dry lime is used in remote rural areas. Dry lime is cheaper to purchase.

b) Dry lime is not a problem if it is in pebble form. More water must be added in the field to the pebble lime versus the dry lime.

c) Lime slurry is only 80% lime, whereas pebble lime is 100% lime.

1.10 ITEM 360.3: CONCRETE PAVEMENT * (Equipment)
I. PROBLEM:
A. Specification has information deficiency: Relevancy of documentation (obsolete equipment

ISSUES AND COMMENTS:

The concrete paving specification references certain equipment such as mechanical vibratory equipment and transverse finishing machines which are rarely used anymore, while slipforming is inadequately covered.

RECOMMENDATION:

Equipment should not be specified in this Item because it will become obsolete before the specification manual can be printed. The contractor should be allowed to select his own equipment to achieve the end result, but he must specify what he intends to use when his bid is submitted.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
B. resources: availability, variability, suitability, intrinsic attributes
    3) machines
C. processes/methods/subprocesses pertaining to:

3) construction
E. information/communication
* 1) documentation
4) completeness
* 6) relevance

DEGREE OF CONSENSUS:

4 out of 4 agree that obsolete equipment is being specified.

ADDITIONAL COMMENTS:

a) If equipment continues to be specified, slipforming needs to be adequatley addressed in the new specification manual.

b) The specification does not allow the functions of machines to be combined into one machine (example: machines in concrete paving trains - a concrete spreader and a concrete paver can be combined by adding a belt to the paver). The Department requires the use of two machines to perform certain work even when a machine is available that can perform both functions.

1.11 ITEM 420.20 & 421.2: CONCRETE STRUCTURES (finish of roadway slabs) & CONCRETE FOR STRUCTURES (materials)
I. PROBLEM:
A. Specification has information deficiency: Completeness of documentation (obsolete testing methods)

ISSUES AND COMMENTS:

Several referenced test methods are not reflective of recent innovations. Examples of these obsolete test methods are: Test Method Tex-436-A (texture depth testing), Test Method Tex-413-A, Tex-410-A, and Tex-411-A (coarse aggregate testing).

RECOMMENDATION:

The most current and up-to-date testing methods need to be used to achieve the best results.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
2) facility characteristics: owner preferences and specifications
D. controls
1) QA/QC, testing and inspection
E. information/communication
* 1) documentation
* 4) completeness

DEGREE OF CONSENSUS:

3 out of 3 agree that the best testing methods are not being used.

ADDITIONAL COMMENTS:

a) The Highway Department requires the same amount of testing on small amounts of minor concrete work as they do on large quantities of concrete work. The amount and type of testing should be reflective of the concrete work that is being tested.

b) Nuclear density gauges and swiss hammers should be employed for efficiency purposes.

1.12 ITEM 421.13: CONCRETE FOR STRUCTURES
I. PROBLEM:
A. Specification has information deficiency: Obsolete bridge construction methods

ISSUES AND COMMENTS:

Outdated bridge construction methods such as pan girders and slab spans are still contained in the specifications. Both of these methods are very labor intensive.

RECOMMENDATION:

These methods need to be eliminated because they are not the best or fastest type of construction. A more modular type of approach is needed for this type of construction.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures
III FACTORS
A. project scoping
   2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
   3) construction
E. information/communication
* 1) documentation
* 6) relevance

DEGREE OF CONSENSUS:

5 out of 5 agree that faster and better bridge construction methods need to

be used.

ADDITIONAL COMMENTS:

a) During freeway upgrading work, it is difficult to make additions to these types of structures.

1.13 ITEM 300.2: ASPHALTS, OILS, AND EMULSIONS (materials)
I. PROBLEM:
A. Specification has information deficiency: Relevancy of documentation (obsolete tests)

ISSUES AND COMMENTS:

Specified liquid asphalt quality tests are outdated. The Department requires that new testing methods must be proven to be better than the old method before their use is allowed.

RECOMMENDATION:

There is a need to use the most modern testing methods to ensure that quality asphalt is being produced. These methods should be specified.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
A. project scoping
  2) facility characteristics: owner preferences and specifications
D. controls
  1) QA/QC, testing and inspection
E. information/communication
* 1) documentation
* 6) relevance

DEGREE OF CONSENSUS:

5 out of 5 agree that the liquid asphalt quality tests are outdated.

ADDITIONAL COMMENTS:

a) Materials should be purchased on a plant basis and stored by the contractor instead of purchased on a job basis. A contractor should not have to make separate purchases for each job. The district engineers want test results for each job, so a contractor might have to buy 6000 gallons of asphalt (when he only needs 1000 gallons) in order to obtain test results (usually asphalt must be bought in large quantity). A contractor should be able to take 1000 gallons, that was inspected previously, out of his storage facility and use it on a job.

1.14 ITEM 132.2: EMBANKMENT (Construction Methods)
I. PROBLEM:
A. Specification has information deficiency: Relevancy of documentation (obsolete construction method)

ISSUES AND COMMENTS:

"Compaction of embankments shall be obtained by the method hereinafter described as "Ordinary Compaction" or the method hereinafter described as the "Density Control" method." The ordinary compaction method has become outdated and is not used anymore.

RECOMMENDATION:

Only the density control method should be specified because it is a much better and easier method.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
A. earthworks

III FACTORS
C. processes/methods/subprocesses pertaining to:
  3) construction
D. controls
  1) QA/QC, testing and inspection

E. information/communication
* 1) documentation
* 6) relevance

DEGREE OF CONSENSUS:

3 out of 3 agree that only the density control method should be used.

ADDITIONAL COMMENTS:

a) The Highway Department does not always use the nuclear density gauge for testing, but instead it sometimes uses the slow sand cone method. Some districts use the balloon method which is also obsolete; with the balloon method only one lift can be done in a day whereas the nuclear density gauge allows two or three lifts to be completed in one day. The latest testing methods should be used.

1.15 ITEM 340.2: HOT MIX ASPHALTIC CONCRETE PAVEMENT (coarse aggregate for skid resistant surface) (also see 2.5)

I. PROBLEM:

A. Specification has information deficiency: Accuracy of documents (apparently contains inconsistent information regarding aggregate blending)

ISSUES AND COMMENTS:

This Item allows the blending of aggregates to obtain the required polish value. "Have a `combined polish value' achieved by blending non-polishing aggregates with polishing aggregates in specific proportions as determined by Method `A' or Method `B' of Test Method Tex-438-A, Part II." Research has shown that blending is not always effective in providing a significant increase in the skid resistance value.

RECOMMENDATION:

All reference to blending or "combined polish value" should be examined and possibly removed from the specification manual. Any mention of blending in the manual lends credibility to the practice, which it possibly should not.

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
E. information/communication
* 1) documentation
* 2) accuracy

1.16 ITEM 264.2: HYDRATED LIME AND LIME SLURRY (Types) (also see para 1.9)

I. PROBLEM:

A. Specification has information deficiency: Relevancy of documents (includes questionable types of lime, yet excludes usable peble lime)

ISSUES AND COMMENTS:

The Highway Department is not using type C lime or pebble lime in its specifications. On the other hand they do specify types of lime which are inadvisable.

RECOMMENDATION:

The lime specifications should reflect present practice and permit innovative practices where feasible. The use of flyash as a substitute for lime also needs to be examined closely.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
A. earthworks
D. pavement

III FACTORS
A. project scoping
    2) facility characteristics: owner preferences and specifications
B. resources: availability, variability, suitability, intrinsic attributes
    2) material
E. information/communication
* 1) documentation
* 6) relevance

DEGREE OF CONSENSUS:

3 out of 3 agree that the permissable types of lime need reconsideration.

ADDITIONAL COMMENTS:

a) Flyash should be placed on prewatered material because it mixes better, produces less blowing of the material, and gives a better end result.

b) There is little need for lime treatment in West Texas because clay is present only in isolated patches of soil.

GENERAL RECOMMENDATION:

The effectiveness of "guideline" specifications relies heavily upon the judgment of the inspector. Such judgment can be made more effective with inspector training and the development of good training materials. Related to this, it has been suggested that an "inspection guidelines book" be developed for certain difficult inspector decisions, such as weather conditions suitable for seal coat placement, suitability of materials for fill material, the weight of rollers to use, tolerances for rebar placement, etc. Such a reference could identify major considerations which would be reflective of different parts of the State, different road types, different weather conditions, different materials, etc.

DEGREE OF CONSENSUS:

Only 6 out of 11 agree that an "inspection guidelines book" would be feasible and effective.

ADDITIONAL COMMENTS:

a) A guideline book would be difficult to write, and it would be too cumbersome to be usable.

b) Inspectors are sometimes not able to make certain day to day decisions, as they should be able to. Then a contractor needs to go higher up, to the district engineer, in order to get a problem resolved.

c) Many decisions are based on a common sense approach, so inspectors need to be realistic.

d) The guideline book would be beneficial because it would tend to unify the parameters under which the inspectors will perform. Copies should be made available to the contractor for reference.

e) Inspectors need to realize that most of their decisions have a drastic effect on the costs of a contractor.

f) The training of inspectors is very important because inexperienced inspectors can slow down a job unnecessarily and can unintentionally hurt the contractor in many ways.

g) It is clear that a guideline book could not possibly identify all of the difficult decisions that might arise on a job. Also, no two jobs or situations are alike.

h) Some guidelines may be detrimental because common sense cannot be written into them.

i) More precise specifications are needed in order to curb interpretation problems.

j) Case study illustrating interpretation problem: The stockpile of a base material was found to be segregated by the inspector. The inspector's method of testing was inadequate, as all that had happened was a few large rocks had rolled down the outside of the pile. The stockpile was also rejected because it had been in place for over 24 hours. The misinterpretation was that if the pile was in the roadway it had to be moved within 24 hours. The stockpile in question was located on the side of the road.

GENERAL COMMENTS:

i) The Highway Department should not specify what equipment contractors are to use; they should allow the contractors to select what they need to obtain the finished product. Modern and innovative equipment cannot be kept updated by the specifications.

ii) Many construction innovations have been used on past projects but have not been accepted state-wide or adequately addressed in the specifications. Following is a list of examples.

   a) precast concrete panels for bridge decks

   b) metal deck forms for bridge slabs

   c) elimination of concrete diaphragms for prestressed beams

   d) various retaining wall options

   e) drum asphalt plant

   f) belly dump (bottom dump) trailors - The asphalt is dumped on the ground and loaded into a spreader machine. Some districts will not allow asphalt to hit the ground before the spreading process.

   g) vibratory roller for asphalt - It takes the place of two different rollers.

   h) storage bins to allow asphalt to be stored over night - The technology is present, but their use is not allowed.

   i) precast end treatments - Just place them on the end of the pipe and finished.

   j) heater scarifying to remove asphalt

2.1 ITEM 1.40: WORKING DAY
I. PROBLEM:
B. Specification has communication deficiency: Inconsistent interpretation of "principal unit of work":

ISSUES AND COMMENTS:

In charging time to a project, the term "principal unit of work" tends to be inconsistently interpreted from project to project. The "principal unit of work" is defined as "that unit which controls the completion time of the contract." Without a corresponding requirement for Critical Path Method (CPM) scheduling of construction activity by the contractor, the principal unit of work is not explicitly established or commonly understood. With CPM scheduling, the principal unit of work is any work Item that is part of a critical path.

RECOMMENDATION:

The "principal unit of work" should be more explicitly defined, such as "critical path activity", and a corresponding requirement should be placed on the contractor to employ CPM scheduling. Some Department representatives have suggested that a percentage of cost be used as a criteria in establishing the principal units of work. The latter approach is more difficult to justify. Another alternative is to allocate a certain number of calendar days for the completion of the project (provide for incentive or liquidated damages depending on time of completion). In other words, the project must be completed in a specified amount of time from the starting date.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
Applicable to all in general

III FACTORS
A. project scoping
4) time constraints: schedule objectives and limits
D. controls
2) cost and financial controls
E. information/communication
* 1) interpretation
* 3) consistency

CONSENSUS OF OPINION:

7 out of 8 agree that there is inconsistent interpretation.

ADDITIONAL COMMENTS/QUESTIONS:

a) Time schedules can become a serious problem for the job. The Highway Department usually does not give any leeway in the schedule regardless of unexpected weather or traffic conditions. The engineer typically does not take into account the unforeseen conditions that delay the contractor's work, but holds him to the schedule.

b) Who for the State determines how long it takes to complete a job, and what method do they use to accomplish this task? Most contractors feel that this is a totally arbitrary process performed by the Highway Department, and in most instances they are not given sufficient time to complete the work.

c) A working day should consist of at least 7 hours of work on pay Items, and time spent on subsidiary Items should not be included. A working day should not be charged for a half day of work due to bad weather.

d) The requirement of a CPM schedule needs to be weighted against the size and type of project.

e) The State fails to realize the amount of time that is required for mobilization on large projects.

f) A CPM schedule will accurately define the length of a project, and delays due to weather and utility problems can be identified and the CPM adjusted accordingly.

2.2 ITEM 316.1: SEAL COAT (Description)
I. PROBLEM:
B. Specification has communication deficiency: Inconsistent interpretation of "unsuitable weather"

ISSUES AND COMMENTS:

"Asphaltic material shall not be placed when general weather conditions, in the opinion of the engineer, are not suitable." Without more definition, the terms "general weather conditions" and "suitable" are subject to inconsistent interpretation.

RECOMMENDATION:

"General weather conditions" should be better defined. Several weather parameters need to be stated to clearly define suitable weather conditions. Some examples of parameters are air temperature precipitation and humidity.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
C. processes/methods/subprocesses pertaining to:
   3) construction
E. information/communication
* 1) interpretation
* 3) consistency
G. environmental systems
   2) weather

CONSENSUS OF OPINION:

4 out of 4 agree that inconsistent interpretation occurs with the terminology.

ADDITIONAL COMMENTS:

a) Seal coat season is from May 1 to September 30 in most districts.

b) Many different weather conditions affect the placement of seal coat, such as air temperature, surface temperature, and wind speed.

c) The placement of seal coat is left to the judgment of the engineer which may cause problems due to subjectivity. An engineer who has been hurt by the specification in the past may require a near-perfect day before he allows the contractor to work.

2.3 ITEM 110.2, 120.2, 130.2, 131.3 & 132.2: FILL MATERIAL (excavation, borrow, and embankment)
I. PROBLEM:
B. Specification has communication deficiency: Inconsistent interpretation by the engineer

ISSUES AND COMMENTS:

The comment has been made that material suitable for stable fill is often left to the judgment of the engineer, and that inconsistent interpretations in this area are not uncommon.

RECOMMENDATION:

Soil parameters need to be specified in order to determine which soils are suitable. Examples of the parameters that should be used are plasticity index, liquid limit, etc. Also, broad guidelines are needed to identify the materials that are unsuitable.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
A. earthworks

III FACTORS
B. resources: availability, variability, suitability, intrinsic attributes
  2) material
E. information/communication
* 1) interpretation
* 3) consistency

CONSENSUS OF OPINION:

4 out of 4 agree that inconsistency occurs among engineers.

ADDITIONAL COMMENTS:

a) In most cases the material on the job will be used as fill. Excavation and borrow Items are used as fill material.

b) A major problem with fill material is the pay Item. Problems arise because different materials have different shrinkages. The contractor must consider this when he decides how much to bid for the amount of fill material.

c) When borrow material is required, good sources need to be specified, and maximum PI's need to be set. Selection of material from a borrow pit can cause problems due to variability.

d) A clay soil with a high PI will be a good fill material if it is placed dry, but if it gets wet during placement it may be unstable.

e) Local materials should be specified if they are cost effective and good for the particular type of job.

NB: The following Item needs to cross referenced to "Liquidated Damages" and I still need to find this specific Item.

2.4 ITEM 340.6: HOT MIX ASPHALTIC CONCRETE PAVEMENT
I. PROBLEM:
B. Specification has communication deficiency: Inconsistent interpretation of liquidated damages

ISSUES AND COMMENTS:

The application of liquidated damages during the "closed asphalt season" has become an issue of concern due to inconsistent interpretation.

RECOMMENDATION:
Time charges for delay should be suspended when the asphalt season closes. When work is not allowed to commence by the SDHPT, damages should not be charged. If only a short time is needed to finish the work, the

deadline may be extended in which case damages should be charged. If the incompleted asphalt prevents other work from being done, time charges should also stop on that work. A set policy needs to be established.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
A. project scoping
 2) facility characteristics: owner preferences and specifications
E. information/communication
* 1) interpretation
* 3) consistency
G. environmental systems
 2) weather

CONSENSUS OF OPINION:

7 out of 7 agree that there is an inconsistency with applying liquidated damages.

ADDITIONAL COMMENTS:

a) The specification manual specifies the air temperatures when asphalt may be placed; it is the individual districts that set the closed asphalt seasons. Time charges should be stopped when the Highway Department tells the contractor to stop working.

b) The contractor bids asphalt work in the spring, and he selects a certain number of days during the "season" to complete the work. If unusual weather conditions prevent the completion of the work during the specified time frame, the contractor should be allowed, within reason, to use any time left in the "season" to finish the work.

2.5 ITEM 340: HOT MIX ASPHALTIC CONCRETE PAVEMENT (also see para 1.15)
I. PROBLEM:
B. Specification has communication deficiency: Inconsistent interpretation of usable aggregates

ISSUES AND COMMENTS:

Some districts allow the blending of aggregates while others do not. Blending allows the use of cheaper aggregates and a more economical design while still meeting the polished stone value requirements of the State.

RECOMMENDATION:

All districts should allow the use of aggregate blending for the purpose of economy. (It should be noted that this plea is supplementary to para 1.15 - Item 340.2, where a plea is made for this.) Uniformity is needed throughout the state on the types of aggregates that can be used.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
A. project scoping
 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:

3) construction
E. information/communication
* 1) interpretation
* 3) consistency
CONSENSUS OF OPINION:

2 out of 2 agree that blending should be allowed to be used.

2.6 ITEM 425.4: PRESTRESSED CONCRETE STRUCTURES (forms)
I. PROBLEM:
B. Specification has communication deficiency: Inconsistent interpretation due to ambiguity regarding tolerance

ISSUES AND COMMENTS:

"The soffit for casting members shall be constructed and maintained to provide not more than one-fourth inch variation in any 50 foot length of the bed from the theoretical plane of the bottom of the member." Some fabricators misinterpret this sentence to mean that the soffit can vary plus or minus one-fourth inch in any 50 foot length. This would allow a total variation of one-half inch rather than the intended allowable total variation of one-fourth inch.

RECOMMENDATION:

The word "total" should be inserted after "one-fourth inch" in the above mentioned sentence to clarify the intention of the specification.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
3) construction
E. information/communication
* 1) interpretation
* 3) ambiguity

GENERAL COMMENTS REGARDING THIS SECTION:

i) Some out-of-state contractors have a familiarity problem with parts of the specification manual.

ii) A cause of incompatible specifications is specification growth without the consideration of related specification sections that may also need updating or modifying.

