# *Essential Testing and Inspection Levels*

***SD91-05***

***Final Report***

Prepared for

The

South Dakota Department of Transportation

April 1992

Prepared by

**Bergstralh-Shaw-Newman, Inc.**

# Table of Contents

## *List of Figures*

## *List of Tables*

# Acknowledgments

The assistance of Department personnel is greatly appreciated. The cooperation of everyone — data processing, materials, research, construction and the — was outstanding.

We appreciate the insight and guidance of the Technical Panel members:

Mike Durick, Construction Management,

Larry Engbrecht, Materials and Surfacing,

Roger Hagenlock, Pierre Region,

Merle Jenner, Huron Area,

Paul Mechling, Rapid City Region,

David Morris, Mitchell Area, and

Daris Ormesher, Office of Research.

We wish to also acknowledge the assistance of those individuals in the states adjacent to South Dakota — Iowa, Minnesota, Montana, Nebraska, North Dakota and — and in other states who graciously answered our questions and provided us with information on their testing and inspection practices and specifications.

Chapter One

# Introduction

## The Problem

It has become increasingly difficult for the South Dakota Department of Transportation to schedule available personnel to provide project inspection. Manpower shortages and an increased number of projects are two of the contributing factors. Another is that many senior engineers and technicians are reaching the age of retirement. Key questions to be resolved through this research include:

- Can some unessential testing and inspection activities be identified and eliminated?
- Can the frequency of tests and inspection be reduced for some activities without jeopardizing quality?
- Will the reduction or elimination of testing and inspection on non-essential items allow the tester or inspector to concentrate on critical tests and inspection?

Research was needed to determine which activities are essential to the successful completion of projects. The goal must be to ensure that quality construction is attained. In the long run, it is not cost effective to reduce testing and inspection if the quality of the end product will suffer.

## Background

During the last decade or so, South Dakota, along with most other state highway and transportation agencies, has reduced staff. During this same time the work load, in terms of the number of projects and constant dollars, has increased. Administration of programs such as Davis-Bacon minimum pay requirements, disadvantaged business enterprise goals, and environmental regulations has increased the need for documentation.

In an effort to better plan and schedule manpower for assignment to construction projects, the Department developed and implemented a Construction Engineering Manpower Management System (CEMMS).

Supervisors are concerned that unnecessary testing may be interfering with adequate inspection.

## Project Objectives

The Department established two research objectives for this project:

- to develop recommendations for the number of preliminary and construction tests and inspection levels necessary to provide a quality product; and

- to evaluate the cost-effectiveness of a reduction of testing and inspection levels on a construction project.

The primary thrust of the study was toward construction materials testing and inspection activities. Staking and office work performed by field construction personnel were included as necessary to evaluate the entire resource demand. Evaluation of preconstruction activities was limited to three activities concerned with materials and borrow investigation.

## *Methodology*

The techniques used in conducting the research are described below.

- A literature search was conducted through TRIS (Transportation Research Information System). Copies of pertinent publications were obtained from the consultant's library or other sources and evaluated for use on the study.
- Applicable Department policies and manuals were reviewed.
- Data on testing and inspection practices in South Dakota were collected. The testing frequencies for critical tests were summarized for selected projects, along with the number of failing tests.
- Information concerning testing and inspection practices in the six states surrounding South Dakota — Minnesota, Iowa, Nebraska, Wyoming, Montana and North Dakota — were collected and summarized.
- The use of performance specifications in South Dakota, the six adjacent states, and selected other states was reviewed and summarized.
- Reported man-hour data and work quantities for selected new construction and resurfacing projects were collected and summarized to determine the significant activities and evaluate the CEMMS planning standards. Man-hour data were collected from the Construction Division's Construction Engineering Manpower Management System (CEMMS). Work quantities were obtained from the CEMMS planning reports and from final estimates.
- Eighteen on-going projects representing all four regions — eleven new construction and seven resurfacing projects — were selected for field reviews. Members of the consultant team visited each of these projects and talked with project personnel to learn first-hand about construction practices and problems. The consultant team members also visited with area engineers, regional engineers and regional materials engineers to get their input concerning staffing problems.

The information and data collected from all of these efforts were summarized and analyzed for use in evaluating current department practices, identifying improvements and developing recommendations. The results of these research efforts are presented in Chapter Two, Research Findings and in Chapter Three, Staffing Analysis.

*Chapter Two*

# Research Findings

This chapter of the report is divided into nine major sections covering literature searches, work load analyses, acceptance testing, quality control testing and assurance specifications, inspections, staking, field reporting, and staffing. This chapter presents summarized information much of which is supported by more detailed information in other chapters and appendixes.

## Literature Search

An electronic literature search was done through TRIS (Transportation Research Information System). Eight *key word* combinations were used:

- *highway and material and quality control* in the NTIS data base produced 40 references and the Compendex Plus data base produced 16;
- *highway and material test* showed 262 in NTIS and 4 in Compendex Plus;
- *highway and construction and administration* showed 89 in NTIS, 13 in Trade and Industry, 225 in Compendex Plus, 47 in PTS PROMT and 90 in Trade and Industry Index;
- *highway and construction and staffing* produced 4 in NTIS and 6 in Compendex Plus;
- *SHRP and pave* gave no references;
- *highway and construction and cost control* showed 41 for NTIS, 8 for Compendex Plus, 5 for PTS PROMT and 1 for Trade and Industry Index;
- *highway and construction and survey* showed 1,476 for NTIS, 2 for Trade and Industry ASAP, 18 for PTS PROMT and 3 for the Trade and Industry Index; and
- *highway and construction staking* resulted in one reference for Compendex Plus.

When searches are made the system first shows the number of references that match key words by data base. It then asks which data base to search and lists the most recent 10 references. As an example of the information provided, the first report, through Compendex Plus, has minimal information. This is one of eight listings given for the key words *highway and construction and cost control:*

> *Development of Price Adjustment Systems for Statistically Based Highway Construction Specifications*

The system then affords the opportunity to selectively review abstracts. The following is the abstract (with the computerese eliminated) for this paper:

> *Author: Willenbrock, Jack H.; Kopac, Peter A.*
> *Corporate Source: Pa State Univ, University Park*
> *Source: Transportation Research Record n 652 1977 p 52-58*

*Publication Year: 1977*
*Language: English*
*Journal Announcement: 7902*
*Abstract: This paper presents a methodology that can be used to develop price-adjustment systems for use in statistically based highway construction specifications. Three approaches are proposed for the development of a price-adjustment system: the serviceability approach, the cost of production approach, and the operating characteristic curve approach. The three approaches are discussed and compared, and their most appropriate applications are recommended. A fourth approach, the cost of quality control approach is also discussed. 11 refs.*

The literature search produced relatively few publications with specific application to this study. Those that were of use, nine of them, are listed under References at the end of Chapter Four. The literature search is too large to include in either the report or the appendix. However, it is available in the project records. One project that we were aware of prior to the start of this project had promise. It is discussed next.

### COSTOP I

The need for rational ways for determining the optimum number of tests to be taken to ensure quality construction has been recognized for many years. Finding a solution is elusive. In 1982, a study entitled "Cost Effectiveness of Sampling and Testing Programs" was undertaken to address this need. The objective of the study was to provide a methodology to determine the cost effectiveness of individual tests and associated sampling frequencies used in controlling the quality of pavement materials as related to performance. (*1*)(*2*) A computer program, "COSTOP1," was developed for asphalt paving. While this program provides a good overall methodology for determining the cost-effectiveness of testing frequencies, further research in the relationships between individual tests and the performance of the completed pavement is needed before COSTOP1 can be used effectively. This research has not yet been funded. Consequently, this program is not now useful in evaluating test frequencies in South Dakota.

## Work Load

Over the years we have conducted many highway and transportation construction work load analyses. The one invariable result is that some project types will be more important, in terms of resources used in their completion, than others. This is known as the Pareto Principal or the significant few and the trivial many. The importance for managers and researchers, trying to devise ways to conserve or concentrate resources, is to focus attention on those types of projects that are the most significant in terms of their resource consumption.

A further explanation is necessary to avoid misunderstanding that may occur. All projects are important and some, although not consuming significant amounts of manpower, materials or money may be extremely important from a safety or service point of view. This effort does not diminish that importance, nor minimize the need for effective design, construction and completion policies, procedures and guidelines. The effort does, however, pinpoint areas where improvement efforts can be expected to have the greatest potential Department impacts.

To determine which types of projects were the most significant, from this perspective, actual work loads for the years 1985 through 1989, and projected work loads for lettings from 1990 to 1994 (the latest information then available) were analyzed. The work load from 1985 through 1989 was analyzed in two ways: by the number and percent of the number of projects awarded; and the amount and percent of contractors' earnings. Summary results are presented in Figure 1 on the next page.

More detailed graphs and supporting data are presented in three figures — Contract Earnings: 1985 through 1989; Percent of Number of Projects Awarded: 1985 through 1989; and Work Load Plan: 1990 through 1994 — in Appendix A.

It is clear from the analysis that construction and resurfacing are the most significant project types from a resource consumption perspective. Five year averages, as shown in Figure 1, reveal that:

- About 82 percent of planned construction expenditures for the period 1990 through 1994 are concentrated in two project types — 60 percent is planned for construction and 22 percent is planned for resurfacing. These numbers are the most important of those shown in Figure 1. The others show historical trends that may or may not be indicative of future work loads. However, the historical trends analyses, in this case, lend support to the credibility of the program and its significance conclusions.
- About 81 percent of contractor payments for the years 1985 through 1989 were devoted to the two same project types — 56 percent for construction and 25 percent for resurfacing.
- As might be expected, when viewed as a percent of the total number of projects awarded from 1985 through 1989, the predominance of construction and resurfacing projects is reduced. The Department has, as now typically seen nationally, a large number of relatively small projects. Still about half of the number of projects awarded during this five-year period were classified as construction and resurfacing.