3.1 ITEM 340.2: HOT MIX ASPHALTIC CONCRETE PAVEMENT
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for aggregate selection

ISSUES AND COMMENTS:

Tolerances for aggregates used in ACP are sometimes too tight. Some believe that job size, traffic volumes, material cost, and material availability should be considered. For example, the same tolerances for freeway mainlanes should not be required for a short term detour. In addition, it is believed that some material suppliers furnish "dirty" aggregate in total compliance with gradation tolerances. Plan notes are then sometimes necessary to define a suitable material.

RECOMMENDATION:

Short-term detours should be built as quickly and as cheaply as possible. The tolerances for detour work should be reduced, and dirty aggregate should only be allowed on detour work.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
B. resources: availability, variability, suitability, intrinsic attributes
   2) material
C. processes/methods/subprocesses pertaining to:
* 1) planning and design
D. controls
   1) QA/QC, testing and inspection

DEGREE OF CONSENSUS:

6 out of 7 agree that unrealistic tolerances exist.

ADDITIONAL COMMENTS:

a) Tolerances should be based on master gradation established for a particular material in the specification manual, as long as they are within the design gradation limits for the project of concern.

b) A problem exists with the magnesium sulfate test (soundness test) because it is not a local test (performed in Austin), and the results of the sample take 2 to 3 weeks.

c) The same mix is specified for all uses whether it is a permanent road or a detour. It is a waste of money to use precoated rock to produce a better finish when it will be covered up the next day.

d) A uniform specification for hot mix needs to be used in each district rather than every district writing its own specification.

e) Some districts have tighter requirements on fine aggregates (crushed screenings) than others. For example, in Waco not more than 20% retained on the No. 10 sieve is allowed, whereas in Dallas it is allowed to have 35% retained on the No. 10 sieve (this does not hurt the mix).

f) Quality control/monitoring and the polished value test need to be examined for effectiveness and efficiency of use. The polished value test is susceptible to personal preferences.

g) Dirty aggregates cause seal coats to strip or ravel from the surface.

3.2 ITEM 420.20: CONCRETE STRUCTURES (Finish of Roadway Slabs)
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for finished grade

ISSUES AND COMMENTS:

The finished surface will be tested with a standard 10 foot straightedge. "The straightedge shall be used parallel to the centerline of the structure to bridge any depressions and touch high spots." The enforced finish grade tolerance on bridge decking is 1/8 inch in 10 feet, but the required roughness may be 3/8 inch deep. The riding quality is not affected by such small variances.

RECOMMENDATION:

The tolerance should be increased from 1/8 inch to 3/8 inch to make the grade and roughness requirements compatible. The 1/4 inch difference will not affect the riding quality at all. The grade should be checked before the roughening process occurs to eliminate problems.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
A. project scoping
1) operational requirements
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
3) construction

DEGREE OF CONSENSUS:

4 out of 4 agree that unrealistic tolerances exist.

3.3 ITEM 440.7: Reinforcing Steel (Placing)
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for rebar placement

ISSUES AND COMMENTS:

Tolerances for the placement of reinforcing steel have been identified as generally too tight. Some inspectors measure to 1/8 inch tolerance, but under some circumstances the strength of the concrete will not suffer even if the bars are an inch off. Inspectors enforcing tight tolerances will spend an entire day measuring steel, which will cost the contractor a day's production.

RECOMMENDATION:

The tolerance should be expanded to 1/2 inch and no loss of strength will occur. Rebar does not always arrive at the site as straight equal length pieces of steel. For this situation, enforcing tight tolerances would not be practical.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:

3) construction

D. controls

1) QA/QC, testing and inspection

DEGREE OF CONSENSUS:

7 out of 8 agree that rebar placement tolerances are too tight.

ADDITIONAL COMMENTS:

a) The inspector causes the problems because the specification manual allows for leeway, but in the field this is not practiced (depends on the particular inspector's interpretatin).

b) Also, the tolerances could be loosened based on the type of project that is being dealt with.

3.4 (10) ITEM 248.6: FLEXIBLE BASE - PREPARATION OF SUBGRADE (Subgrade With Thick Flexbase)

I. PROBLEM:

C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for subgrade preparation

ISSUES AND COMMENTS:

Earth subgrade tolerances for designs with thick flexbase tend to be too restrictive. "The surface of the subgrade shall be finished to line and grade as established and in conformity with the typical section shown on plans, and any deviation in excess of 1/2 inch in cross section and in a length of 16 feet measured longitudinally shall be corrected."

RECOMMENDATION:

The tolerances need to be relaxed, depending upon pavement structure requirements, when working with a thick flexible base in order to speed up the work. The grade needs to be close but not exact because only the finished surface of the roadway is of concern for exactness of finish.

II. ELEMENTS OF HIGHWAY CONSTRUCTION

D. pavement

III FACTORS

A. project scoping

* 2) facility characteristics: owner preferences and specifications

C. processes/methods/subprocesses pertaining to:

3) construction

D. controls

1) QA/QC, testing and inspection

DEGREE OF CONSENSUS:

10 out of 11 agree that tolerances are too tight on subgrade preparation.

ADDITIONAL COMMENTS:

a) Too much time is spent getting the subgrade to the exact elevation needed for the placement of the flexible base. However, the subgrade needs to be close to the elevation needed because the flexible base is paid for on an in place measurement.

b) Both the subgrade and the flexible base need to be taken to the specified density, but it is not necessary to use 4 lifts on a 12 inch base. Only use the number of lifts needed to achieve the proper density.

c) A steel wheel roller is needed to finish the flexible base, but the Highway Department does not allow its use in the specifications. Instead, they want the contractors to use a pneumatic roller which will do the same job but requires more effort.

d) Additives are sometimes needed to make the base meet certain requirements (PI, etc.), but some districts do not allow their use.

e) No two people can string-line a road and obtain the same result or the finished grade. Tight tolerances are not practical.

f) In some cases, the subgrade has been finished smoother than the actual road surface. The additional expense must be weighted against its value toward the finished product.

3.5 ITEM 260.4: LIME TREATMENT FOR MATERIALS IN PLACE (Subgrade)
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for subgrade finish before lime treatment

ISSUES AND COMMENTS:

Finish surface tolerances for earth subgrade are too strict where lime treatment is involved. Under these conditions, the subgrade is typically finished to tolerance prior to liming, plowed up and lime treated, and then finished again to tolerance.

RECOMMENDATION:

Before liming occurs, the subgrade should only be loosely finished so that double work does not occur. This Item should be made into an end result specification.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
A. earthworks

III FACTORS
A. project scoping
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
3) construction
D. controls
1) QA/QC, testing and inspection

DEGREE OF CONSENSUS:

7 out of 8 agree that surface tolerances for subgrade are too tight where lime is being applied.

ADDITIONAL COMMENTS:

a) When the subgrade is finished to tolerance before the lime is added, there is excess material because when the lime is added the material tends to fluff and expand.

3.6 ITEM 360.4, 420 & 421.9: CONCRETE STRENGTH (Concrete Pavement & Structures)
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: No tolerances exist for concrete strength

ISSUES AND COMMENTS:

Concrete strength specifications do not address tolerances. Only a minimum required psi is stated in the specifications. If a 3000 psi strength is needed and only a 2950 psi strength is obtained, the mix may or may not be usable depending on the inspector's judgment.

RECOMMENDATION:

Concrete strength specifications should be based on a statistical approach to tolerances. The high and low readings should be thrown out and not averaged with the other readings.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement
F. bridges/structures

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

ADDITIONAL COMMENTS:

a) Contractors have had mixes rejected on slump and air entrainment test results, even though the department sets the W/C ratio on the mixes.

b) Tolerances are needed so the resident engineer is not faced with the decision of accepting or rejecting work that almost meets the standard. Also, he would not be faced with the problem of what penalties to impose on work that is accepted but did not quite meet the required strength.

3.7 ITEM 131.2, 132.2, 246.2, 249.4 & 274.2: PLASTICITY INDEX (PI) (Borrow, Embankment, Foundation Course, Flexible Base, Flexible Base Delivered, and Cement Stabilized Base)
I. PROBLEM:
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.

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
D. 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:

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

ADDITIONAL COMMENTS:

a) Different labs can test the same material and produce different results because the results depend on the way the material was tested. 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.

3.8 ITEM 132.2: EMBANKMENT (Density)
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for embankment densities

ISSUES AND COMMENTS:

Embankment density requirements are strictly enforced, even for inconsistent materials (and striated materials). "If the material fails to meet the density specified, the course shall be reworked as necessary to obtain the specified compaction."

RECOMMENDATION:

A statistical approach to tolerancing is needed for enforcing embankment density requirements. Many different soils exist on a project so looser tolerances for meeting density requirements are needed to allow soils that are similar to be accommodated in one test. This will reduce the amount of testing that is required which will reduce delays in the project.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
A. earthworks

III FACTORS
A. project scoping
    2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
* 3) construction
D. controls
    1) QA/QC, testing and inspection

DEGREE OF CONSENSUS:

8 out of 8 agree that unrealistic tolerances exist for embankment densities.

ADDITIONAL COMMENTS:

a) Tolerances need to be specified, as well as materials that can be used (instead of specifying materials that cannot be used).

b) Soil samples are taken from a project and placed in bottles. An attempt is made to match the samples to previously tested materials so additional testing is not required. However, sometimes the only criterion that is used is color.

3.9 ITEM 425.7: PRESTRESSED CONCRETE STRUCTURES (Workmanship and tolerance)
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: Unrealistic casting and erection tolerances

ISSUES AND COMMENTS:

In segmental construction, casting tolerances are sometimes incompatible with erection tolerances. "Where sections of forms are to be joined, an offset of 1/16 inch for flat surfaces and 1/8 inch for corners and bends will be permitted. Offsets between adjacent end header sections shall not exceed 1/4 inch."

RECOMMENDATION:

The erection tolerances need to be loosened slightly to be made compatible with the casting tolerances.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
 3) construction
E. information/communication
 1) documentation
 3) compatibility

DEGREE OF CONSENSUS:

4 out of 4 agree that erection and casting tolerances are sometimes incompatible.

3.10 ITEM 427.7: SURFACE FINISHES FOR CONCRETE (Exposed Aggregate Finish)
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for aggregate exposure finished concrete

ISSUES AND COMMENTS:

The tolerances for the depth of aggregate exposure are very unrealistic. "The depth of finish shall be one-fourth of an inch minimum to one-half of an inch maximum, unless otherwise directed by the engineer or required by the plans." However, if one-half of an inch is specified, most of the aggregate must be taken out of the face of the panel while trying to achieve that tolerance.

RECOMMENDATION:

The depth of finish should be changed to one-eighth of an inch because realistically this is all that can be achieved.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
A. project scoping
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
3) construction

DEGREE OF CONSENSUS:

2 out of 2 agree that the tolerances are unrealistic for proper aggregate exposure.

ADDITIONAL COMMENTS:

a) A W/C of 5.5 is usually specified with a required slump of 5 inches which cannot be obtained together. A 6 to 7 inch slump is needed to make exposure work.

3.11 ITEM 360.3: CONCRETE PAVEMENT (Equipment-forms)
I. PROBLEM:
C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for form depth

ISSUES AND COMMENTS:

Metal forms are required for most concrete pavements. With the many different depths of pavements that are specified, the contractor could not possibly have forms for every depth. "Forms with depth greater or less than the required edge thickness of the pavement will be permitted provided the difference between the form depth and the edge thickness is not greater than 1 inch, and further provided that the forms of a depth less than the pavement edge are brought to the required edge thickness by securely attaching metal strips of approved section to the bottom of the form."

RECOMMENDATION:

The tolerance should be expanded to include forms that differ by 2 or 3 inches from the pavement depth. The quality of compaction need not be lost by increasing the tolerance 1 or 2 inches, however precautionary steps to achieve this, may be necessary.

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
C. processes/methods/subprocesses pertaining to:
1) planning and design

DEGREE OF CONSENSUS:

2 out of 2 agree that more tolerance should be given to expanding form depths.

3.12 ITEM 425.4: PRESTRESSED CONCRETE STRUCTURES (finishing of concrete)

I. PROBLEM:

C. Specification has unrealistic tolerances/requirements: Unrealistic tolerances for finish

ISSUES AND COMMENTS:

"When the plans require that a concrete overlay be placed on prestressed concrete box members, the top slab of the box shall be given a metal tine finish having an average texture depth of approximately 0.050 inches." Many fabricators have complained that the depth of 0.050 inches is too restrictive.

RECOMMENDATION:

The average texture depth should be changed to 0.10 inches with a tolerance of 0.050 inches. This will alleviate many fabricating problems.

II. ELEMENTS OF HIGHWAY CONSTRUCTION

F. bridges/structures

III FACTORS

A. project scoping

* 2) facility characteristics: owner preferences and specifications

C. processes/methods/subprocesses pertaining to:

1) planning and design

3) construction

3.13 ITEM 292.2: ASPHALT STABILIZED BASE (mineral aggregate)

I. PROBLEM:

C. Specification has unrealistic tolerances/requirements: Unrealistic tolerance for sand equivalent value

ISSUES AND COMMENTS:

"Sand equivalent value shall not be less than 40." With a P.I. requirement of 15 maximum, the material will not be able to meet the sand equivalent value of 40 minimum. No tolerances are given for either requirement.

RECOMMENDATION:

The sand equivalent requirement should be deleted, or the value should be lowered to 35 minimum so as not to conflict with the plasticity index requirement.

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

E. information/communication

1) documentation

3) consistency

3.14 ITEM 425.4: PRESTRESSED CONCRETE STRUCTURES (placing concrete)

I. PROBLEM:

C. Specification is inconsistent with practice (unrealistic requirements): Obsolete method of placing concrete which is not followed under certain conditions
Department needs to review method of placing concrete

ISSUES AND COMMENTS:

"Concrete shall be deposited as near as possible in its final position in the forms. Depositing large quantities of concrete at one location in the forms and running or working it along the forms will not be permitted." When placing concrete on the top of a void as in prestressed concrete box beams, it is necessary to place the concrete at the top center portion of the void and work it down the sides evenly to avoid moving the void to one side or the other.

RECOMMENDATION:

The statement needs to be revised to allow concrete to be worked along the forms. This will accomodate the proper placement of concrete in box beams.

II. ELEMENTS OF HIGHWAY CONSTRUCTION

F. bridges/structures

III FACTORS

A. project scoping
   2) facility characteristics: owner preferences and specifications

C. processes/methods/subprocesses pertaining to:
   3) construction

E. information/communication
* 1) documentation
   3) consistency

GENERAL COMMENTS REGARDING THIS SECTION:

i) It has been suggested that for certain Items, pay practices should be based on a percentage of tests that pass (within limits), and that this should be stated explicitly in the specifications. However, not all contractors agree with this statement; some believe that a product should be either totally acceptable or not acceptable. Perhaps additional research is needed here.

ii) Experienced engineers do not enforce unrealistic tolerances, but less experienced engineers lack the judgment to know when or when not to enforce specified tolerances.

4.1 ITEM 360.8: CONCRETE PAVEMENT (Spreading and Finishing)

I. PROBLEM:

D. Gold-plated designs, specifications, etc: Unnecessary finishing of rural roads (gold-plated)

ISSUES AND COMMENTS:

Concrete finishes exist on farm-to-market roads that are equivalent to those for urban or high-traffic areas.

RECOMMENDATION:

The quality of finish for a road should be based on its location and usage.
The extra expense of placing a quality finish on a rural road is not justifiable to the tax payer.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
A. project scoping
1) operational requirements
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
1) planning and design

DEGREE OF CONSENSUS:

Only 4 out of 8 agree that excessive finishing of rural roads occurs.

ADDITIONAL COMMENTS:

a) Some contractors still believe that all roads should be finished the same with the same tolerances.

4.2 ITEM 340 & 360: ROAD SHOULDERS (Pavement Items)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Gold-plated design of road shoulders

ISSUES AND COMMENTS:

Although not explicitly mentioned in the specification, overdesign of road shoulders sometimes occurs for certain kinds of roads.

RECOMMENDATION:

In most cases, shoulders should be designed the same as the roads to ensure safety and easy construction. However, where shoulders are unlikely to carry heavy traffic at any stage, different materials and different designs can be used to save cost and possibly enhance constructability.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement

III FACTORS
A. project scoping
1) operational requirements
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
1) planning and design

DEGREE OF CONSENSUS:

5 out of 5 agree that the main aim should be to design the road shoulders to ensure safe passage of vehicles when necessary.

ADDITIONAL COMMENTS:

a) Care should be taken to ensure that road shoulders which are constructed to lower material design standards do not cause drainage problems.

b) From a construction standpoint, it is not always practical to have two significantly different designs for the road and the shoulder.

c) If shoulders are designed to be strong and durable, they will help to reinforce the outer lanes of the road.

4.3 ITEM 446.9: CLEANING, PAINT AND PAINTING (Painting)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Excessive painting (gold-plated)

ISSUES AND COMMENTS:

Although not explicitly mentioned in the specification, some districts require that bridgework be painted below the ground line. The reason for this is if erosion results the bridgework that is seen will still be painted. If bridgework is painted below the ground line, extra labor is required to clear away the dirt. The added expense is not worth the result. If the soil washes away, the exposed bridgework can be painted.

RECOMMENDATION:

The only Items that should be painted are the ones that will be seen by the traveling public unless required for other reasons such as maintenance.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
1) planning and design

DEGREE OF CONSENSUS:

3 out of 3 agree that bridgework should not be painted below the ground line.

4.4 ITEM 420.22: CONCRETE STRUCTURES (Removal of Forms and Falsework)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Excessive curing times for follow-on work (gold-plated)

ISSUES AND COMMENTS:

There should be different requirements of fixed curing times or strength requirements for different structure types under different conditions provided design parameters are met. Needless delays in follow-on activities may result. For example, a cap cannot be placed on columns until the column reaches 600 psi, when columns may need only 100 psi to support the cap (vs. the entire traffic bearing structure). The same situation applies to beams on caps, walls on footings, etc. Of course, project schedules can be speeded up by allowing for earlier start of follow-on activities.

RECOMMENDATION:

When the concrete reaches a certain percentage of the acceptance strength, follow-on work should be allowed to commence. A safety factor should be applied to the strength that is actually needed to support the follow-on work.
II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
   2) facility characteristics: owner preferences and specifications
B. resources: availability, variability, suitability, intrinsic attributes
* 2) material
C. processes/methods/subprocesses pertaining to:
   1) planning and design
   3) construction

DEGREE OF CONSENSUS:

Only 4 out of 5 agree that excessive curing times exist.

ADDITIONAL COMMENTS:

a) A certain strength (psi) is required to allow traffic on roads. Accelerators are not allowed in the mix even when time is of the essence to place traffic on the roads.

4.5 ITEM 427.4: SURFACE FINISHES FOR CONCRETE (CLASS OF FINISH)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Excessive finishing for appearance (gold-plated)

ISSUES AND COMMENTS:

With respect to concrete finishing, the painting of concrete was chosen to eliminate costly and time-consuming rubbing. However, sometimes specifications are interpreted to require both rubbing and painting.

RECOMMENDATION:

Concrete should not be rubbed and painted; the projections should be knocked off and the concrete painted. Painting is all that needs to be done to a structure to give it a good appearance. The main feature of a structure is to serve its purpose not to be aesthetically pleasing.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
* 2) facility characteristics: owner preferences and specifications
B. resources: availability, variability, suitability, intrinsic attributes
* 2) materials
C. processes/methods/subprocesses pertaining to:
   3) construction

DEGREE OF CONSENSUS:

6 out of 6 agree that excessive finishing of concrete occurs.

ADDITIONAL COMMENTS:

a) A lesser quality of finish should be allowed on Items that will not be seen by traffic.

b) For a perfect appearance, it may be necessary to rub and paint, but this should be clearly stated.

c) Instead of rubbing, a latex grout is sometimes spread over the concrete before it is painted.

d) Concrete forms exist today that produce a good finish without painting. Humidity, temperature, and dust affect painting, and after a couple of years, the structure looks worse than if it was never painted.

4.6 ITEM 450.2: RAILING
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Gold-plated amount of railings

ISSUES AND COMMENTS:

Steel and aluminum bridge railings are easily and frequently vandalized. These types of railings are expensive to replace and have high maintenance costs. The variety of different railings that are used makes bidding cumbersome.

RECOMMENDATION:

The State should consider using the same type of bridge railing as far as possible. The use of steel and aluminium railing should be minimized and only one type of standard concrete railing, which is cheaper to maintain and install, should generally be used. A popular form for concrete railing, such as T501, T502, or T503, should be selected and used in all locations. Having one form will create uniformity throughout the state. One type of railing will also reduce the number of payment Items.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
* 2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
1) planning and design

DEGREE OF CONSENSUS:

2 out of 2 agree that standardization is needed for bridge railing.

4.7 ITEM 422.3: REINFORCED CONCRETE SLAB
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Indiscriminate use of diaphragms (gold-plated)

ISSUES AND COMMENTS:

Diaphragms between bridge girders are occasionally specified needlessly.

RECOMMENDATION:

Do not use diaphragms unless they are needed. When possible, use steel diaphragms instead of concrete ones to ease the difficulty of construction. Diaphragms should become a separate bid Item because they are expensive and are not used uniformly.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
    2) facility characteristics: owner preferences and specifications
C. processes/methods/subprocesses pertaining to:
* 1) planning and design

DEGREE OF CONSENSUS:

Only 4 out of 5 agree that diaphragms are sometimes used needlessly.

4.8 ITEM 440.7: REINFORCING STEEL (Placing)
I. PROBLEM:
D. Inflexibility of design and specification requirements: Inflexibility regarding alternative techniques for meeting design requirements relating to truss bars

ISSUES AND COMMENTS:

Although not specifically referred to in the specifications, designs can cause difficulty with the placing of rebar. For bridge decking, truss bars are required in order to take care of the moments between beams. These truss bars are very difficult to fabricate as well as difficult to place.

RECOMMENDATION:

At the contractor's discretion, truss bars should be eliminated and replaced with straight mats of steel which will serve the same purpose. Another alternative would be to use prefabricated welded wire fabric to eliminate the tying of steel. These techniques must meet design requirements in order to be used.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
C. processes/methods/subprocesses pertaining to:
* 1) planning and design
    3) construction

DEGREE OF CONSENSUS:

1 out of 1 agrees that truss bars are not always needed and alternative proposals should be permissible.

4.9 ITEM 512.3: PORTABLE CONCRETE TRAFFIC BARRIER (Construction methods)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Gold-plated curing

ISSUES AND COMMENTS:

"Concrete shall be form cured or water cured for a minimum of four curing days." Four days of curing is not necessary, and it is not being enforced for CIP barrier or precast barrier. Time is being needlessly wasted by waiting four days.

RECOMMENDATION:

The requirement of curing concrete for four days should be removed from this Item. Instead, it should be stated that concrete shall be continuously cured until handling strength is attained. Likewise, the handling strength needs to be specified under this Item.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
H. incidental construction

III FACTORS
A. project scoping
* 2) facility characteristics: owner preferences and specifications
B. resources: availability, variability, suitability, intrinsic attributes
2) material
C. processes/methods/subprocesses pertaining to:
3) construction

4.10 ITEM 260.4: LIME TREATMENT FOR MATERIALS IN PLACE (Construction methods - compaction)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Gold-plated density requirements

ISSUES AND COMMENTS:

When the density control method of compaction is indicated on the plans, 95% density is required by the specifications. 95% density is very difficult to achieve in the field, no matter how many passes are made.

RECOMMENDATION:

Density requirements should be reduced to 90% which has been proven to be sufficient when lime is being used as a working table.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
A. earthworks
D. pavement

III FACTORS
A. project scoping
2) facility characteristics: owner preferences and specifications
B. resources: availability, variability, suitability, intrinsic attributes
2) material
C. processes/methods/subprocesses pertaining to:
* 3) construction

4.11 ITEM 360.6 & 420.11: CONCRETE PAVEMENT (Concrete mixing and placing)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Gold-plated placing time

ISSUES AND COMMENTS:

"Any concrete not placed as herein prescribed within 30 minutes 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 more minutes were added to the time period, quality would not be affected, and less concrete would be wasted due to the restrictive time period. According to Fulton's "Concrete Technology" - PCI Midrand, South Africa, 1986 - up to 90 minutes can be safely allowed.

RECOMMENDATION:

Air or concrete temperature spreads 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 will permit the extension of the time periods by 30 minutes.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
D. pavement, bridges and structures

III FACTORS
A. project scoping
2) facility characteristics: owner preferences and specifications
B. resources: availability, variability, suitability, intrinsic attributes
* 2) material
C. processes/methods/subprocesses pertaining to:
3) construction

DEGREE OF CONSENSUS:

2 out of 2 agree that the time period allowed for placing concrete is not sufficient.

4.12 ITEM 340.2: HOT MIX ASPHALTIC CONCRETE PAVEMENT (coarse aggregate, general)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Gold-plated aggregates

ISSUES AND COMMENTS:

"The `Pressure Slaking Value' shall not exceed 4 percent when tested in accordance with Test Method Tex-431-A. The `Aggregate Freeze-thaw Loss' shall not exceed 7 percent when tested in accordance with Test Method Tex-432-A." These percentages tend to be too restrictive, and many successful lightweight surface treatment asphalt projects have been done with lightweight aggregate which did not meet the current "pressure slake" of 4% and freeze-thaw of 7% and are still in service.

RECOMMENDATION:

The "Pressure Slaking Value" should be raised to 6 percent, and the "Aggregate Freeze-thaw Loss" should be changed to 15 percent. This change would allow many quality lightweight aggregates to be used. These materials have the highest R.S.P.V. in the state which would produce a safer driving surface which is one of their greatest advantages.

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

4.13 ITEM 425.4: PRESTRESSED CONCRETE STRUCTURES (placing concrete)
I. PROBLEM (also see para 4.11):
D. Gold-plated designs, specifications, etc: Gold-plated placing time

ISSUES AND COMMENTS:

"Not more than one hour shall elapse between the placing of the successive layers." The one hour time limit should be reconsidered since in many cases a layer of concrete can remain in a plastic state after one hour has elapsed.

RECOMMENDATION:

Consideration should be given to replacing the above quoted sentence with the following sentence to relax the time of placing. "The sequence of successive layers shall be such that they can be vibrated into a homogeneous mass with the previously placed concrete in order to avoid cold joints."

II. ELEMENTS OF HIGHWAY CONSTRUCTION
F. bridges/structures

III FACTORS
A. project scoping
    2) facility characteristics: owner preferences and specifications
B. resources: availability, variability, suitability, intrinsic attributes
* 2) material
C. processes/methods/subprocesses pertaining to:
    3) construction

4.14 ITEM 274.6: CEMENT STABILIZED BASE (Construction methods - finishing)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Gold-plated time element

ISSUES AND COMMENTS:

Modifications are needed for the time period allowed from start of mixing to completion of compaction (under this Item only 2 hours is allowed). This time element is too restrictive and is not often followed. Many field personnel do not believe that time is that critical for this operation.

RECOMMENDATION:

The wording of the Item needs to be changed to allow for an extended time period. It is recommended that the finishing operations be completed within a period of up to 5 hours after the cement is added to the base material since it is considered that this will not have any serious detrimental effect on the end product.

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
C. processes/methods/subprocesses pertaining to:
* 3) construction

4.15 ITEM 7.12: LEGAL RELATIONS AND RESPONSIBILITIES (Contractor's Responsibility for Work)
I. PROBLEM:
D. Gold-plated designs, specifications, etc: Gold-plated maintenance during construction

ISSUES AND COMMENTS:

The extent of the contractor's maintenance of roadways during construction has become a problem. "The contractor shall rebuild and make good at his own expense all injuries and damages to the work occurring before its completion and acceptance."

RECOMMENDATION:

The contractor's maintenance of the road should be based on the type of work he is performing. For example, a contractor should not have to patch and maintain a road over the life of the project if all he is doing is placing a seal coat on the road. The Item needs to be clarified to take into account different situations.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
H. incidental construction

III FACTORS
A. project scoping
  1) operational requirements
* 2) facility characteristics: owner preferences and specifications
E. information/communication
  1) documentation
  4) clarity

DEGREE OF CONSENSUS:

3 out of 3 agree that the maintenance of roads during some types of construction has become a problem.

GENERAL COMMENTS:

i) Normally, material can be hauled in any available trucks or trailors, but on occasion the Highway Department has required the use of special trucks. These trucks are expensive to rent and cannot haul as much material as regular trucks.

ii) A representative from the Highway Department should review the general notes on plans to make sure they are not gold-plated. The notes could alter many specification Items and cause problems or cost increases and poorer constructability.

iii) Gold-plating generally results from job fear and is an attempt to avoid peer criticism.

iv) The Highway Department should not specify any more than what is actually needed. If they do, they will be paying a premium for it.

v) Many projects require the contractor to keep certain equipment on the site at all times in case it's use is needed. Many times the equipment is not used, and an unnecessary additional expense is incurred.

5.1 ITEM 477.6: SAFETY END TREATMENT (Payment)
I. PROBLEM:
E. Specifications 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 state wide 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:

8 out of 8 agree that a practical method is needed to pay for safety end treatments.

ADDITIONAL COMMENTS:

a) In Ft. Worth, 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.

5.2 ITEM 502.1 & 502.4: BARRICADES, SIGNS AND TRAFFIC HANDLING (discription and payment)
I. PROBLEM:
E. Specifications with unsatisfactory method(s) of payment: Improper payment method

ISSUES AND COMMENTS:

"This Item shall consist of providing, installing, moving, replacing, maintaining, cleaning, and removing upon completion of work, all barricades, signs, barriers, cones, lights, signals, and other such type devices and of handling traffic as indicated in the plans or as directed by the Engineer." The Item is bid as a lump sum for everything that needs to be done to control traffic. It is very hard for the contractor to anticipate everything that he will need. In most cases, more things are needed than what is actually bid.

RECOMMENDATION:

The State needs to better define what will actually be needed to control traffic. Pay Items are needed to eliminate the confusion of payment for this specification.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
H. incidental construction

III FACTORS
A. project scoping

2) facility characteristics: owner preferences and specifications
D. controls
2) cost and financial controls
E. information/communication
* 1) documentation
4) completeness

DEGREE OF CONSENSUS:

1 out of 1 agrees that the payment method for this Item is not efficient.

5.3 ITEM 664.8 & 664.9: ABBREVIATED PAVEMENT MARKINGS (measurement and payment)
I. PROBLEM:
E. Specifications with unsatisfactory method(s) of payment: Poor payment method

ISSUES AND COMMENTS:

"Abbreviated pavement markings will be measured by the linear foot of markings placed." The markings must be placed every night if traffic is allowed on the road. The road might require several courses of hot mix before it is completed, and each course must have pavement markings applied to it. Existing markings are covered by the next course of hot mix, and the Highway Department typically only pays for one set of markings.

RECOMMENDATION:

The Highway Department should pay for pavement markings placed on all courses of hot mix. When bidding, the contractor may not know how many courses will be required or how much work he can complete in a day. Hence, he would not be able to bid properly on the amount of pavement markings required.

II. ELEMENTS OF HIGHWAY CONSTRUCTION
G. lighting & signing

III FACTORS
A. project scoping
2) facility characteristics: owner preferences and specifications
D. controls
2) cost and financial controls
E. information/communication
* 1) documentation
4) completeness

DEGREE OF CONSENSUS:

1 out of 1 agrees that the payment method is poor.

5.4 ITEM 401.2: EXCAVATION AND BACKFILL FOR SEWERS (Construction methods)
I. PROBLEM:
E. Specifications with unsatisfactory method(s) of payment: Unnecessary payment method

ISSUES AND COMMENTS:

Excavation of sewer pipe should be made subsidiary to the pipe sewers specification (Item 465). If the two Items were made subsidiary, the inspector's job would be easier, and less payment Items would be required.

RECOMMENDATION:

The two Items complement each other so if they were made subsidiary, it would help to consolodate the material contained in the specification manual and reduce the number of seperate payment Items.

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:

Only 4 out of 8 agree that the two Items should be made subsidiary.

ADDITIONAL COMMENTS:

a) The department's figure for excavation is usually only half of what is actually needed for the job. If more excavation is required, it is helpful to have a separate pay Item for the excavation of backfill.

5.5 ITEM 462.10: CONCRETE BOX CULVERTS (Payment)
I. PROBLEM:
E. Specifications with unsatisfactory method(s) of payment: Improper payment method

ISSUES AND COMMENTS:

Payment for this Item is "per linear foot for the various sizes and types of concrete box culvert." This Item includes too much subsidiary work to be bid correctly.

RECOMMENDATION:

Some of the subsidiary work such as the preparation and shaping of bed, jointing of sections, and concrete and reinforcing steel should become separate bid Items to make bidding easier for the contractor. Much of the subsidiary work is unrelated to the basic bid Item.

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
E. information/communication
* 1) documentation
    4) completeness

DEGREE OF CONSENSUS:

1 out of 1 agrees that too much subsidiary work is associated with this Item.

5.6 ITEM 260.7 & 262.8: LIME TREATMENT FOR MATERIALS IN PLACE AND LIME TREATMENT FOR BASE COURSES (Payment)

I. PROBLEM:

E. Specifications with unsatisfactory method(s) of payment: Unnecessary payment methods

ISSUES AND COMMENTS:

The current specifications are unnecessarily cumbersome when multiple layers are treated with lime. Many times existing pavement structures are lime treated with combinations of base and subgrade, new base and existing base, etc. It is not practical or efficient to keep track of two separate bid Items and two sets of quantities.

RECOMMENDATION:

The two Items should be combined into one Item for lime treating subgrade, subbase, base courses, or combinations there of. This would eliminate confusion in the field, and not create as many errors. Likewise, it would be more economical and efficient to combine the two Items to facilitate the payment method.

II. ELEMENTS OF HIGHWAY CONSTRUCTION

D. pavement

III FACTORS

A. project scoping

  2) facility characteristics: owner preferences and specifications

  D. controls

* 2) cost and financial controls

G. MISCELLANEOUS COMMENTS FOR SPECIFICATION MODIFICATIONS

a) Many contractors would like to see the specifications become more end-result. They want to be told what end product is desired and not the methods to achieve that result. They want to use their own methods, and have freedom to produce the desired result without interference from the Highway Department. By inference, the contractors have to be qualified to do the work because the bidding process is risky.

b) End-result specifications can effectively restrict competition by eliminating non-sophisticated contractors.

c) End-result testing requirements can be excessive and redundant when similar testing is conducted by both state and contractor personnel.

d) If a product can be produced to meet the specification, the Highway Department should not tell the contractor how to achieve that result. For example, the Highway Department should not specify the type of equipment to be used on a job. However, some end-result specifications are costly because of the duplication of tests and of the harsh penalties that are associated with them. The percentages used for penalties may not coincide with the percentage of life expectancy that was lost due to the imperfect end-result (this in not fair to the contractor).

e) End-result specifications might be beneficial to the Highway Department on a manpower perspective. The end-result specification would permit personnel previously occupied with the implementation of descriptive specifications to be utilized in other positions with the Highway Department.

f) End-result specifications should produce quality products at a cheaper price as well as incorporate new ideas at a faster pace. Also, with end-result specifications, material variability is better accommodated.

g) A contractor should be allowed to stockpile as much material as he needs (the Highway Department should not limit the contractor to 300 or 500 ton stockpiles).

h) Cement stabilized backfill should be used for all types of underground work. This type of backfill eliminates the problem of obtaining density and allows for faster construction. From a safety standpoint, no one has to enter the ditch in order to compact the material.

i) For most jobs, the plans are not given to the contractors soon enough for them to obtain bids from subcontractors. More preparation time is needed.

j) The state could be divided into geographical regions for the application of the specifications. If the state was broken into regions, the specifications could better accommodate weather conditions, material variability, etc.

k) The resident engineer needs to be given as much as possible authority to make field changes and agree on a price with the contractor as soon as a problem arises. This will eliminate much delay in the work of the project.

l) Many Items related to construction could to be standardized for cost efficiency. Examples include curb and gutters, light poles, manhole covers, signing, inlets, concrete barriers, and guardrails.

m) The Highway Department generally does not accept alternates or substitutions, and no incentives are available. One problem is that it takes too long for alternates to get through the administrative process. The following is an example where an alternate method was allowed. For the repair of a road, the Highway Department required that 18 inches of material be cut out of the road. Also, they required that a lime course and four base courses be placed before any paving could be done. On this particular stretch of road, driveways existed every 100 feet so an alternate method of repair had to be developed by the contractor. The contractor suggested using a batch design with a black base so that the road could be cut and replaced the same day. The Highway Department allowed the alternate method and adopted it on future projects.

n) The only incentive on alternates for the contractor is to hasten the speed of the job for cost effectiveness. The contractor does not share any cost savings with the Highway Department, who keeps all savings and advantages. Incentive programs could help to develop good innovative ideas which would lead to cost efficiency in the future.

o) In most circumstances, single-source procurement is not in the best interest of the Highway Department to use.

p) The specifications do not address the variability of materials in different parts of the state, but the plan notes sometimes allow for deviations in the specification Items. The Highway Department typically does not make use of local materials; it specifies the same material for a job no matter the location. An additive can sometimes be used to make local materials meet job requirements, but the Highway Department does not always allow their use. The rising cost of fuel to haul materials necessitates the use of local materials whenever possible. Rai transport is occasionally used to haul materials in order to save on fuel costs.