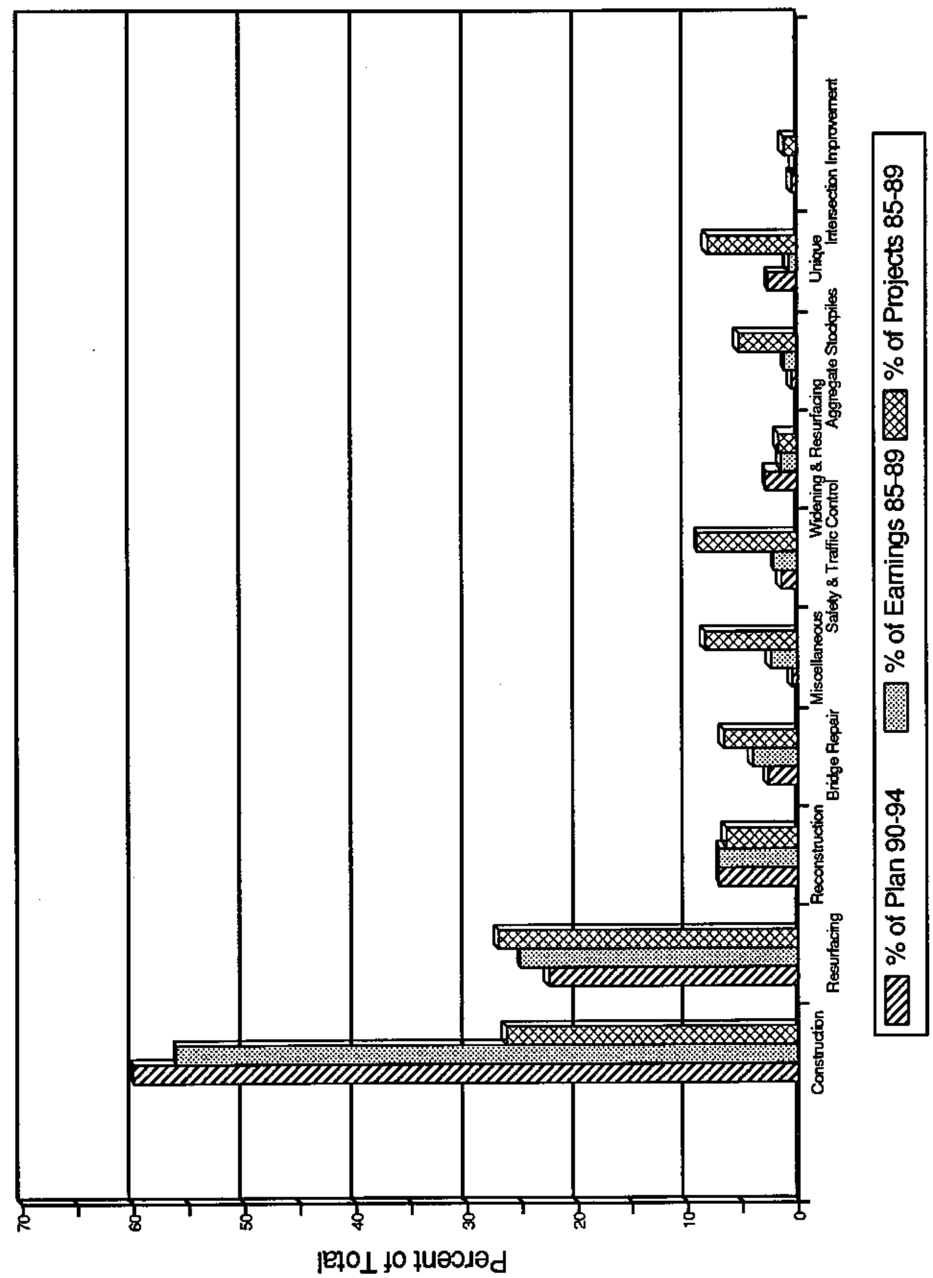
It should be noted that many of the projects classified as construction projects involved major reconstruction of existing facilities. Because of their size, they were classified as construction projects. Had that not been the case, the reconstruction project type may have been of greater significance in all three analyses.

## Activity Significance

Our experience has also shown that there are significant activities, as well as significant project types. Again, all work done is important. And it is probable that some key activities contribute disproportionately to project quality, safety and environmental safeguarding through limited numbers of man-hours and costs. Still, managers and researchers working within tight resource restraints, as they nearly always are, must focus their attention on those project and activity types that can be documented to have the greatest potential payoff. That is particularly true in construction inspection and testing where direct relationships among the quality of the final product, given the current state of the art, and the levels of inspection and testing done to achieve minimum quality levels are difficult to quantify, except in subjective, judgmental and logical ways. That is especially true when construction control responsibilities are assumed by secondary parties rather than the producers themselves. A thought that is explored in greater depth later in this and other chapters.

The Department's Construction Engineering Manpower Management System (CEMMS) plans and reports to 35 activities. That, in itself, is an indication that the Department understands and applies the Pareto rationale. Many departments historically used 75, or more, activities; a practice that was probably curtailed through the implementation of CEMMS projects around the country.