CHAPTER V. ANALYSIS OF SPIB

Specification Items apparently impeding constructability were organized into a database, referred to as SPIB, to facilitate the process of analyzing the information. In compiling SPIB the information was initially structured with reference to five problem types viz. information deficiencies, communication deficiencies, unrealistic tolerances/ requirements, gold-plated designs, specifications, etc, and unsatisfactory methods of payment. An analysis was done to determine how improvements could be made to the specifications to enhance constructability. Two primary methods were used for analysis. These were respectively, cross classification tables and a HOT diagram. These methods allowed for the identification of problems as well as their respective causes.

To facilitate the analysis of the problem types with respect to constructability, the cross classification tables were structured under four main headings. These were:

— communications deficiencies
— information deficiencies
— functional exorbitance
— practicality limitations

This is in accordance with the main features of specifications set out in Table 2.1.

The comments contained in the text in SPIB were also reviewed to establish findings not addressed by the cross classification tables or the HOT diagram.

CROSS CLASSIFICATION TABLES

Cross classification tables were used to show the relative importance of Problem Types, Apparent Causal Constructability Factors, and Elements of Highway Construction relative to particular specification Items. As mentioned briefly in Chapter III, the structure and function of the cross classification table was developed from the constructability influence matrix (Brown 1988).

The constructability influence matrix operates in the following manner. Across the top of the matrix, Elements of Highway Construction are listed, the left side of the matrix contains Constructability Factors, and the bottom lists different phases of engineering for each Element of Highway Construction. The boxes of the matrix are then used to categorize Items, which are influenced by the various constructability factors, in relation to the respective elements of highway construction during the different phases of engineering. The cross classification tables operate in a similar manner,except that the only phase of engineering that is of concern is the standard specifications of the Department, which forms part of the documentation of the design. The placement of the respective Items shows which factors are influencing the particular specification Item. The concentrations of Items in the tables shows which factors are having the greatest influence on the specifications in general or vise versa.

Three cross classification tables marked 5.1(A), 5.2(A), and 5.3(A) were utilized to analyze the specification Items contained in SPIB. This was done so that the interrelationship between the three aspects: Problem Types, Apparent Causal Constructability Factors, and Elements of Highway Construction, could be established. The numbers in the tables correspond to the reference numbers contained in Table 4.2 in front of the specification Items (see Chapter 4). The cross classification tables were also transformed into numerical format and these are contained in tables marked 5.1(B), 5.2(B) and 5.3(B).

Table 5.1 relates Apparent Causal Constructability Factors to Problem Types. Specification Items were placed in the table according to the information established in SPIB. Where more than one constructability factor was apparently causing problems for a specification Item, it was listed in the table that many times. However a distinction was made between primary and secondary factors, where primary was taken to be the driving factor apparently impeding constructability the most.

From an analysis of the information in SPIB, the constructability factors that are apparently causing the most problems, as Primary Factors, are in order of importance:

* information and communication (49%)
* project scoping (30%)
* processes and methods (11%)

Resources and controls were of little significance.

Table 5.2 shows the relationship between Elements of Highway Construction and Problem Types. The specification Items were arranged in the table according to the respective Problem Types they represent and the Element(s) of Highway Construction with which they are concerned. By selecting any Item from SPIB, this table thus shows its area of construction work and its related problem of concern. The table shows that "pavement" (48%) and "bridges" and "other structures" (25%) are the two construction elements with which the most specification problems were found. It is also noteworthy that pavements experienced almost twice as many problems as bridges and other structures!

Likewise, the major problem types were found to be:

* information deficiencies (specification content) (39%)
* practicality limitations (27%)
* functional exorbitance (25%)

From Table 5.2 it is further evident that three problems overshadow the others. These are lack of definitiveness, irrelevancy/non-currentness and unrealistic tolerances/ impractical requirements.

TABLE 5.1(A): CROSS CLASSIFICATION - PRIMARY & SECONDARY FACTORS RELATED TO PROBLEM TYPES

APPARENT CAUSAL FACTORS

Problem Types	Project (*)	Scoping (++)	Resource (*)	Resource (++)	Processes (*)	Processes (++)	Controls (*)	Controls (++)	Info./Comm. (*)	Info./Comm. (++)	Env. Systems (++)	Totals (%)
Communication Deficiency:												
Inconsistent Interpretation		2.1, 2.4 2.5, 2.6		2.3		2.2, 2.5 2.6		2.1	2.1, 2.2 2.3, 2.4 2.5, 2.6		2.2, 2.4	17 (11%)
Information Deficiencies:												60 (40.6%)
Irrelevancy/ Non-Currentness		1.12, 1.13 1.16		1.8, 1.9 1.10, 1.16		1.8, 1.10 1.12, 1.14		1.13, 1.14	1.8, 1.9 1.10, 1.12 1.13, 1.14 1.16		1.9	21 (13.5%)
Lack of Definitiveness		1.11, 5.2 5.3, 5.5		1.3, 1.4, 1.5 1.7				1.2, 1.6 1.11, 5.2 5.3, 5.5	1.2, 1.3, 1.4 1.5, 1.6, 1.7 1.11, 5.2 5.3, 5.5			24 (15.5%)
Inconsistency		1.1, 1.15 3.9, 3.13 3.14		1.15, 3.13		3.9, 3.14		1.1	1.1, 1.15 3.9, 3.13 3.14			15 (9.7%)
Functional Exorbitance:												
Gold-Plating	4.1, 4.2, 4.3 4.5, 4.6, 4.9 4.12, 4.15	4.1, 4.2, 4.4 4.7, 4.10 4.11, 4.13 4.14, 4.15	4.4 4.11 4.13	4.5, 4.9 4.10, 4.12 4.14	4.7, 4.10 4.14	4.1, 4.2, 4.3 4.4, 4.5, 4.6 4.9, 4.11 4.13				4.15		38 (24.5%)
Practicality Limitations:												40 (26.5%)
Unrealistic Tolerances/ Impracticle Requirements	3.2, 3.3, 3.4 3.5, 3.6, 3.7 3.10, 3.11 3.12	3.2, 3.8		3.1, 3.6 3.7, 3.11	3.1 3.8	3.2, 3.3, 3.4 3.5, 3.10 3.11, 3.12 3.14		3.1, 3.3, 3.4 3.5, 3.6, 3.7 3.8				30 (20.6%)
Inflexibility					4.8	4.8						2 (1.3%)
Impracticle Measurement/ Payment Methods		5.1, 5.4, 5.6					5.1, 5.4, 5.6					6 (3.9%)
Subtotals:	17	30	3	20	6	27	3	17	28	1	3	155
%, Prim.	29.8		5.3		10.5		5.3		49.1			57 (100%)
Cum. Factor Total	47		23		33		20		29		3	155
% Prim. + Sec.	30.3		14.8		21.3		12.9		18.7		2	100%

(*) Primary Factors , (++) Secondary Factors
Items may relate to more than one element.

TABLE 5.2(A): CROSS CLASSIFICATION (ELEMENTS RELATED TO PROBLEM TYPES)

	ELEMENTS OF HIGHWAY CONSTRUCTION						
Problem Types	Earthworks	Pavement	Drainage	Bridges/ Structures	Other	Subtotal (%)	Total
Communication Deficiency: Inconsistent Interpretation	2.3	2.2, 2.4, 2.5		2.6	2.1		6 9.4%
Information Deficiency:							25 39.0%
Irrelevancy/ Non-currentness	1.8, 1.9* 1.14, 1.16	1.8, 1.9 1.10, 1.13 1.16		1.12		10 15.6%	
Lack of Definitiveness		1.2, 1.3, 1.4 1.5, 1.6, 1.7	5.5	1.11	5.2, 5.3	10 15.6%	
Inconsistency		1.1, 1.15 3.13		3.9, 3.14		5 7.8%	
Functional Exorbitance: Gold Plating	4.10	4.1, 4.2, 4.10 4.11, 4.12 4.14		4.3, 4.4, 4.5 4.6, 4.7, 4.11 4.13	4.9, 4.15		16 25.0%
Practicality Limitations:							17 26.6%
Unrealistic Tolerances/ Impractical Requirements	3.5, 3.7, 3.8	3.1, 3.2, 3.4 3.6, 3.7 3.10, 3.11		3.3,3.6 3.12		13 20.3%	
Inflexibility				4.8		1 1.6%	
Impractical Measurement/ Payment Methods		5.6	5.1, 5.4			3 4.7%	
Total	9	31	3	16	5	64	
%	14.1%	48.4%	4.7%	25.0%	7.8%	100.0%	

* Note: Items may relate to more than one element.

TABLE 5.3(A): CROSS CLASSIFICATION OF ITEMS- ELEMENTS OF HIGHWAY CONSTRUCTION RELATED TO APPARENT CAUSAL FACTORS

ELEMENTS ELEMENTS OF HIGHWAY CONSTRUCTION

APPARENT CASUAL FACTORS*	EARTHWORKS	PAVEMENTS	DRAINAGE	BRIDGES/ STRUCTURES	OTHER	TOTAL NO. ITEMS	% PERCENTAGE	
PROJECT SCOPING: (A2) FACILITY CHARACTERISTICS	3.5, 3.7**	3.2, 3.4, 3.6 3.7, 3.10, 3.11 4.1, 4.12, 4.2		3.3, 3.12, 3.6 4.3, 4.5, 4.6	4.15, 4.9	19		29.7
RESOURCES: (B2) MATERIALS		4.11		4.11, 4.13, 4.4		4		6.3
PROCESSES: (E3)CONSTRUCTION	3.8, 4.10	3.1, 4.10, 4.14		4.7,4.8		7		10.9
CONTROLS: (D2) COST & FINANCIAL CONTROL		5.6	5.1, 5.4			3		4.7
INFORMATION & COMMUNICATION:								48.4
DOCUMENTATION: (E6)RELEVANCY/ CURRENTNESS	1.14,1.16 1.8, 1.9,	1.8, 1.9, 1.10 1.13, 1.16		1.12		10	15.6	
(E4)DEFINITIVENESS/ COMPLETENESS		1.2, 1.3, 1.4 1.5, 1.6, 1.7	5.5	1.11	5.2, 5.3	10	15.6	
(E3)CONSISTENCY		1.1, 1.15, 3.13		3.9, 3.14		5	7.8	
INTERPRETATION: (E3)CONSISTENCY	2.3	2.2, 2.4, 2.5		2.6	2.1	6	9.4	
TOTAL # OF ITEMS	9	31	3	16	5	64		100
%	14.1	48.4	4.7	25	7.8	100		

* Only Primary Factors have been considered.

** Items may relate to more than one element.

TABLE 5.1(B): CROSS CLASSIFICATION - PRIMARY & SECONDARY FACTORS RELATED TO PROBLEM TYPES

APPARENT CAUSAL FACTORS

Problem Types	Project (*)	Scoping (++)	Resource (*)	Resource (++)	Processes (*)	Processes (++)	Controls (*)	Controls (++)	Info./Comm. (*)	Info./Comm. (++)	Env. Systems (++)	Totals (%)
Communication Deficiency: Inconsistent Interpretation		4		1		3		1	6		2	17 (11%)
Information Deficiencies:												60 (40.6%)
Irrelevancy/ Non-Currentness		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 Exorbitance: Gold-Plating	8	9	3	5	3	9				1		38 (24.5%)
Practicality Limitations:												40 (26.5%)
Unrealistic Tolerances/ Impracticle Requirements	9	2		4	2	8		7				30 (20.6%)
Inflexibility					1	1						2 (1.3%)
Impracticle Measurement/ Payment Methods		3					3					6 (3.9%)
Subtotals:	17	30	3	20	6	27	3	17	28	1	3	155
%, Prim.	29.8		5.3		10.5		5.3		49.1			57 (100%)
Cum. Factor Total	47		23		33		20		29		3	155
% Prim. + Sec.	30.3		14.8		21.3		12.9		18.7		2	100%

(*) Primary Factors , (++) Secondary Factors
Items may relate to more than one element.

TABLE 5.2(B): CROSS CLASSIFICATION (ELEMENTS RELATED TO PROBLEM TYPES)

ELEMENTS OF HIGHWAY CONSTRUCTION

Problem Types	Earthworks	Pavement	Drainage	Bridges/ Structures	Other	Subtotal (%)	Total
Communication Deficiency: Inconsistent Interpretation	1	3		1	1		6 9.4%
Information Deficiency:							25 39.0%
Irrelevancy/ Non-currentness	4	5		1		10 15.6%	
Lack of Definitiveness		6	1	1	2	10 15.6%	
Inconsistency		3		2		5 7.8%	
Functional Exorbitance: Gold Plating	1	6		7	2		16 25.0%
Practicality Limitations:							17 26.6%
Unrealistic Tolerances/ Impractical Requirements	3	7		3		13 20.3%	
Inflexibility				1		1 1.6%	
Impractical Measurement/ Payment Methods		1	2			3 4.7%	
Total	9	31	3	16	5	64	
%	14.1%	48.4%	4.7%	25.0%	7.8%	100.0%	

*Note: Items may relate to more than one element.

TABLE 5.3(B): CROSS CLASSIFICATION OF ITEMS- ELEMENTS OF HIGHWAY CONSTRUCTION RELATED TO APPARENT CAUSAL FACTORS

ELEMENTS OF HIGHWAY CONSTRUCTION

APPARENT CASUAL FACTORS*	EARTHWORKS	PAVEMENTS	DRAINAGE	BRIDGES/ STRUCTURES	OTHER	TOTAL NO. ITEMS	% PERCENTAGE	
PROJECT SCOPING: (A2) FACILITY CHARACTERISTICS	2	9		6	2	19		29.7
RESOURCES: (B2) MATERIALS		1		3		4		6.3
PROCESSES: (E3)CONSTRUCTION	2	3		2		7		10.9
CONTROLS: (D2) COST & FINANCIAL CONTROL		1	2			3		4.7
INFORMATION & COMMUNICATION:								48.4
DOCUMENTATION: (E6)RELEVANCY/ CURRENTNESS	4	5		1		10	15.6	
(E4)DEFINITIVENESS/ COMPLETENESS		6	1	1	2	10	15.6	
(E3)CONSISTENCY		3		2		5	7.8	
INTERPRETATION: (E3)CONSISTENCY	1	3		1	1	6	9.4	
TOTAL # OF ITEMS	9	31	3	16	5	64		100
%	14.1	48.4	4.7	25	7.8	100		

* Only Primary Factors Have Been Considered.

Impractical methods of measurement and payment and communication deficiencies were found to be significantly less of a problem. The importance of documentation is evident.

Table 5.3 gives a summary of the results of the analysis relating Elements of Highway Construction to the Apparent Primary Causal Constructability Factors. It is once again clear that two Primary Factors are causing the most problems namely information and communication (48%) and project scoping (30%).

In the case of project scoping, it is apparent that the problems primarily stem from facility characteristics which are in many instances defined or influenced by departmental policy or prescription. It would therefore be necessary to review these in order to make changes to the specification.

In summary, the matters identified to be of greatest concern were:

PROBLEM TYPES:

* Information deficiencies
  - Irrelevancy/non-currentness
  - Lack of definitiveness
* Practicality limitations
  - Unrealistic tolerances and/or requirements
* Functional exorbitance
  - Gold-plated specifications

AFFECTED ELEMENTS OF HIGHWAY CONSTRUCTION:

* Pavement, bridges and other structures

APPARENT CAUSAL CONSTRUCTABILITY FACTORS:

* Information and communication
  - Documentation relevancy/currentness
* Project scoping
  - Facility characteristics

ANALYSIS BY HIERARCHY OF OBJECTIVES TECHNIQUE (HOT DIAGRAM)

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). HOT diagrams offer a particularly effective way of communicating the complex and detailed hierarchy of objectives supportive of improved specifications for constructability. Figure 5.1 illustrates the logic use for the HOT diagram. It can be seen that there are a number of basic tiers. These are: objectives, constraints, tactics and solutions or stated otherwise, concern, problems, ideas and solutions. The objective (concern) is established on the left side of the diagram, and it is constrained by problems that must be solved to appease the concern. Next, the problems generate ideas which in turn generate solutions for the problems).

Diagram interpretation is thus 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. The technique possesses a dual system of logic. 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.

The following example will demonstrate how the logic of these diagrams works. The primary concern may be to enhance constructability through improved specifications, and a major problem with this concern is to eliminate gold-plated specifications. This problem may be addressed by using the idea of not performing excessive work for aesthetic purposes, and a specific solution may be to eliminate the painting of bridgework below the ground line. This same logic can be applied to any part of the diagram. A HOT diagram is thus an effective method for generating possible ideas and solutions for constructability concerns. Figure 5.2 shows a HOT diagram that was developed from the information contained in SPIB to show in a logical manner how constructability can be enhanced through specification improvements. The HOT diagram in effect summarizes the options which need to be considered for addressing the various problems which were identified in this study.

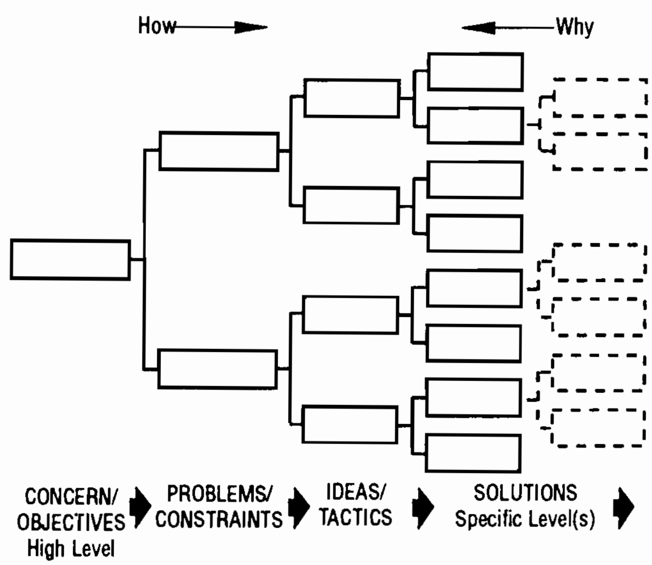

Figure 5.1. Constructability HOT diagram logic.