**Figure 1 — Work Load Distributions: Five Year Average**



All CEMMS data available for all years, nearly 1.7 million man-hours, were used for the analyses. Separate analyses were made for each project type, as was a summary analysis for all project types. The summary, construction and resurfacing analyses (the two most significant project types) are described and discussed in this chapter. Analyses for other project types are presented in Appendix B.

Significant project type and activity analyses guided the Consultant in their field reviews, and in the emphasis accorded to each in the review of current policies and practices, and the development of improvement recommendations.

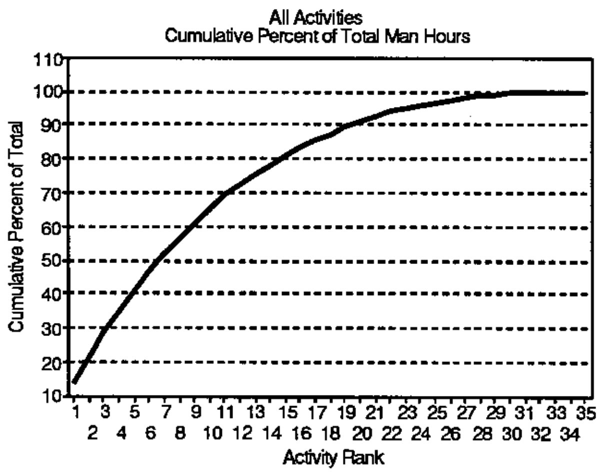
## *All Project Types*

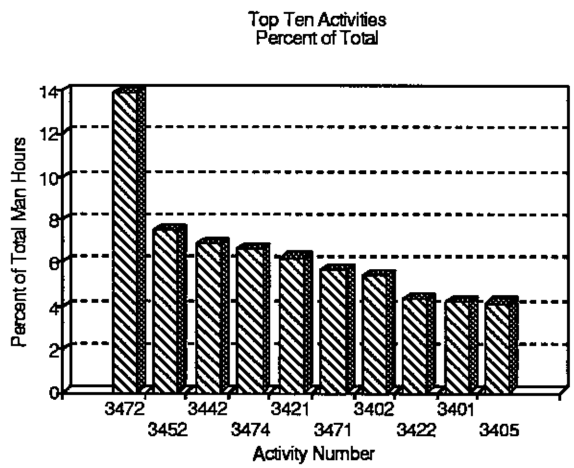
Figure 2, on the next page shows the most significant 20 work activities when all project types are merged. These data show that:

- nearly 30 percent of all field construction management, engineering, inspection, testing and staking man-hours are spent on three key activities — project management and coordination, inspection of miscellaneous items, and structure and box inspection;
- the first 10 ranked activities account for two-thirds of all man-hours; and
- 20 of the Department's activities account for more than 90 percent of all man-hours used in field construction.

The first two ranked activities account for more than 20 percent of total man-hours and that is likely to be a matter of concern for Department officials. These activities are discussed later in this chapter.

# Figure 2 -- Activity Analysis: All Project Types



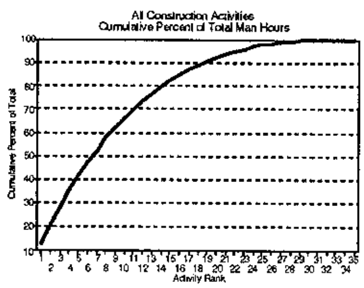

| Rank | Act No | Activity Name | Man Hours | Percent of Total Man Hours | Percent Cumulative |
|---|---|---|---|---|---|
| 1 | 3472 | PROJECT MGMT & COORD | 233,094 | 14 | |
| 2 | 3452 | INSPECT MISC ITEMS | 126,176 | 8 | 22 |
| 3 | 3442 | STRUCT/BOX INSPECT | 115,220 | 7 | 29 |
| 4 | 3474 | TRAVEL | 111,660 | 7 | 35 |
| 5 | 3421 | ASPHALT PAV INSPECT | 104,466 | 6 | 42 |
| 6 | 3471 | GENERAL OFFICE WORK | 94,394 | 6 | 47 |
| 7 | 3402 | X-SECT & SLOPE STAKE | 91,077 | 5 | 53 |
| 8 | 3422 | ASPHLT PLANT INSPECT | 72,857 | 4 | 57 |
| 9 | 3401 | ROADWAY LAYOUT STAKE | 71,060 | 4 | 61 |
| 10 | 3405 | EARTHWORK INSPECTION | 69,510 | 4 | 66 |
| 11 | 3416 | WEIGH AGG MATERIALS | 64,812 | 4 | 69 |
| 12 | 3412 | UNTREAT AGG INSPECT | 58,502 | 3 | 73 |
| 13 | 3411 | LINE/GRADE CONTROL | 51,034 | 3 | 76 |
| 14 | 3403 | GRADE CNTRL--SUBGRAD | 44,927 | 3 | 79 |
| 15 | 3431 | PCC PAVE INSPECTION | 44,201 | 3 | 81 |
| 16 | 3406 | TEST-STRUCT,EARTH,UT | 39,199 | 2 | 84 |
| 17 | 3433 | JCT REP PROJ INSP | 36,242 | 2 | 86 |
| 18 | 3451 | STAKING MISC ITEMS | 32,321 | 2 | 88 |
| 19 | 3413 | TESTING--UNTREAT AGG | 31,545 | 2 | 90 |
| 20 | 3408 | EARTHWORK--OFFICE | 28,848 | 2 | 91 |
| | | TOTAL MANHOURS | 1,673,147 | | |

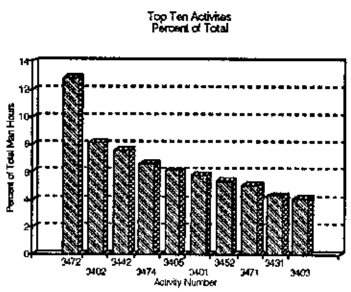
## *Construction Projects*

As earlier noted, construction type projects account for more than 65 percent of the total expenditures planned for the 1990 through 1994 period. In addition, this project classification has almost a million man-hours, nearly 60 percent of all man-hours reported to CEMMS. Figure 3, below, shows that:

- about two-thirds of all man-hours charged to this project classification were to 9 activity types. Project management and coordination again head the list followed by cross sectioning and slope staking, structures inspection, travel and earthwork inspection; and
- 80 percent of all man-hours were charged to 14 of the 35 activities.

**Figure 3 — Type A: Construction**



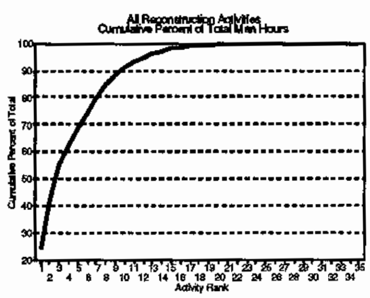



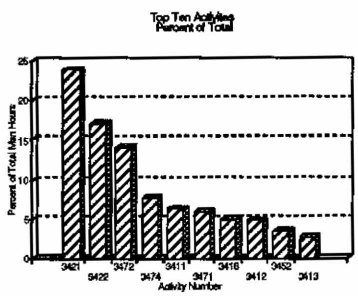

| Rank | Act No | Activity Name | Man Hours | Percent of Total Man Hours | Cumulative Percent of Man Hours |
|---|---|---|---|---|---|
| 1 | 3472 | PROJECT MGMT & COORD | 125,824 | 13 | |
| 2 | 3402 | X-SECT & SLOPE STAKE | 80,915 | 8 | 21 |
| 3 | 3442 | STRUCT/BOX INSPECT | 75,241 | 8 | 29 |
| 4 | 3474 | TRAVEL | 65,172 | 7 | 35 |
| 5 | 3405 | EARTHWORK INSPECTION | 60,480 | 6 | 41 |
| 6 | 3401 | ROADWAY LAYOUT STAKE | 57,634 | 6 | 47 |
| 7 | 3452 | INSPECT MISC ITEMS | 53,105 | 5 | 53 |
| 8 | 3471 | GENERAL OFFICE WORK | 50,181 | 5 | 58 |
| 9 | 3431 | PCC PAVE INSPECTION | 42,441 | 4 | 62 |
| 10 | 3403 | GRADE CNTRL–SUBGRAD | 40,547 | 4 | 66 |
| 11 | 3416 | WEIGH AGG MATERIALS | 38,519 | 4 | 70 |
| 12 | 3406 | TEST-STRUCT,EARTH,UT | 37,053 | 4 | 74 |
| 13 | 3412 | UNTREAT AGG INSPECT | 36,316 | 4 | 77 |
| 14 | 3411 | LINE/GRADE CONTROL | 28,036 | 3 | 80 |
| 15 | 3407 | MINOR STRUCT INSPECT | 25,939 | 3 | 83 |
| 16 | 3408 | EARTHWORK–OFFICE | 24,518 | 2 | 85 |
| 17 | 3432 | PCC PLANT–PAVING | 19,882 | 2 | 87 |
| 18 | 3451 | STAKING MISC ITEMS | 18,477 | 2 | 89 |
| 19 | 3421 | ASPHALT PAV INSPECT | 17,568 | 2 | 91 |
| 20 | 3413 | TESTING–UNTREAT AGG | 16,873 | 2 | 93 |
| | | TOTAL MAN HOURS | 986,798 | | |

## *Resurfacing Projects*

A bit less than 20 percent of the five-year plan is for resurfacing projects. As might be expected the predominate portion of this work load, based on historical CEMMS data, is for asphalt paving and plant inspection, and project management and coordination. Nearly all of the remaining 45 percent, as shown in Figure 4 below, is spread among another eight activities. Six of these eleven key activities are inspection oriented, one is staking oriented and four are office and management oriented.