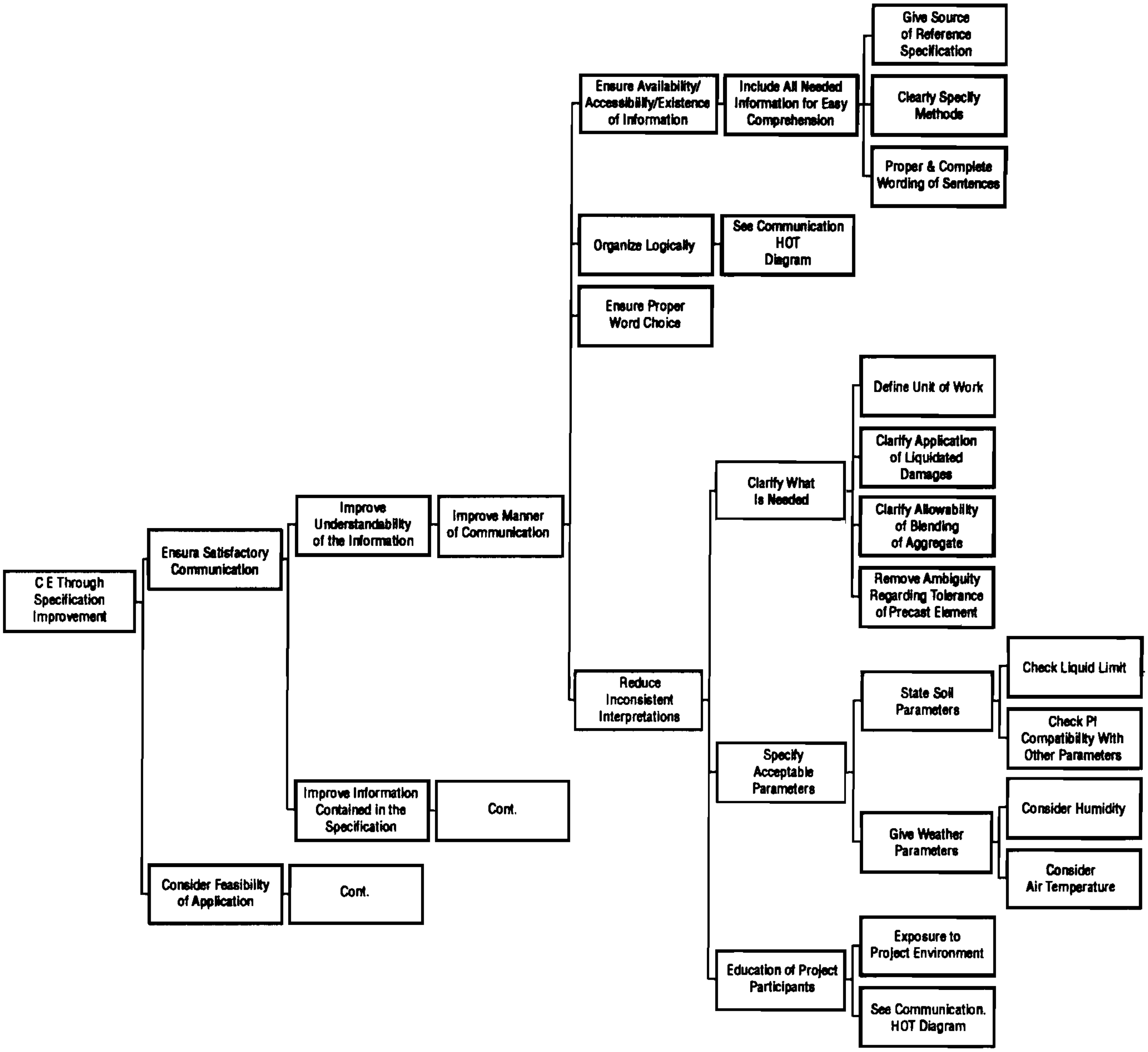

Figure 5.2. Constructability enhancement through specification improvement HOT diagram.

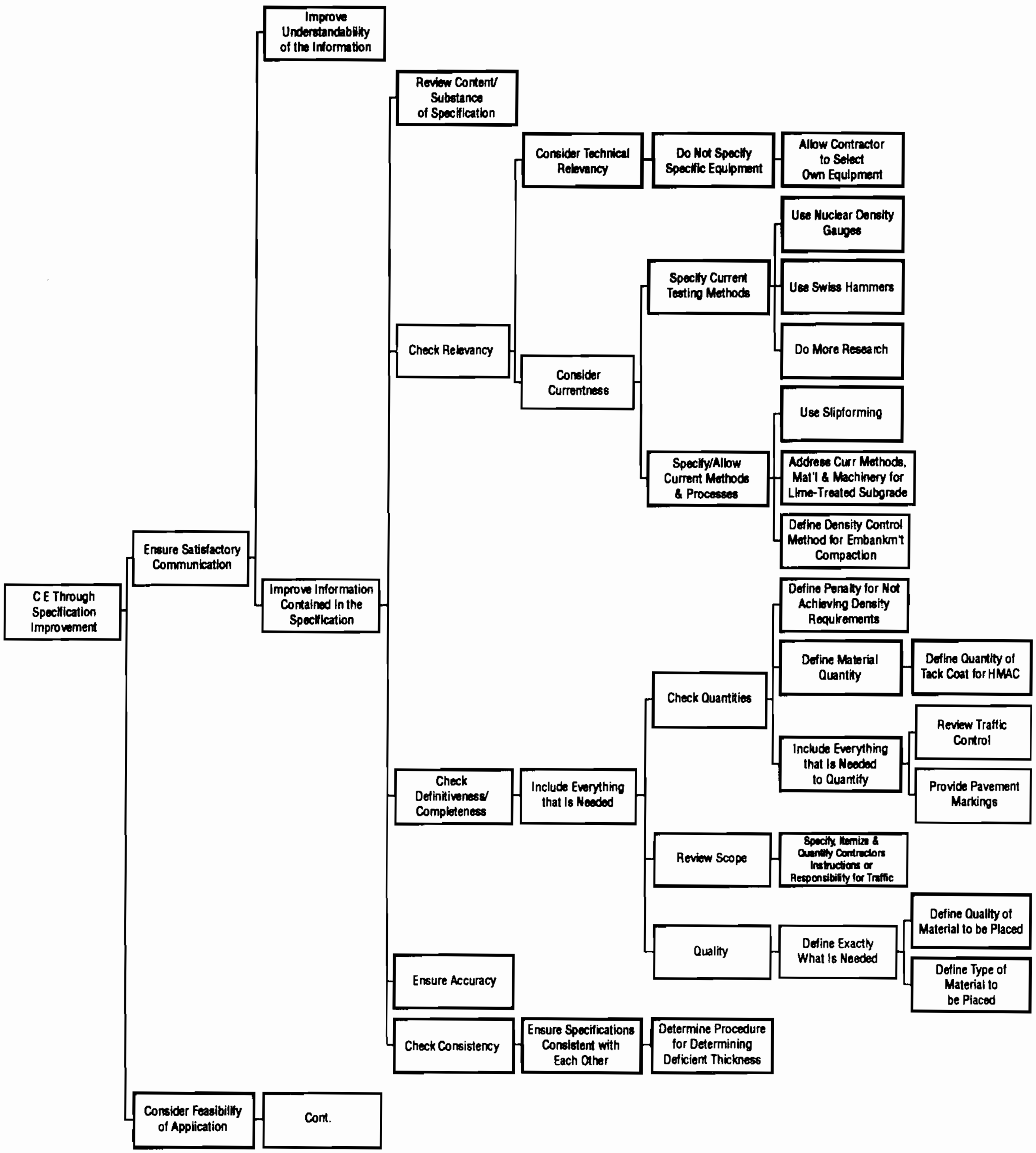

Figure 5.2. Constructability enhancement through specification improvement HOT diagram (continued).

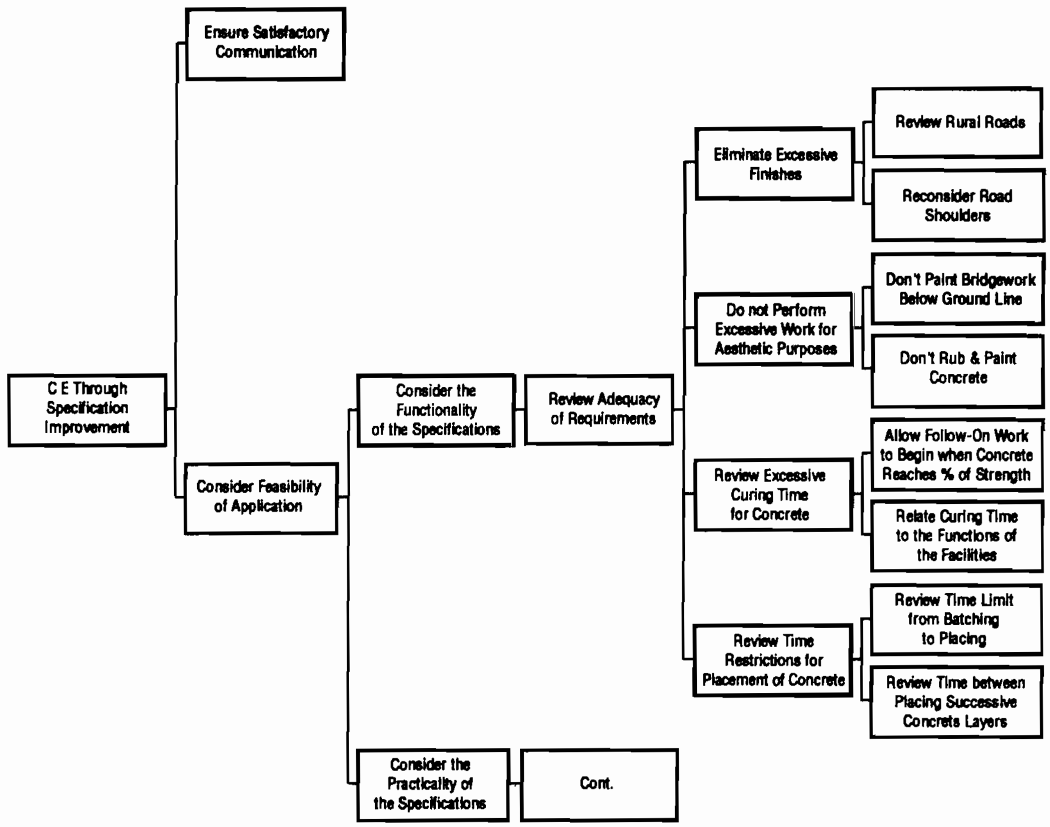

Figure 5.2. Constructability enhancement through specification improvement HOT diagram (continued).

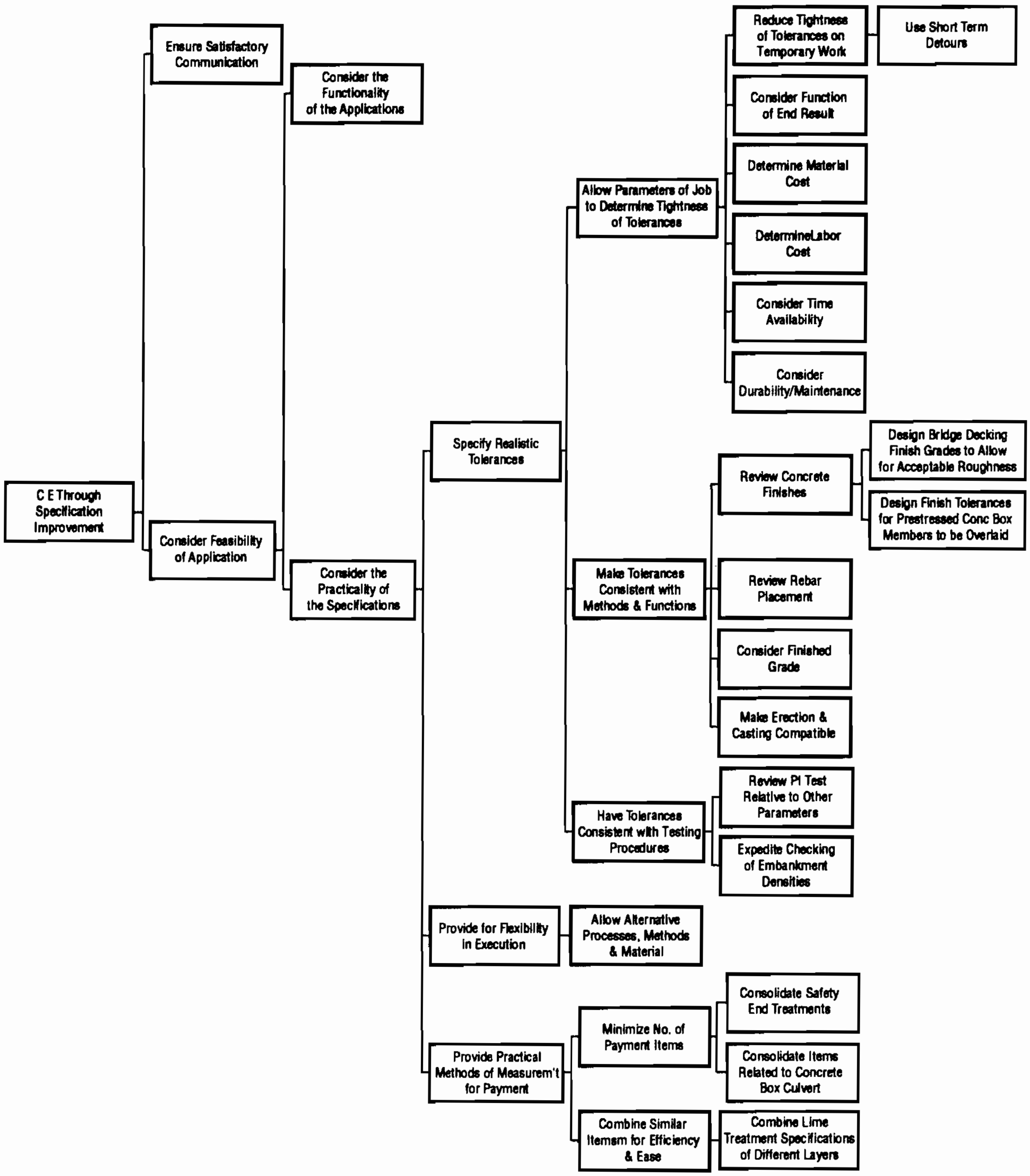

Figure 5.2. Constructability enhancement through specification improvement HOT diagram (continued).

GENERAL FINDINGS COMPILED FROM TEXT DATA IN SPIB

Additional significant, yet specific findings from this research were extracted from the text data in SPIB and these are given below:

(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 found to be effective.These lead to greater consistency 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 state-wide 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 also 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 modern or innovative equipment.To the greatest extent possible, highway departments should not specify what 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 I 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.

(9) 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 currently 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 form this and other research are given:

Pros:

i) Innovation is encouraged and rewarded. Contractors are free to select cost-effective methods and to utilize equipment in a cost-effective manner.

ii) Wide variations in equipment characteristics and continuing advances in equipment technology are less problematic to the spec writer.

iii) Material variability is accommodated.

iv) Quality assurance/quality control efforts (and thus manpower requirements) by the highway department are reduced.

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

Cons:

i) 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).

ii) Contractor pre-qualification may be necessary to ensure that only skilled, responsible contractors are awarded contracts.

iii) Bidding may be more difficult due to uncertain construction methods that may exist.

iv) 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).

v) Performance penalties are often excessive.

SUMMARY

The two methods used for data analysis proved to be very effective tools for interpreting and presenting the data contained in SPIB. The cross classification tables enabled the most critical areas of Problem Types, Apparent Causal Constructability Factors, and Affected Elements of Highway Facility, to be determined. These areas should now be investigated to determine whether the proposed solutions can be utilized to improve the specifications. The HOT diagram proved to be an excellent tool for analyzing ways to make improvements in the specification manual. Once these suggested improvements have been considered and where possible, implemented, the main objective of enhancing constructability will have been achieved.

It is apparent that the proposed solutions will need to be scrutinized by the specification task forces charged with the respective specification Items. They should also pay particular attention to the other specific findings extracted from SPIB.

The following chapter presents an analysis of the Department's specification review and updating process, from the point of view of constructability enhancement.

CHAPTER VI. SPECIFICATION REVIEW AND UPDATING PROCESS

The Department has been developing a new standard specifications manual since January of 1988, and it is scheduled for completion in June of 1990. The 1982 standard specifications are being used as the basis for the new manual. The process of rewriting the Department specifications manual has occurred at approximately eight to ten year intervals since 1938. As part of the constructability study, the procedures that are being used by the Department to rewrite the specification manual, were investigated in order to determine to what extent constructability issues were being considered.

REASONS FOR REWRITE OF SPECIFICATIONS MANUAL

There are several reasons which are causing the rewriting and updating of the specifications manual. The primary reason is the existence of numerous special specifications and special provisions which have been formulated since the previous revision and which now have to be incorporated into the new specifications manual. The large number of such Items makes the job proposals quite massive and cumbersome, as well as difficult to read and comprehend. Another reason for the update is that many Items and methods have become outdated and obsolete and must be deleted from the specifications manual. This obsolescence has occurred because of the many technological advances that have taken place since 1982, and the specifications should be updated to meet the standards of current technology. The update also has to examine test methods to see if any additions, deletions, or updates are needed. Furthermore, the specifications manual is being reviewed to recognize the shifting emphasis from new construction to reconstruction. Lastly, the intent of the update is to correct errors and omissions.

The previous update of the standard specifications manual occurred in 1982. The process that occurred at that time was not as extensive or detailed as the current process. During the previous update, many specification Items were not changed or even examined. It is thus apparent that the present comprehensive approach is warranted.

SPECIFICATION UPDATING ON A PROJECT BY PROJECT BASIS

Instances occur on projects that require specifications to be altered. When a change needs to be made in the specification manual, either a special provision or a special specification is written. A special provision alters an existing specification Item while a special specification replaces an existing Item or creates a new Item. When a district has a need for a special specification or a special provision (SS/SP), the plans for the job will be sent, together with a letter, to the appropriate field section of the Department requesting the change. Every field section has a reviewer who determines if a SS/SP is needed. If one is required, the reviewer will make a request to the specification committee for its adoption. If the SS/SP is to be used for only one project the Engineer of Design Services can approve the request. However, for a SS/SP that is required for statewide use or for use by a district at any time, the specification committee, which meets only once a month, has to approve the request. If the SS/SP is approved by the specification committee, it is referred to the Associated General Contractors (AGC) for comments. The AGC is given 60 days in which to review the SS/SP, and if they do not like the SS/SP, they must present reasons which may or may not be considered by the specification committee. Finally, the SS/SP is forwarded to the administration of the Department for approval.

Special specifications and special provisions begin to increase in number soon after the adoption of a new specification manual. This creates problems because every applicable SS/SP has to be sent with each proposal for bidding a job. This causes the development of some very large documents.

If during construction specification problems that require immediate attention occur, the construction committee of Division 6 handles the situation. The problems are resolved by issuing field changes or supplemental agreements, which later may become SS/SP. Thus, specifications may be updated in different ways depending on the need and the available time.

THE PROCESS OF DEVELOPING A NEW SPECIFICATION MANUAL

For projects such as the rewriting of the specifications manual the Department uses task forces which are simply groups of knowledgeable staff charged with the duty of accomplishing a specific task.

Six task forces were established to handle the specific task at hand. Each task force has been assigned a particular area of the specification manual to investigate. These areas are:

(1) Items 1-9 and incidental construction Items,
(2) earthwork, subbase, and base courses,
(3) ACP-asphalt,
(4) concrete pavement and concrete for structures,
(5) structures, and
(6) lighting and signing.

Each task force consists of seven members, which has been found to be the ideal size for a group in order to achieve effective performance (Daft 1988).

The task forces are meeting at the Balcones Research Center in Austin, Texas. Each task force sets its own schedule for approving specification Items and finishing the update process. However, their schedules have to coincide with the final schedule established by the specification committee.

The approach being used by the task forces to accomplish their goals is as follows. First, the 700 comments that were solicited by the Department are examined to determine pertinent information and problems. Second, each specification Item is read paragraph by paragraph, and suggestions are made for possible changes. Much time is spent outside of the meetings performing research on the specification Items. Finally, after discussion and research have occurred on a specification Item, its final form and wording are agreed upon and completed.

The review process consists of thirteen primary steps which are shown in a bar chart produced by the Department (see Appendix F for bar chart). The following is a listing of these steps along with an explanation of each step:

(1) Development and approval of bar chart:

The chart was developed by Ms. Peggy Chandler and approved by the specification committee.

(2) Assignment of responsibility of the six task forces and approval by specification committee.

(3) Recommendation by specification committee of people to serve on task forces and approval by specification committee:

Each member of the specification committee nominated individuals for each task force. Together the committee members selected from the nominees the persons to constitute each task force. In this process, they took into consideration the person's work load, and they asked permission from the appropriate district to use the individual on a task force. A task force consists of 2 or 3 district representatives and a representative of each division. The divisions are located in Austin and include:

D-5 — Bridges (reviews designs and plans);

D-6 — Construction (lets job, handles construction and field changes);

D-8 — Highway Design (reviews designs and plans);

D-9 — Materials and Testing (performs testing); and

D-18 — Safety and Traffic Operations (handles signing, traffic flow, and traffic signals).

(4) Organize existing special specifications and special provisions for use by task forces:

Each district submitted the SS/SP that they had been using on past projects.

(5) Notify task force members of assignment with first meeting by May 31, 1988:

Individuals selected for task forces were told of their duties by the specification committee.

(6) Letter to districts, divisions, AGC, and suppliers requesting proposed specifications to be included in specification book or problems with "Yellow Book" that need to be corrected:

Hundreds of letters requesting comments on specific Items in the specification manual, as well as general comments were mailed to individuals involved in highway construction.

(7) Monthly or bi-monthly meetings of task forces to develop specifications and meetings of task forces with AGC:

The task forces read through the comments that have been submitted and examine the changes that need to be made. Every Item in the specification manual is being analyzed. Some task forces read each Item as a group and make comments on them, and others read each Item on their own and make suggestions when the group convenes. Some Items require changes to be made, others are totally rewritten, and some are left as they are in the current specification manual. The task forces meet 1 or 2 times a month for a day and a half each time. The meetings held with the AGC are intended to interact the contractors with the specification rewrite process. During these meetings, the Items are looked at one by one, and comments are solicited from the contractors.

(8) Copies of proposed specifications (from task forces) are sent to districts, division, and AGC for comments:

Every updated Item is sent to these groups for review, and problems and changes are sent back to the task forces for further consideration.

(9) Approval of individual specifications by specification committee:

As each Item is completed, the task force sends it to the specification committee for review. The Item is either approved, or changes are made and the Item is sent back to the appropriate task force for corrections. The approval process is on an Item by Item basis.

(10) Printing and proof reading of check copy of specification book:

After the Items are finalized, the work of the task forces is compiled into a preliminary specification book. This book is sent back to the AGC and the districts for a final review. If any problems are discovered, the task forces will examine the Items before the book is sent for final approval.

(11) Final approval by specification committee and administration:

The specification book is first approved by the specification committee which may make some minor changes. The book is then sent to the Department administration for final approval.

(12) Printing of standard specification book:

Upon final approval, the specification book will be sent to the printer. The scheduled time for printing is January 1990.

(13) Distribution of standard specification book:

The book is scheduled for distribution to contractors, districts, etc. in the middle of 1990.

A flow chart (see Figure 6.1) was developed from the information contained in the bar chart. The flow chart shows the interrelationships between the steps, and shows which ones occur concurrently. Also, the flow chart includes some secondary steps which explain in further detail some of the primary steps. In the flow chart, the secondary steps are placed to the right of the primary steps.

From the above it is apparent that many steps and much time are involved in the development of a new specification manual.

INCORPORATION OF CHANGES

The new specification manual will incorporate all required special provisions into their appropriate place. The required special provisions include the ones that dis-

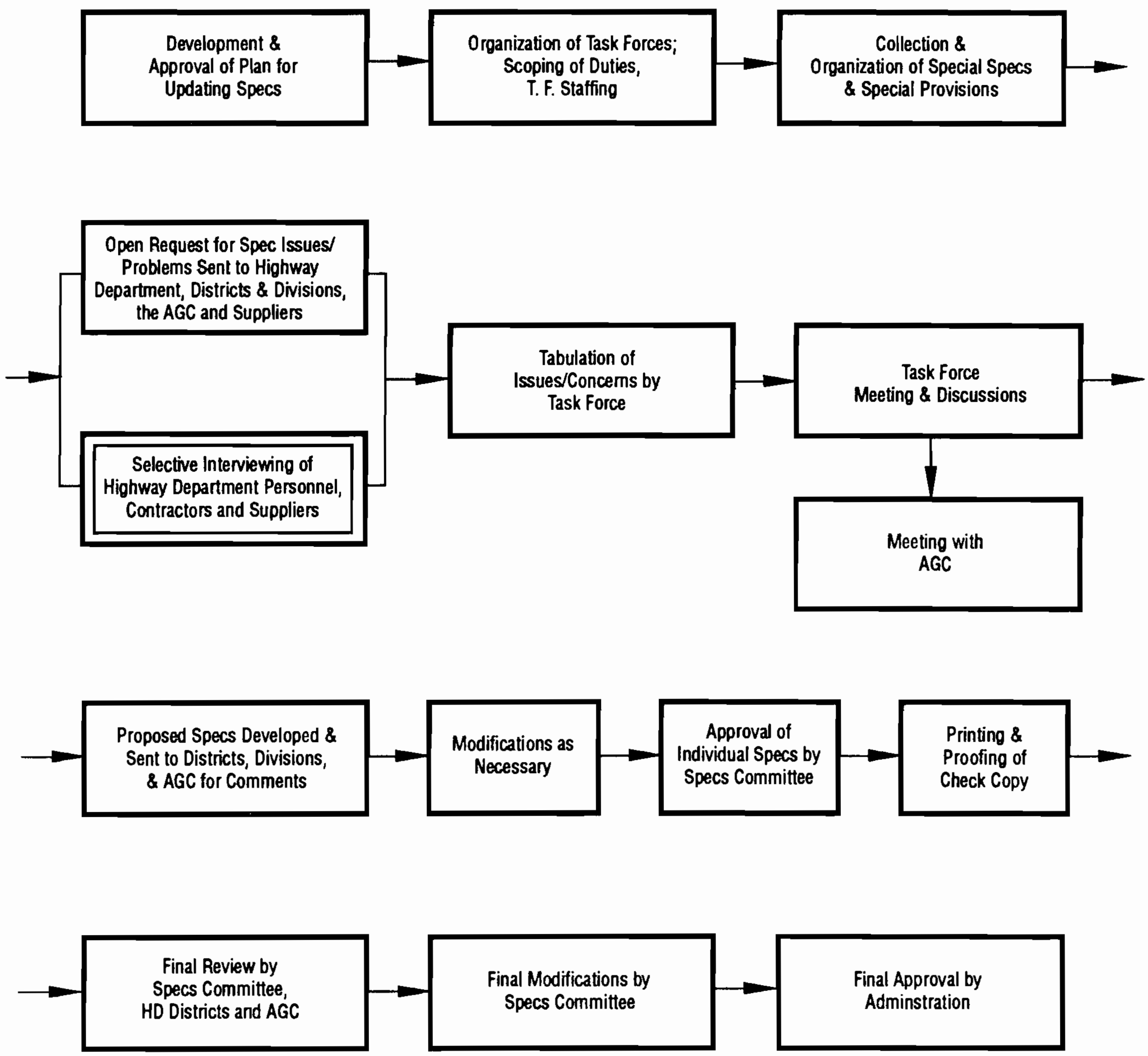

Figure 6.1. Flow chart for specification review and updating process.

tricts must use on every contract. The special provisions that are not required will be examined by the task forces to see if their inclusion in the new specification manual is warranted. Also, special specifications that have been frequently used on jobs will be included in the manual. The remaining special specifications will be examined by the task forces to see which ones have enough use to be incorporated into the specification manual.

The task forces are also examining the specification manual to discover Items that can be deleted due to obsolescence. Likewise, new methods are being added to existing Items or new Items are being created to keep the specification manual in pace with current technology. Also, some Items are being combined into one Item to reduce repetition and increase conciseness. The task forces are examining areas that may overlap in the specification manual, and they are solving the problems of overlap by deleting certain Items and combining some with other Items. This should go a long way to addressing the problems identified during this investigation.

TESTING OF NEW SPECIFICATIONS

New specifications are tested when they are used on a job as special specifications or special provisions. Specifications must be thoroughly tested by being used on several jobs to see if any problems exist with them. If a specification is not thoroughly tested, it will not be placed in the new specification manual. For those specifications that have been used only once, a careful examination is required to determine why the specification was needed and if it will be needed in the future. If future use of the specification is foreseen, it will probably be included in the new specification manual.

The wording and intent of proposed new specifications are tested when the AGC, districts, and divisions review the Items before they are approved for incorporation into the specification manual.

CRITIQUING OF THE REVISION PROCEDURE

The task forces appear to have undertaken the rewrite process of the specification manual in the best possible manner. They have obtained input from every district as well as from the AGC. Also, the individual members of the task forces have solicited remarks about the specifications from their district colleagues. Every specification Item in a task force's scope of work is thoroughly read by each member. All of the special specifications and special provisions have been examined to determine which ones need to be incorporated into the new specification manual.

The task forces have examined AASHTO specifications, as well as the specifications of highway departments of other states. They use these specifications to determine how other states and organizations handle similar problems that are confronting by the State of Texas.

The proceedings of the task forces are all handled about the same with only slight variances occurring. The specification Items are examined one by one with open discussion. Problems that have occurred in the past are discussed in relation to the Item and how they relate to the changes that are required for an Item.

It was determined that placing examples in the specification manual was not a good idea because the Item may only be used on that particular example and not in general. It was also observed that too much time was spent on discussing the appropriateness of certain words. If disagreements occurred during discussions, the validity of the opposing comments was examined to settle the dispute. Finally, not every member of a task force contributed to the discussions of a meeting. From the foregoing it is apparent that the task forces were working very thoroughly but were not specifically addressing constructability improvement, in their work.

In order to do this, the task force should focus particular attention on the specific problem types, apparent causal factors, and affected elements of highway construction, discussed in Chapter V.

The need for the creation of some end result specifications was also apparent from the SPIB-analysis and trends in this regard are to be encouraged. If appropriate solutions cannot be readily determined for certain problematic performance specifications, the adoption of a specification in an end result format should be considered.

From the comments in the SPIB-analysis it is also apparent that more interaction, beyond the solicitation of comments, is needed from the AGC, as well as from individual contractors. The AGC should meet with the task forces more often in order to supply pertinent input which will make the specifications more workable for the contractors. If the specifications are better suited for the contractors, less problems will result on jobs, and the Department will receive more cost efficient bidding. The proper improvement of the specifications will reduce the budget of the Department due to less waste of money and in effect save the taxpayer money.

From the foregoing it is apparent that the work being performed by the Department to rewrite the specification manual, addresses some of the problems related to constructability. However, more enhanced constructability should result if attention is focused on the specific problem areas found in SPIB, as well as the constructability factors that are causing the most problems.

A basis for achieving this is set out in the flow diagram. Conclusions and Recommendations relating to the study on specifications are presented in Chapter VII.

CHAPTER VII. CONCLUSIONS AND RECOMMENDATIONS

In this study, the ability to enhance constructability through improved specifications was considered. From this the following conclusions and recommendations can be made:

(1) Specification problems are common for a multitude of reasons. The structure of desirable attributes of specifications (and corresponding problem 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/structured specifications deserve particular scrutiny.

(4) Common apparent causal factors that lead to problems include information and communication (documentation) and project scoping (facility characteristics). With regard to the latter it should be noted that facility characteristics are determinants which are generally defined or influenced by the Department. These should be reviewed from time to time to ensure timely changes to specifications.

(5) It is imperative to note that overall, processes and methods and project scoping are the apparent causal factors causing the majority of problems with tolerances and gold-plating. Also "lack of definitiveness" is the major problem related to "control" as apparent causal factor. The need to reconcile these discrepancies is apparent.

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

(7) 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.

(8) 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.

(9) 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.

(10) Additional statistical research is needed into the causes of specification-driven project problems.

(11) Future updating of the Specification Manual can be streamlined. As changes occur and special specifications and special provisions are needed, the appropriate specification Items should be incorporated into the computer file. These should be examined and analyzed by a committee periodically and when appropriate, a new specification should be printed and implemented. The form of the manual could be a book or a loose leaf binder to save the reprinting of the entire manual. The committee should be a standing committee composed of Department personnel and contractors.

(12) Some of the issues presented in SPIB need further research by the respective Divisions of the Department in order to fully clarify the information. Likewise, more investigation of the problem types should occur in order to determine other problematic specification Items of concern. With an increase in the amount of information contained in SPIB, more conclusions may emerge which will help to enhance constructability.

Highway constructability 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 and of the information they generate.

APPENDIX A

CONSTRUCTABILITY SCOPING QUESTIONNAIRE

APPENDIX A. CONSTRUCTABILITY SCOPING QUESTIONNAIRE

A. Pre-Construction Planning

1. Scope the constructability-sensitive issues that the Department should give early consideration to:

   a) establishment of design duration ....( )

   b) establishment of construction duration ....( )

   c) traffic control during construction ....( )

   d) extent of site evaluation/field surveys (terrain, geotechnical, climate, etc.) ....( )

   e) ROW/alignment for construction working space ....( )

   f) selection of major materials and methods
      1) scope of modularization/preassembly ....( )
      2) constructor-design of exotic bridges ....( )
      3) ________________________ ....( )

   g) constructability planning for adverse weather.........( )

   h) planning for constructor accessibility ....( )

   i) value engineering and constructability ....( )

   j) ________________________ ....( )

   k) ________________________ ....( )

2. When should these issues be considered in the pre-construction process? What are the constructability aspects of the "project concept review"? ....( )

3. How can construction expertise be acquired early, when needed? ....( )

4. ________________________ ....( )

5. ________________________ ....( )

B. Construction Methods

1. Document innovative construction practices that reduce project cost ....( )

2. Identify specific needs for new methods ....( )

3. ____ ....( )

C. Specifications

1. Strict prescriptive specs vs guideline specifications:

   a) identify "trouble specs" which are not consistently interpreted in either a strict manner or as guidelines, specs in which there often is not a mutual understanding of owner expectations ....( )

   b) what is the proper role of engineering judgement in assuring compliance for each type? how can such judgement be effectively and uniformly exercised? ....( )

   c) which specs are too rigid, inflexible? ....( )

2. Goldplated specs ....( )

3. Unrealistic tolerances ....( )

4. Misapplied specs ....( )

5. Incompatible specs ....( )

6. Obsolete specs ....( )

7. Relevance of tests and inspections ....( )

8. Poorly communicated specs ....( )

9. ____________________________________ ....( )

10. ____________________________________ ....( )

D. Innovation

1. In terms of promoting contractor innovation, what does the low-bid system neglect? ....( )

2. How to appropriately allow for constructor innovation in the specs?

   a) recognizing that regional or contractor preferences can save money ....( )

b) allowing for the use of new technology ....( )

3. How to effectively manage innovation in projects?

a) getting timely Department approvals ....( )

b) ________________________________ ....( )

4. Improving methods of constructability problem identification ....( )

5. How can incentives be used to exploit cost-effective innovation? ....( )

6. ____ ....( )

7. ____ ....( )

E. Design Configurations

1. Identify overly-complex, "unconstructable" design details and suggest improved alternatives ....( )

2. Identify specific needs for greater design standardization and suggest design details ....( )

3. ____ ....( )

F. Constructability Program

1. Investigate the structure, procedures, documentation and organization of Department constructability programs:

a) at the state/district level ....( )

b) at the project level ....( )

2. Needs and tools for constructability training ....( )

3. Methods for documenting "lessons learned":

a) post-completion constructor debriefing ....( )

b) final project reports ....( )

c) ________________________________ ....( )

4. __________________________________ ....( )

G. Allocation of Responsibility/Risk

1. Identify risk-sensitive responsibilities

a) the Department's ....( )

b) contractor's/subcontractor's ....( )

c) design consultant's ....( )

2. Effective use of prequalification practices ....( )

3. Insurance aspects/risk sharing ....( )

H. Construction Plans/Drawings

1. Critique the typical content of project plans ....( )

2. Critique the typical format/method of communication of project plans ....( )

3. ____________________________________ ....( )

I. Rework/Claims Prevention

1. Analyze constructability-related claims/rework ....( )

2. Determine strategies for claims/rework prevention ....( )

3. ____________________________________ ....( )

APPENDIX B

SUBTOPICS OF SPECIFICATION ISSUE WITH AVERAGE RANKINGS

APPENDIX B. SUBTOPICS OF SPECIFICATION ISSUE WITH AVERAGE RANKINGS

A. Specifications

1. Strict prescriptive specs vs guideline specifications:

   a) identify "trouble specs" which are not consistently interpreted in either a strict manner or as guidelines, specs in which there often is not a mutual understanding of owner expectations ....(2.85)

   b) what is the proper role of engineering judgement in assuring compliance for each type? how can such judgement be effectively and uniformly exercised? ....(2.38)

   c) which specs are too rigid, inflexible? ....(2.54)

2. Goldplated specs ....(2.00)

3. Unrealistic tolerances ....(2.38)

4. Misapplied specs ....(2.08)

5. Incompatible specs ....(2.38)

6. Obsolete specs ....(2.00)

7. Relevance of tests and inspections ....(2.54)

8. Poorly communicated specs ....(2.31)

9. AA-Reliance on intent of specs (ambiguous?) ....(2.00)

10. A-Vendor specs ....(2.00)

11. A-Practical end-result specs ....(3.00)

12. A-More uniformity of interpretation statewide ....(3.00)

13. A-Local materials ....(3.00)

APPENDIX C

FIRST INTERVIEW GUIDE

(INFORMATION CLASSIFIED UNDER PROBLEM AREAS OF SPECIFICATIONS)

APPENDIX C. FIRST INTERVIEW GUIDE

(INFORMATION CLASSIFIED UNDER PROBLEM AREAS OF SPECIFICATIONS)

A. Strict explicit specs vs. guideline specs
   1. identify examples of specs which are explicit and strictly interpreted and specs which are treated more as guidelines in their interpretation by inspectors
      a) explicit specs can be the prescriptive type or end-result type
   2. identify "trouble specs" which are not CONSISTENTLY interpreted in EITHER a strict manner or as guidelines; these are specs in which there often is not a mutual understanding of owner expectations
      a) item I.40 - the manner of charging time to the project ... the term "principal unit of work" is inconsistently interpreted from proj to proj. charging time to projects on the basis of principal unit of work is problematic and is subject to interpretation. a preferred approach would be based on MAJOR items of work or critical path items, which would be determined by $ volume
      b) item 316.1 - general weather conditions
      c) in need of study: specs incorporating "as approved" or" as directed by the engineer" ... this often opens Pandora's box ... some examples:
         1) material suitable for stable fill
         2)
   3. the effectiveness of guideline specs relies heavily upon the judgement of the inspector. how can such judgement be effectively and uniformly exercised on a statewide basis?
      a) needed: training, "guidelines book"
         1) guidelines should consider different parts of the state, different weather conditions, different materials
         2) beware: a statewide guideline for interpretation may lead to the most strict interpretation ..... this is to be avoided
   4. authority problem
      a) who has the authority?
      b) needed: quick, on-site response to problems
      c) should guidelines be developed that enhance the decision-making capabilities of site personnel?