**Figure 4 -- Type D: Resurfacing**





| Rank | Act No | Activity Name | Man Hours | Percent of Total Man Hours | Cumulative Percent of Man Hours |
|---|---|---|---|---|---|
| 1 | 3421 | ASPHALT PAV INSPECT | 79,008 | 24 | |
| 2 | 3422 | ASPHLT PLANT INSPECT | 56,425 | 17 | 41 |
| 3 | 3472 | PROJECT MGMT & COORD | 46,713 | 14 | 55 |
| 4 | 3474 | TRAVEL | 25,709 | 8 | 63 |
| 5 | 3411 | LINE/GRADE CONTROL | 20,804 | 6 | 69 |
| 6 | 3471 | GENERAL OFFICE WORK | 19,250 | 6 | 75 |
| 7 | 3416 | WEIGH AGG MATERIALS | 16,371 | 5 | 80 |
| 8 | 3412 | UNTREAT AGG INSPECT | 15,973 | 5 | 85 |
| 9 | 3452 | INSPECT MISC ITEMS | 11,308 | 3 | 88 |
| 10 | 3413 | TESTING–UNTREAT AGG | 9,306 | 3 | 91 |
| 11 | 3417 | OFFICE WORK-AGG/PAV | 8,808 | 3 | 93 |
| 12 | 3451 | STAKING MISC ITEMS | 4,532 | 1 | 95 |
| 13 | 3401 | ROADWAY LAYOUT STAKE | 4,049 | 1 | 96 |
| 14 | 3473 | STANDBY | 3,467 | 1 | 97 |
| 15 | 3414 | TREATED AGG INSPECT | 2,675 | 1 | 98 |
| 16 | 3405 | EARTHWORK INSPECTION | 1,317 | 0 | 98 |
| 17 | 3453 | OFFICE WRK MISC ITEM | 1,282 | 0 | 99 |
| 18 | 3402 | X-SECT & SLOPE STAKE | 928 | 0 | 99 |
| 19 | 3415 | TESTING–TREATED AGG | 774 | 0 | 99 |
| 20 | 3403 | GRADE CNTRL–SUBGRAD | 524 | 0 | 99 |
| | | TOTAL MAN HOURS | 331,429 | | |

## *PCEMS*

Three preconstruction activities were included in the study:

- Activity 3143 — Final Materials Investigation, which covers the location and testing of materials sources, and obtaining pit options and haul road agreements;
- Activity 3145 — Final Borrow Investigation which covers the location and testing of suitable borrow material and preparing a pit layout; and
- Activity 3146 — Secure Borrow Option, which covers obtaining a borrow pit option.

The Department has identified and tested aggregate and borrow sources and obtained options on those sources so they would be available to all contractors who bid the projects. Contractors are not required to use the Department-optioned source and are free to locate their own. The concern is whether the Department should continue to locate, test and option sources or to specify contractor-furnished sources. In areas of the State, such as the Sioux Falls vicinity, where all aggregates must come from commercial quarries, the Department does not investigate or option pits.

The advantages of Department-optioned materials and borrow sources include:

- All contractors are assured of having a source of material. In some states where contractor-furnished material is specified, contractors have bought or leased all suitable aggregate sources in their area of operation which limits competition — especially in areas where good aggregates are in short supply. Contractors can, of course, buy or lease gravel pits to limit competition even though the Department does option pits.
- The results of the Department's materials source investigations are available to all prospective bidders. Without these results, every contractor that wanted to bid on a project would have to conduct an investigation to locate suitable aggregate or borrow material (unless the contractors acquired their own sources in the area of the State in which they work). Contractors' bid prices must reflect their total costs if they are to remain in business. The Department can expect that the extra cost of materials source investigations would ultimately be included in the contractors' bids.

The disadvantages are:

- The Department may have some liability, as noted in the specifications, if the preliminary test results are not representative of the actual quantity or quality of material from the designated source.
- Department personnel must devote time to investigating sources and obtaining options — time that might be better spent on other activities. The amount of time spent on these three activities throughout the State in the last three years is summarized in Table 1 below. The summary is based on man-hours reported to the Preconstruction Engineering Management System (PCEMS).

**Table 1 — PCEMS Activity Analysis**

| | Activity | | | | | |
|---|---|---|---|---|---|---|
| | 3143 — Final Materials Investigation | | 3145 — Final Borrow Investigation | | 3146 — Secure Borrow Option | |
| Year | No. of Projects | Man-hours | No. of Projects | Man-hours | No. of Projects | Man-hours |
| 1988 | 204 | 5,398 | 23 | 1,005 | 23 | 312 |
| 1989 | 217 | 5,262 | 9 | 827 | 10 | 384 |
| 1990 | 122 | 5,040 | 15 | 319 | 9 | 216 |
| Average | 181 | 5,233 | 16 | 717 | 14 | 304 |

The total man-hours spent on all three activities averaged 6,254 hours per year or about 3.5 person years. The level of effort for borrow investigations and options appears to be decreasing.

The level of effort averages 29 man-hours per project for Activity 3143, 45 man-hours for Activity 3145 and 22 man-hours for Activity 3146. It can be assumed that each contractor would have to spend about the same amount of time to conduct similar investigations on each project where commercial sources are not available, and that those costs will ultimately be passed on to the Department in the form of increased bid prices. If the contractors were required to find their own sources, each contractor would have to prospect for material. This would likely result in several contractors testing the same source, with each digging separate test holes. Besides the extra cost of prospecting, the landowners would not likely be in favor of having so many prospecting the same source.