B. End-result specs
   1. what conditions are conducive to end-result specs (vs prescriptive)?
      a) project elements:
      b) project type:
      c) project location:
      d) project size:
   2. guidance for inspectors is lacking in:
      a) extent of testing
      b) relevance of testing
   3. end-result tolerances need definition
      a) what is acceptable with no penalty?

- b) what is acceptable with what penalty?
  - 1) these penalties should be rationally established
- c) what is unacceptable?
- d) big problem: no tolerances (acceptable deviation from the spec) and severe penalties when product is in any way deficient
- e) "statistical oriented end-result" approach
  - 1) has this been done anywhere?
- f) for end-result tests that fall short, where acceptable and within limits, corrective action should be allowed for and treated in the specs
- g) perhaps needed: a write-up on statistical approaches to project quality control

4. sophisticated contractors generally prefer end-result specs
   - a) they enjoy a cost advantage by knowing how to best achieve the required end result
   - b) end-result specs can effectively restrict competition by eliminating non-sophisticated contractors
5. there's a trend toward use of the end-result spec
   - a) the FHWA is pushing it
   - b) poor contractor performance is often associated with prescriptive specs
   - c) material variability is better accomodated with end-result
6. end-result testing requirements can be excessive, redundant (tests by both contractor and state)
7. issue: what is the timing of acceptance for end-result specs? at the end of the day or at the end of the project?
   - a) should this vary depending on the item being inspected?
   - b) example: % asphalt voids, pavement roughness
8. problems with specs that mix both end-result and prescriptive? such as pavement roughness?
9. surety bonding and end-result specs ???

C. Flexible specs: dealing with proposed alternates/ substitutions
   1. what is the State and FHWA policy and attitude toward accepting alternates, what do they allow for and require?
      - a) technical limitations?
      - b) contractor pay-backs for cost-savings?

D. Gold plated specs/overspecifying/specifications in excess of needs
   1. examples
      - a) concrete finishes on F-M/country roads
      - b) design and materials of road shoulders sometimes over-designed
      - c) requiring bridgework to be painted below the ground line
      - d) specs require fixed curing times or strength requirements for various segments of structures. Delays in follow-on activities often result needlessly. For example, a cap

can't be placed on columns until the column reaches 600 psi, when column may only need 300 psi to support the cap (vs the entire traffic bearing structure). the same applies to beams on caps, or walls on footings, etc. Schedules can be speeded up by allowing earlier start of follow-on activities

e) requiring excessive post-project cosmetic clean-up

2. perhaps worthwhile: life cycle analysis of designs and actual life cycles of materials, components
3. gold plating results from job-fear, is an attempt to avoid peer criticism

E. Unrealistic tolerances

1. in general many tolerances are too tight. good engineers then don't enforce them but less experience engineers lack the judgement to know when or when not to enforce written tolerances. interpretation consistency problems then result. example: tolerances of placement of reinforcing steel. the FHWA can have serious problems when specified tolerances are not totally complied with... example: strength of concrete in bridge slabs
2. examples of tolerance problems
   a) item 340 - tolerances for aggregates used in ACP are sometimes too tight. Job size, traffic volumes, and material availability should be considered. The same tolerances for a short term detour are used for freeway main lanes
   b) item 340 - some material suppliers furnish "dirty" aggregate in compliance with gradation tolerances. plan notes are necessary to get a suitable material. the spec needs upgrading (tolerance too broad)
   c) finish grade on bridge deck of 1/8" in 10' enforced, but roughness required 3/8" deep. the riding quality is not affected by such minute variances
   d) concrete strength specifications need some tolerances
   e) finish surface tolerances for earth subgrade are too severe, especially where lime subgrade is required. Subgrade is finished to tolerance prior to lime, then is plowed up. Lime is mixed into subgrade, then subgrade is finished to tolerance again
   f) where flexbase up to 16" thick is to be placed, there should be no reason for exacting tolerance on earth subgrade
   g) the PI test procedure is not very accurate, yet results are strictly interpreted
   h) for flex base gradation, the emphasis is on (-40) vs larger size of fines, is this necessary?
   i) embankment density requirements are strictly enforced for such an inconsistent material. if a single density test fails, then the contractor reworks the section until he gets density. what percent of tests have to pass or fail before

an item of work is accepted or rejected?
   j) surface tolerances need to vary under different conditions. for example a distinction should be drawn for some tolerances between urban work and rural work, MPH speed of road (bumps at low or high speed?), function of road (?) ...
   k) what tolerances are incompatible with common construction methods (vs. sophisticated methods which may be unavailable to many contractors)
3. specified tolerances should be based on statistics of performance and cost and pay practices should be based on "% of conformance"
   a) FHWA perspective on this ...
   b) what is the impact of tight tolerances on project cost? where do tight tolerances slow productivity and increase cost? does the benefit outweigh the cost?

F. Incompatible specs
1. examples:
   a) in segmental construction, casting tolerances incompatible with erection tolerances
   b) rebar tolerances (material fabrication spec) vs. in-field construction tolerances (installation spec)
2. incompatibility problems between the spec and the general notes on the plans/in the proposal; examples:
   a) plasticity index requirement on embankment work
3. problem: specs that incorporate multiple criteria to the extent that "something not yet invented" is specified (closely related to gold-plating) - so individual criteria are effectively incompatible
4. 1 cause of incompatible specs: "spec growth" without consideration of related spec sections that may also need updating/modifying
5. need to see that Part I of the specs is compatible with Part II

G. Obsolete specs
1. serve no purpose but to clutter spec book (get rid of them)
2. examples:
   a) item 260 - lime subgrade spec goes into great detail about mixing equipment and secondary subgrade, neither of which is applicable anymore
   b) item 264 - lime and lime slurry (dust control - dry lime is not permitted in some urban areas due to excessive dust)
   c) item 340 - HMAC pow (???)
   d) item 360 - concrete paving; this is written around equipment rarely used anymore, slipforming is not covered
   e) item 401 - excavation for sewer pipe; make it subsidiary to pipe sewer -item 465
   f) items 420 and 421 - still contain many outdated restrictive clauses. tests have not kept up with new innovations

g) item 477 - difficult item - need a practical way to pay for safety end treatments
h) concrete finishing spec - painting concrete was developed to eliminate costly and time-consuming rubbing, but specs (and interpretation) now result in rubbing plus painting
i) testing of materials should be updated to use latest instrumentation for quicker, more reliable results
   1) related specs:
j) certain parts of excavation, embankment, compaction, lime treatment
   1) specific specs:
k) includes old style bridge construction, i.e., pan girder, and slab span
l) quality tests for liquid asphalt
   1) spec:

3. cited materials that are no longer available:
   a)
   b)
4. cited equipment that is no longer available:
   a)
   b)
5. cited construction methods that are no longer practiced:
   a)
   b)
6. elements of design no longer required/needed/desired
   a) diaphragms between bridge girders were originally cast-in-place and then metal; used for lateral bracing
   b)
7. Part I specs that are non-current
   a)
   b)

H. Missapplied specs
   1. in general this is not a serious problem
   2. examples
      a) use 24" subbase in both Houston and West Texas
      b)

I. Relevance of required tests and inspections (THESE WILL ALL NEED EXTENSIVE INVESTIGATION)
   1. questionable: testing concrete beams in flexure as a measure of pavement adequacy. this test is easy to run but does not adequately model field conditions and its relevance is questionable
   2. asphalt test needed. there is no chemical test for the make-up of ashalt, just a physical test. What's in it? How will it react?
   3. density testing of embankments is easy, but wouldn't a shear test be more meaningful? how much more difficult would this be?

4. riding surface tolerances do not mean anything. Compliance with them does not necessarily give a good ride
5. with respect to materials which undergo multiple testing by vendor/manufacturer, contractor, and the Department, where is this excessive?
6. need to address the supplier monitoring by the contractor or State. For what type of material/component is it needed? who should be responsible for the monitoring? where and when should the monitoring occur?
7. acceptable test result variances need more attention. guidelines need to be developed

J. Poorly communicated specs
1. generally problematic specs
   a) new excavation & embankment spec with all the recent revisions and specials
   b) lime and lime treatment spec
   c) new hot mix special (end-result)
2. ambiguous specs
   a) the yellow book in general is not ambiguous; general/ special notes and special provisions are more often the problem; examples:
      1) placement of tack coat for HMACO
3. problems with the language of the spec:
   a) seal coat operations may be conducted under suitable weather conditions. how do you define suitable weather? several different interpretations appear to exist. also, liquidated damages are extremely sensitive to the "closed asphalt season" but the new spec fails to define liquidated damages during this season
   b) problems with general notes in the plans not being fully understood:
      1)
      2)
4. problems with the content of the spec:
   a) Item 340 - coarse aggregate shall be crushed stone - siliceous gravel is often ruled out. this should be so stated
   b)
5. problems with the format of the spec:
   a) tabulated information vs. paragraphs
   b)
6. question: how familiar are inspectors with the intent of the specs?
7. suggested litmus test for new specs: solicit the interpretation of several contractors and compare with the intent
8. comment: some out-of-state contractors have a familiarity problem with part of the specs

K. Use of vendor specs
   1. problem: over-reliance on suppliers in developing specifications for new, unique items
   2. related issue: designer discretion for single-source procurement should be allowed where it best suits the needs of the owner
      a) example: "guard rail energy absorption terminal" for traffic control (Energy Absorption Systems of Chicago Illinois, at the end of their patent period, someone else may build one)

L. Consideration to local materials
   1. where should the specs recognize the variability of certain materials in different parts of the state (beyond that variability already treated in the basic measures of material quality, i.e., moisture content, density, PI, etc.)

M. Use of reference/referral specs (AASHTO, ASTM, ANSI, etc.)
   1. good quote: "we do it when we don't know what we're talking about"
   2. how frequent are these references?
   3. how available are the referenced standards at project sites?
   4. contractors in general want needed information adequately described in the project plans and specs

N. Related issues
   1. needed: Dept decision authority at the site to allow for timely responses to needs for spec changes, with Dept-wide follow-up of needs for similar changes on other projects
   2. many innovative design ideas have been developed by the Department, but have not been accepted in all districts; intra-Departmental communications could be improved
      a) precast concrete panels
      b) metal deck forms for bridge slabs
      c) elimination of concrete diaphragms for pre-stressed beams
      d) various retaining wall options

APPENDIX D

SECOND SET OF INTERVIEW GUIDES

(SPECIFICATION ITEMS CLASSIFIED UNDER PROBLEM TYPES)

APPENDIX D. SECOND SET OF INTERVIEW GUIDES

(SPECIFICATION ITEMS CLASSIFIED UNDER PROBLEM TYPES)

SPECIFICATION IMPROVEMENTS FOR ENHANCED CONSTRUCTABILITY

A. SPECIFICATIONS WHICH ARE OFTEN INCONSISTENTLY INTERPRETED

1. Item 1.40 - Working Day

   In charging time to a project, the term "principal unit of work" tends to be inconsistently interpreted from project to project. The "principal unit of work" is defined as "that unit which controls the completion time of the contract." (p. 4) Without a corresponding requirement for Critical Path Method (CPM) scheduling of construction activity by the contractor, the principal unit of work is not explicitly established or commonly understood. With CPM scheduling, the principal unit of work is any work item that is part of a critical path.

   RECOMMENDATION: The "principal unit of work" should be more explicitly defined, such as "critical path activity", and a corresponding requirement should be placed on the contractor to employ CPM scheduling. Some Department representatives have suggested that a percentage of cost be used as a criteria in establishing the principal units of work. The latter approach is more difficult to justify. Another alternative is to allocate a certain number of calendar days for the completion of the project (provide for incentive or liquidated damages at time of completion).

2. Item 316.1 - Seal Coat (Description)

   "Asphaltic material shall not be placed when general weather conditions, in the opinion of the engineer, are not suitable." (p. 212) Without more definition, the terms "general weather conditions" and "suitable" are subject to inconsistent interpretation.

   RECOMMENDATION: "General weather conditions" should be better defined.

3. Item ??? - Fill Material (MORE RESEARCH NEEDED)

   The comment has been made that material suitable for stable fill is often left to the judgment of the engineer, and that inconsistent interpretations in this area are not uncommon.

   RECOMMENDATION: ....

4. Item ??? -

   Liquidated damages during the "closed asphalt season."

   RECOMMENDATION: ....

5. GENERAL RECOMMENDATION: The effectiveness of "guideline" specifications relies heavily upon the judgment of the inspector. Such judgment can be made more effective with inspector training and the development of good training materials. Related to this, it has been suggested that an "inspection guidelines book" be developed for certain difficult inspector decisions, such as ____________________ ____. Such a reference could identify major considerations which would be reflective of different parts of the State, different road types, different weather conditions, different materials, etc.

B. UNREALISTIC TOLERANCES

1. Item 340 - Hot Mix Asphaltic Concrete Pavement

   Tolerances for aggregates used in ACP are sometimes too tight. Some believe that job size, traffic volumes, material cost, and material availability should be considered. For example, the same tolerances for freeway mainlanes should not be required for a short term detour.

   In addition, it is believed that some material suppliers furnish "dirty" aggregate in total compliance with gradation tolerances. Plan notes are then sometimes necessary to define a suitable material.

   RECOMMENDATION: ....

2. Item ??? - (CLARIFY)

   The enforced finish grade tolerance on bridge decking is 1/8" in 10', but the required roughness may be 3/8" deep. The riding quality is not affected by such small variances.

   RECOMMENDATION: ....

3. Item 440.7 - Reinforcing Steel (Placing)

Tolerances for the placement of reinforcing steel have been identified as generally too tight.

RECOMMENDATION: ....

4. Item 248.6 - Flexible Base - Preparation of Subgrade (Subgrade With Thick Flexbase)

   Earth subgrade tolerances for designs with thick flexbase tend to be excessive.

   RECOMMENDATION: ....

5. Item 260.4 - Lime Treatment for Materials in Place (Subgrade)

   Finish surface tolerances for earth subgrade are too strict where lime treatment is involved. Under these conditions, the subgrade is typically finished to tolerance prior to liming, plowed up and lime treated, and then finished again to tolerance.

   RECOMMENDATION: ....

6. Item ??? - Concrete Strength (CLARIFY)

   Concrete strength specifications do not address tolerances.

   RECOMMENDATION: Concrete strength specifications should be based on a statistical approach to tolerances.

7. Item ??? - Plasticity Index

   The PI test procedure is not very accurate, yet test results tend to be strictly interpreted.

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

8. Item 132.2 - Embankment (Density)

   Embankment density requirements are strictly enforced, even for inconsistent materials.

   RECOMMENDATION: A statistical approach to tolerancing is needed for enforcing embankment density requirements.

9. Item 425 - Prestressed Concrete Structures

In segmental construction, casting tolerances are sometimes incompatible with erection tolerances.

RECOMMENDATION: ....

10. GENERAL COMMENT: It has been suggested that for certain items, pay practices should be based on a percentage of tests that pass (within limits), and that this should be stated explicitly in the specs.

C. GOLD-PLATED SPECIFICATIONS (SPECIFICATIONS IN EXCESS OF NEEDS)

1. Item 360.8 - Concrete Pavement (Spreading and Finishing) (CLARIFY)

   Concrete finishes on farm-to-market roads that are equivalent to those for urban or high-traffic areas.

   RECOMMENDATION: ....

2. Item ??? (CLARIFY)

   Overdesign of road shoulders for certain kinds of roads. (?)

   RECOMMENDATION: ....

3. Item 446.9 - Cleaning, Paint and Painting (Painting) (CLARIFY)

   Requirement that bridgework be painted below the ground line. (?)

   RECOMMENDATION: ....

4. Item ??? - (CLARIFY)

   Requirements of fixed curing times or strength requirements for different structure types under different conditions. Needless delays in follow-on activities may result. For example, a cap cannot be placed on columns until the column reaches 600 psi, when columns may need only 100 psi to support the cap (vs. the entire traffic bearing structure). The same situation applies to beams on caps, walls on footings, etc. Of course, project schedules can be speeded up by allowing for earlier start of follow-on activities.

RECOMMENDATION: ....

5. Item 427.4 - Surface Finishes for Concrete (Class of Finish)

   With respect to concrete finishing, the painting of concrete was chosen to eliminate costly and time-consuming rubbing. However, some specification interpretations now require both rubbing and painting.

   RECOMMENDATION: ....

D. SPECIFICATIONS WITH REFERENCES TO OBSOLETE CONSTRUCTION METHODS, MATERIALS, EQUIPMENT, PROCUCTS, ETC.

   1. Item 260.4 - Lime Treatment for Materials in Place (CLARIFY)

      Lime subgrade specification contains extensive detail on certain mixing equipment and secondary grade, neither of which are relevant anymore.

      RECOMMENDATION: ....

   2. Item 264 - Hydrated Lime and Lime Slurry

      Lime and lime slurry (Dust control) ???

      RECOMMENDATION: ....

   3. Item 360.3 - Concrete Pavement (Equipment) (CLARIFY)

      The concrete paving specification references certain equipment that are rarely used anymore, while slipforming is inadequately covered.

      RECOMMENDATION: ....

   4. Item 420 & 421 - Concrete Structures & Concrete For Structures (CLARIFY)

      Several referenced test methods are not reflective of recent innovations.

      RECOMMENDATION: ....

   5. Item ??? -

Diaphragms between bridge girders are occassionally specified needlessly.

RECOMMENDATION: ....

6. Item ??? -

   Outdated bridge construction methods such as pan girders and slab spans are still contained in the specifications.

   RECOMMENDATION: ....

7. Item ???

   Specified liquid asphalt quality tests are outdated.