***Recommendation No. 2-1:*** ***It is recommended that the Department continue to provide materials and borrow sources as it has in the past rather than specifying contractor furnished sources for all projects.***

## Acceptance Testing

### Testing Frequencies

How many tests are enough to ensure that materials meet specifications? To help answer that question, two analyses were made for selected tests. The first was a comparison of the testing requirements for the states surrounding South Dakota. The surrounding states were selected because it was thought that their operating conditions would most closely resemble those of South Dakota. In the second analysis, the actual numbers of tests taken (for selected tests and projects) in South Dakota were analyzed. In this analysis, the actual numbers of tests taken were compared with the minimum testing requirements and the number of failing tests was noted. Recently completed projects were randomly selected for the analysis. In a number of instances, the central materials files did not include the minimum number of tests required. The data were included anyway to determine the percent of tests that failed. Retests were not included in the data.

The results of the two analyses and recommendations concerning each test are presented in this section.

Minimum test frequencies represent the least number of tests that should be taken to adequately assure that materials meet specifications, where contractors have reasonably effective quality control programs. Where problems are detected in contractors' quality control procedures on specific projects, more tests will be required to assure that materials meet specifications.

## *Embankment*

The earthwork acceptance tests analyzed were those required for density and moisture control. Table 2 below compares Department frequency practices with those of surrounding states.

**Table 2 — Surrounding States Test Requirements — Embankment**

| State | Density | Moisture | Remarks |
|---|---|---|---|
| South Dakota | 1/0.5 mile/zone | 1 each 2 hours | 4 zones * |
| Iowa | 1/lift/mile or 1/500 CY | 1/lift/1,500 feet | |
| Minnesota | 1/6" layer/0.5 mile | 1/6" layer/0.5 mile | Top 3 feet |
| | 1/12" layer/0.5 mile | 1/12" layer/0.5 mile | Below 3 feet |
| Montana | 1/4,000 CY | 1/4,000 CY | A1 through A3 soils |
| | 1/2,000 CY | 1/2,000 CY | A4 through A7 soils |
| Nebraska | 1/1,000 to 3,000 CY | 1/1,000 to 3,000 CY | Depending on soil type |
| North Dakota | 1/12" layer/1,500 feet per roadway | 1/12" layer/1,500 feet per roadway | |
| Wyoming | 1/4,000 CY | 1/4,000 CY | A1 through A3 soils |
| | 1/2,000 CY | 1/2,000 CY | A4 through A7 soils |

* Zone 1: 0 to 1 foot; 2: 1 to 3 feet; 3: 3 to 5 feet; 4: 5 feet to base (1 test per 4 feet)

Table 3, presented next, compares the Department's minimum testing criteria with the number of tests actually made. Actual tests do not include retests. The table also shows the number and percent of tests that failed. The total tests include the actual tests where minimum tests were specified. Density tests for backfill for pipes are not included in these tabulations.

**Table 3 — Test Frequency Data Summary — Embankment**

| Item/Test | Minimum Tests Specified or Total Tests | Minimum No. of Tests | Actual Tests | Actual as % of Minimum | No. of Tests Failed | Failed as % of Actual |
|---|---|---|---|---|---|---|
| Density | Min. tests specified | 594 | 737 | 124 | 0 | 0 |
| | Total tests | | 1223 | | 75 | 6.1 |
| Moisture | Min. tests specified | 593 | 1215 | 205 | 0 | 0 |
| | Total tests | | 1817 | | 19 | 1.0 |

To compare the various test frequencies, it is necessary to convert them to a common base. To accomplish this, an estimate of the minimum number of tests required by each agency was made for a one-half mile section of roadway for various average fill heights. For this estimate, a subgrade width of 54 feet was assumed. Four-to-one slopes were used for all calculations. The comparisons are shown in Table 4 on the next page.

**Table 4 — Comparison of Density Testing Requirements**

| Average Fill Height — Feet | | 3 | 5 | 7 | 9 | 11 | 15 |
|---|---|---|---|---|---|---|---|
| CY per 1/2 Mile | | 17,600 | 31,300 | 46,500 | 63,400 | 81,700 | 123,200 |
| **Agency** | **Testing Frequency** | **Minimum Number of Density Tests** | | | | | |
| South Dakota | 1/0.5 mile/zone | 2 | 3 | 4 | 4 | 5 | 7 |
| Iowa | 1/lift/mile[1] | 2 | 4 | 5 | 7 | 8 | 11 |
| **Proposed** | **1/12"-layer/0.5 mile** | **3** | **5** | 7 | **9** | **11** | **15** |
| Minnesota | 1/layer/0.5 mile[2] | 6 | 8 | 10 | 12 | 14 | 18 |
| North Dakota | 1/12" layer/1,500 feet | 5 | 9 | 12 | 16 | 19 | 26 |
| Montana | 1/4,000 CY- A1—A3 Soil | 4 | 8 | 12 | 16 | 20 | 31 |
| Wyoming | 1/4,000 CY- A1—A3 Soil | 4 | 8 | 12 | 16 | 20 | 31 |
| Nebraska | 1/3,000 CY[3] | 6 | 10 | 16 | 21 | 27 | 41 |
| Montana | 1/2,000 CY- A4—A7 Soil | 9 | 16 | 23 | 32 | 41 | 62 |
| Wyoming | 1/2,000 CY- A4—A7 Soil | 9 | 16 | 23 | 32 | 41 | 62 |
| Nebraska | 1/1,000 CY[3] | 18 | 31 | 47 | 63 | 82 | 123 |