   RECOMMENDATION: ....

8. Item ??? -

   Excavation

   RECOMMENDATION: ....

9. Item ??? -

   Embankment

   RECOMMENDATION: ....

10. Item ??? -

    Lime treatment

    RECOMMENDATION: ....

11. Item ??? -

    Compaction

    RECOMMENDATION: ....

12. Item 477.6 - Safety End Treatment (Payment)

    A practical method is needed to pay for safety end treatments.

    RECOMMENDATION: ....

E. POORLY COMMUNICATED SPECIFICATIONS

1. Item ??? -

   Placement of tack coat for HMAC

   RECOMMENDATION: ....

2. Item 340 - ???

   Siliceous gravel is often unacceptable for coarse aggregate, yet this is not explicitly stated.

   RECOMMENDATION: ....

3. Item ??? - Lime and Lime Treatment

   ....

   RECOMMENDATION: ....

4. Item ??? - New Excavation and Embankment Specification

   ....

   RECOMMENDATION: ....

F. MISCELLANEOUS NEEDS FOR SPECIFICATION MODIFICATIONS

1. Item 401.2 - Excavation and Backfill for Sewers

   Excavation of sewer pipe should be made subsidiary to the pipe sewer specification. (Item 465)

   RECOMMENDATION: ....

G. QUESTIONS TO BE ANSWERED

1. What is the State and FHWA policy and attitude toward accepting alternates or substitutions? How are quality and cost-efficiency accounted for (balanced)? What incentives are in place that promote the identification of cost-effective alternates?

2. Are there any specified tolerances that are incompatible with common construction methods (vs. "sophisticated" construction methods)?

3. Do the specifications adequately address the variability of certain materials in different parts of the State? (beyond that variability controlled with the existing measures of material quality, such as moisture content, density, PI, etc.)

4. Where in the specifications is the use of reference specifications (AASHTO, ASTM, ANSI, etc.) excessive and a hindrance to productivity?

5. What construction innovations have been used on past projects but have not been accepted State-wide or have been adequately addressed in the specifications? Why?
   a) precast concrete panels (retaining wall?)
   b) metal deck forms for bridge slabs
   c) elimination of concrete diaframs for prestressed beams
   d) various retaining wall options

SPECIFICATION IMPROVEMENTS FOR ENHANCED CONSTRUCTABILITY

A. SPECIFICATIONS WHICH ARE OFTEN INCONSISTENTLY INTERPRETED

1. Item 1.40 - Working Day

   In charging time to a project, the term "principal unit of work" tends to be inconsistently interpreted from project to project. The "principal unit of work" is defined as "that unit which controls the completion time of the contract." (p. 4) Without a corresponding requirement for Critical Path Method (CPM) scheduling of construction activity by the contractor, the principal unit of work is not explicitly established or commonly understood. With CPM scheduling, the principal unit of work is any work item that is part of a critical path.

   RECOMMENDATION: The "principal unit of work" should be more explicitly defined, such as "critical path activity", and a corresponding requirement should be placed on the contractor to employ CPM scheduling. Some Department representatives have suggested that a percentage of cost be used as a criteria in establishing the principal units of work. The latter approach is more difficult to justify. Another alternative is to allocate a certain number of calendar days for the completion of the project (provide for incentive or liquidated damages at time of completion).

2. Item 316.1 - Seal Coat (Description)

   "Asphaltic material shall not be placed when general weather conditions, in the opinion of the engineer, are not suitable." (p. 212) Without more definition, the terms "general weather conditions" and "suitable" are subject to inconsistent interpretation.

   RECOMMENDATION: "General weather conditions" should be better defined.

3. Item ??? - Fill Material (MORE RESEARCH NEEDED) (item 110?)

   The comment has been made that material suitable for stable fill is often left to the judgment of the engineer, and that inconsistent interpretations in this area are not uncommon.

   RECOMMENDATION: ....

4. Item 340 - Hot Mix Asphaltic Concrete Pavement

   Liquidated damages during the "closed asphalt season."

   RECOMMENDATION: ....

5. GENERAL RECOMMENDATION: The effectiveness of "guideline" specifications relies heavily upon the judgment of the inspector. Such judgment can be made more effective with inspector training and the development of good training materials. Related to this, it has been suggested that an "inspection guidelines book" be developed for certain difficult inspector decisions, such as ____________________ ____. Such a reference could identify major considerations which would be reflective of different parts of the State, different road types, different weather conditions, different materials, etc.

B. UNREALISTIC TOLERANCES

1. Item 340 - Hot Mix Asphaltic Concrete Pavement

   Tolerances for aggregates used in ACP are sometimes too tight. Some believe that job size, traffic volumes, material cost, and material availability should be considered. For example, the same tolerances for freeway mainlanes should not be required for a short term detour.

   In addition, it is believed that some material suppliers furnish "dirty" aggregate in total compliance with gradation tolerances. Plan notes are then sometimes necessary to define a suitable material.

   RECOMMENDATION: ....

2. Item 422 - Reinforced Concrete Slab (item 420.20?)

   The enforced finish grade tolerance on bridge decking is 1/8" in 10', but the required roughness may be 3/8" deep. The riding quality is not affected by such small variances.

   RECOMMENDATION: ....

3. Item 440.7 - Reinforcing Steel (Placing)

   Tolerances for the placement of reinforcing steel have been identified as generally too tight. Some inspectors measure to 1/8 inch tolerance, but the strength of the concrete will not be hurt even if the bars are an inch off. Inspectors enforcing tight tolerances will spend an entire day measuring steel, which will cost the contractor a day's production.

RECOMMENDATION: ....

4. Item 248.6 - Flexible Base - Preparation of Subgrade (Subgrade With Thick Flexbase)

   Earth subgrade tolerances for designs with thick flexbase tend to be excessive.

   RECOMMENDATION: ....

5. Item 260.4 - Lime Treatment for Materials in Place (Subgrade)

   Finish surface tolerances for earth subgrade are too strict where lime treatment is involved. Under these conditions, the subgrade is typically finished to tolerance prior to liming, plowed up and lime treated, and then finished again to tolerance.

   RECOMMENDATION: ....

6. Item ??? - Concrete Strength (CLARIFY) (item 420, 421, 360?)

   Concrete strength specifications do not address tolerances.

   RECOMMENDATION: Concrete strength specifications should be based on a statistical approach to tolerances.

7. Item ??? - Plasticity Index

   The PI test procedure is not very accurate, yet test results tend to be strictly interpreted.

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

8. Item 132.2 - Embankment (Density)

   Embankment density requirements are strictly enforced, even for inconsistent materials.

RECOMMENDATION: A statistical approach to tolerancing is needed for enforcing embankment density requirements.

9. Item 425 - Prestressed Concrete Structures

   In segmental construction, casting tolerances are sometimes incompatible with erection tolerances.

   RECOMMENDATION: ....

10. Item 427.7 - Surface Finishes for Concrete (Exposed Aggregate Finish)

    The tolerances for the depth of exposure are very unrealistic. "The depth of finish shall be one-fourth of an inch minimum to one-half of an inch maximum, unless otherwise directed by the engineer or required by the plans." If one-half of an inch is specified, most of the aggregate will be taken out of the face of the panel while trying to achieve that tolerance.

    RECOMMENDATION: The depth of finish should be changed to one-eighth of an inch because realistically this is all that can be achieved.

11. GENERAL COMMENT: It has been suggested that for certain items, pay practices should be based on a percentage of tests that pass (within limits), and that this should be stated explicitly in the specs.

C. GOLD-PLATED SPECIFICATIONS (SPECIFICATIONS IN EXCESS OF NEEDS)

1. Item 360.8 - Concrete Pavement (Spreading and Finishing) (CLARIFY)

   Concrete finishes on farm-to-market roads that are equivalent to those for urban or high-traffic areas.

   RECOMMENDATION: ....

2. Item ??? (CLARIFY)

   Overdesign of road shoulders for certain kinds of roads. (?)

   RECOMMENDATION: ....

3. Item 446.9 - Cleaning, Paint and Painting (Painting) (CLARIFY)

   Requirement that bridgework be painted below the ground line. (?)

   RECOMMENDATION: ....

4. Item 420.22 - Concrete Structures (Removal of Forms and Falsework)

   Requirements of fixed curing times or strength requirements for different structure types under different conditions. Needless delays in follow-on activities may result. For example, a cap cannot be placed on columns until the column reaches 600 psi, when columns may need only 100 psi to support the cap (vs. the entire traffic bearing structure). The same situation applies to beams on caps, walls on footings, etc. Of course, project schedules can be speeded up by allowing for earlier start of follow-on activities.

   RECOMMENDATION: ....

5. Item 427.4 - Surface Finishes for Concrete (Class of Finish)

   With respect to concrete finishing, the painting of concrete was chosen to eliminate costly and time-consuming rubbing. However, some specification interpretations now require both rubbing and painting.

   RECOMMENDATION: ....

6. GENERAL COMMENT: Special or elaborate equipment is sometimes specified needlessly.

D. SPECIFICATIONS WITH REFERENCES TO OBSOLETE CONSTRUCTION METHODS, MATERIALS, EQUIPMENT, PROCUCTS, ETC.

   1. Item 260.4 - Lime Treatment for Materials in Place (CLARIFY)

      Lime subgrade specification contains extensive detail on certain mixing equipment and secondary grade, neither of which are relevant anymore.

      RECOMMENDATION: ....

   2. Item 264 - Hydrated Lime and Lime Slurry

Lime and lime slurry (Dust control) ???

RECOMMENDATION: Pebble limestone should be used to avoid messy slurries and dust hazards.

3. Item 360.3 - Concrete Pavement (Equipment) (CLARIFY)

   The concrete paving specification references certain equipment that are rarely used anymore, while slipforming is inadequately covered.

   RECOMMENDATION: ....

4. Item 420 & 421 - Concrete Structures & Concrete For Structures (CLARIFY)

   Several referenced test methods are not reflective of recent innovations.

   RECOMMENDATION: ....

5. Item 422 - Reinforced Concrete Slab?

   Diaphragms between bridge girders are occassionally specified needlessly.

   RECOMMENDATION: ....

6. Item 421 - Concrete for Structures

   Outdated bridge construction methods such as pan girders and slab spans are still contained in the specifications.

   RECOMMENDATION: ....

7. Item ???

   Specified liquid asphalt quality tests are outdated.

   RECOMMENDATION: ....

8. Item 477.6 - Safety End Treatment (Payment)

   A practical method is needed to pay for safety end treatments.

   RECOMMENDATION: ....

9. Are there any obsolete items dealing with excavation, embankment, or compaction?

10. GENERAL COMMENT: The Highway Department should not specify what equipment contractors are to use; they should allow the contractors to select what they need to obtain the finished product.

E. POORLY COMMUNICATED SPECIFICATIONS

1. Item 340.6 - Hot Mix Asphaltic Concrete Pavement (Tack Coat)

   Placement of tack coat for HMAC

   RECOMMENDATION: Tack coat should become a separate bid item.

2. Item 340 - Hot Mix Asphaltic Concrete Pavement

   Siliceous gravel is often unacceptable for coarse aggregate, yet this is not explicitly stated.

   RECOMMENDATION: ....

3. Item ??? - Lime and Lime Treatment

   ....

   RECOMMENDATION: ....

F. MISCELLANEOUS NEEDS FOR SPECIFICATION MODIFICATIONS

1. Item 401.2 - Excavation and Backfill for Sewers

   Excavation of sewer pipe should be made subsidiary to the pipe sewer specification. (Item 465)

   RECOMMENDATION: ....

2. Item 7.12 - Contractor's Responsibility for Work

   The contractor's maintenance of roadways during construction has become a problem. "The contractor shall rebuild and make good at his own expense all injuries and damages to the work occurring before its completion and acceptance."

RECOMMENDATION: The contractor's maintenance of the road should be based on the type of work he is performing. For example, a contractor should not have to patch a road over the life of the project if all he is doing is placing a seal coat on the road.

G. QUESTIONS TO BE ANSWERED

1. What is the State and FHWA policy and attitude toward accepting alternates or substitutions? How are quality and cost-efficiency accounted for (balanced)? What incentives are in place that promote the identification of cost-effective alternates?

2. Where is there a need for life cycle analysis? Striping paint? Traffic buttons?

3. Are there any specified tolerances that are incompatible with common construction methods (vs. "sophisticated" construction methods)?

4. Under what conditions can single-source procurement (and closed specifications) best serve the State?

5. Do the specifications adequately address the variability of certain materials in different parts of the State? (beyond that variability controlled with the existing measures of material quality, such as moisture content, density, PI, etc.)

6. What construction innovations have been used on past projects but have not been accepted State-wide or have been adequately addressed in the specifications? Why?
   a) precast concrete panels (retaining wall?)
   b) metal deck forms for bridge slabs
   c) elimination of concrete diaframs for prestressed beams
   d) various retaining wall options

APPENDIX E

LETTER AND FORM USED BY SDHPT TO SOLICIT COMMENTS

APPENDIX E. LETTER AND FORM USED BY SDHPT TO SOLICIT COMMENTS

COMMISSION

ROBERT H. DEDMAN, CHAIRMAN
JOHN R. BUTLER, JR.
RAY STOKER, JR.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

DEWITT C. GREER STATE HIGHWAY BLDG.
11TH & BRAZOS
AUSTIN, TEXAS [illegible]

ENGINEER-DIRECTOR
R. E. STOTZER, JR.

March 22, 1988

IN REPLY REFER TO
D-8P

TO: MEMBERS OF PRIVATE INDUSTRY INVOLVED IN TEXAS HIGHWAY CONSTRUCTION

SUBJECT: 1990 BOOK OF STANDARD SPECIFICATIONS

The Standard Specifications for Construction of Highways, Streets and Bridges adopted by this Department in September, 1982 are being revised and current planning provides for publication of a new book by 1990.

You may wish to provide comments on the current specifications, special specifications or special provisions (required or approved for general use) and/or provide suggested input to revise, replace or supplement the 1982 specifications. Please utilize the format on the attached sheets to furnish any suggested revisions, additions or comments. A separate sheet should be used for each Item.

The Department's Specifications Committee, having overall responsibility for all construction specifications, has assigned Peggy Chandler the duties and responsibilities as the Specifications Book Engineer to accomplish the necessary work in updating the Specifications Book. Your response should be to the above address, attention: Peggy Chandler, D-8; and should be transmitted by July 16, 1988.

Sincerely,

R. E. Stotzer, Jr.
Engineer-Director

By: Frank D. Holzmann

Frank D. Holzmann
Chief Engineer, Highway Design

Attachment

TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

PUBLICATION OF STANDARD SPECIFICATIONS BOOK FOR 1990

Check One: Item No.________

_____Comments _____Suggested Revisions _____Suggested Addition

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Company Name:

Address:

Contact Person:

Telephone Number:

APPENDIX F

QUALITY LEVEL ANALYSIS

APPENDIX F. QUALITY LEVEL ANALYSIS

The Federal Highway Administration has developed a procedure to determine the acceptance level of material of 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 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 and 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 (USDOT-FHWA 1985).

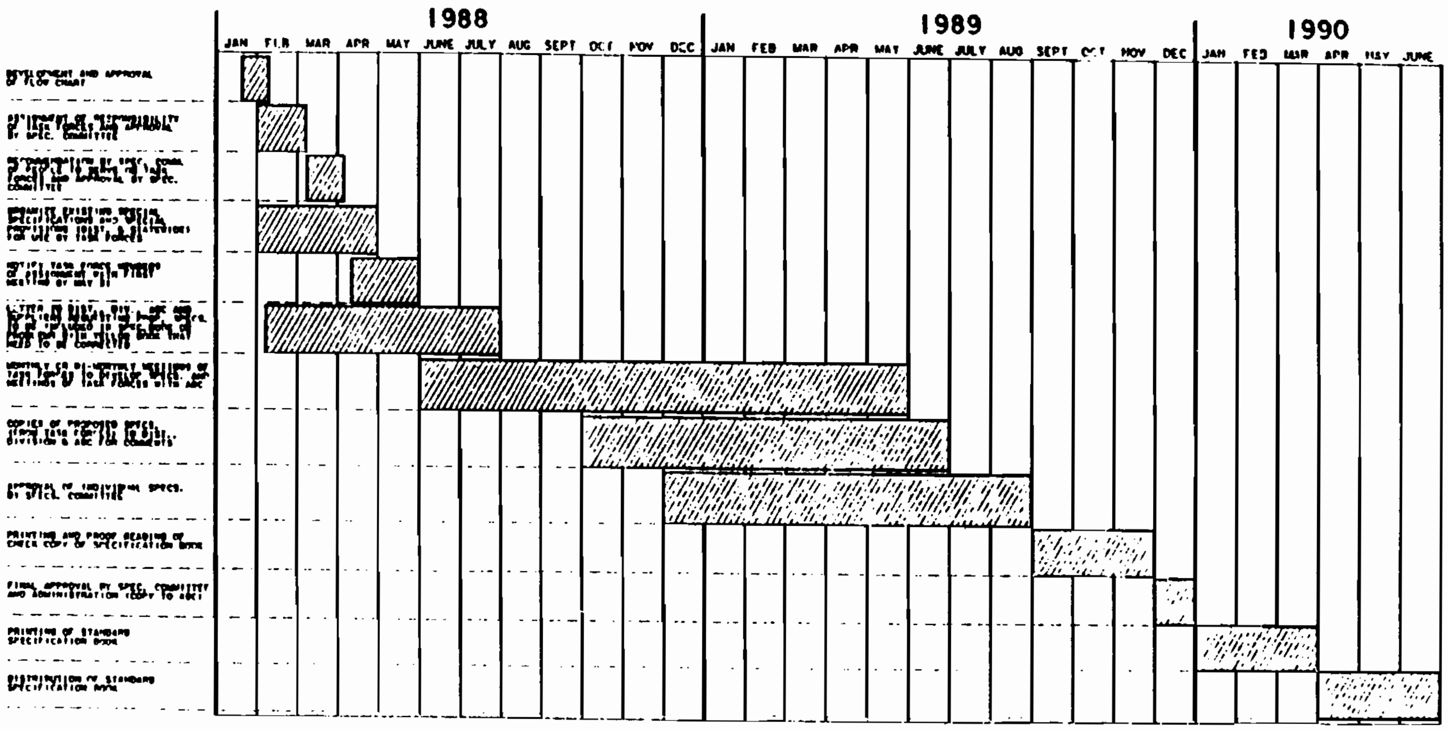
APPENDIX G

BAR CHART SHOWING DEVELOPMENT OF NEW SPECIFICATION MANUAL

APPENDIX G. BAR CHART SHOWING DEVELOPMENT OF NEW SPECIFICATION MANUAL

2/3/88

FLOW CHART SHOWING DEVELOPMENT OF NEW
STANDARD SPECIFICATIONS BOOK FOR
CONSTRUCTION OF HIGHWAYS, STREETS AND BRIDGES



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