### Density Frequencies

South Dakota has the lowest minimum density testing frequency requirement of any of the states in the comparison. The number of failing tests was only 6.1 percent — not a particularly high failure rate for earthwork. This indicates that contractors are attaining the desired compaction, or inspectors are being selective in choosing sites for tests. There is no evidence that the latter is true. Therefore, it must be assumed that compaction is being attained so increasing the minimum to the average of the surrounding states is not necessary. However, it is the Consultant's opinion that the minimum should be increased in view of the relatively high variance between the Department's practice and the prevailing practices of surrounding states.

The different test frequency requirements, in each of the four embankment zones, requires substantial record keeping on the part of density testers. That is necessary to ensure that the minimum requirements are met for each zone. The zones also apply to backfill for pipe culverts and other underground installations. The record keeping to ensure coverage in each zone is time consuming — time that might be better spent on inspection and testing. Minnesota, with two zones, is the only other adjacent state that has established minimum zone criteria.

***Recommendation No. 2-2*: Eliminate the zone requirements for embankment density testing, and change the minimum requirement to 1 density test per 12-inch layer per one-half mile of all embankment construction.**

---

[1] Assumed 8-inch lifts in accordance with specification book.

[2] Top 3 feet: 6-inch layers; below 3 feet: 12-inch layers.

[3] Depends on soil type.

### Moisture Test Frequencies

The minimum requirement for moisture tests is 1 test every two hours during grading operations. While the frequency for moisture tests is stated differently than the number of density tests, the test frequency data indicate that the minimum is essentially the same for both tests. South Dakota density test procedures require that a moisture test be taken each time a density test is made. While additional moisture tests may be needed to ensure that material is not too dry for compaction, the minimum is practically the same as the density testing requirement. Only one percent of the moisture tests failed. Despite this, twice as many moisture tests were taken as were required. Nearly all of the surrounding states use the same frequency for both moisture and density testing.

***Recommendation No. 2-3:* The minimum test frequency for embankment moisture tests should be the same as that for density testing.**

### Earthwork Moisture Requirements

Getting stability in the grade is difficult if the material is much wetter than optimum. Currently, South Dakota has no maximum moisture specification other than "too wet for density". During the interviews, it was suggested that the specifications be modified to include a maximum percentage. The results of a review of several recent specification books are summarized in Table 5.

**Table 5 — Embankment Moisture Requirements**

| State | Points Below Optimum | Points Above Optimum |
|---|---|---|
| South Dakota | 4 | Too wet for density |
| Arkansas | Substantially at optimum | Substantially at optimum |
| Indiana | 2 | 1 |
| Iowa | 3 | Not specified |
| Minnesota | None specified for 95% of maximum density; 35 for 100% of maximum density | 15 for 95% of maximum density; 2 for 100% of maximum density |
| Michigan | Not specified | 2 in top 3 ft.; 3 below 3 ft. |
| Montana | 2 | 2 |
| Pennsylvania | Not specified | Not specified |
| Ohio | Not specified | Not specified |
| Washington | 3 | 3 |
| Wyoming | 4 | 2 |

Most of the surrounding states do specify an upper limit on moisture, and we believe it is desirable to do so.

***Recommendation No. 2-4:* The specifications should be revised to provide an upper limit for the maximum permissible moisture content for embankments. The limit should be consistent with the characteristics of the soils on the project.**

## Base, Subbase and Cushion Courses

Table 6, on the next page, summarizes the base, subbase and cushion course gradation and density testing requirements that have been established by surrounding states.

Table 6 — Surrounding States Test Requirements — Base, Subbase, and Cushion Course

| State | Gradation | Density |
|---|---|---|
| South Dakota | 1/3,000 tons | 1/mile/lift/roadbed |
| Iowa — Subbase aggregates | 1/project | 1/3 miles (minimum 2/project) |
| Compacted base/subbase | 1/1,500 tons | 3/2-lane mile |
| Minnesota | 1/1,000 tons or 500 CY (compacted) | 1/layer/half mile |
| Montana — Aggregate surfacing | 1/1,500 tons | 5/test section (2,000 l.f.) |
| QA projects | 1/2,500 tons | 5/test section (2,000 l.f.) |
| Nebraska — Granular base | 1/500 feet | 1/1,000 feet (12" thick) |
| Crushed rock base | 1/200 CY | None specified |
| North Dakota | Per specifications | 1/lift/1,500 feet |
| Wyoming | 1/5,000 tons | 1/5,000 tons |

The table presented next compares the Department's current practices with its minimum testing criteria for the same types of construction. The number and percent of failing tests are also shown.

Table 7 — Test Frequency Data Summary — Base, Subbase, & Cushion Course

| Item/Test | Minimum Tests Specified or Total Tests | Minimum No. of Tests | Actual Tests | Actual as % of Minimum | No. of Tests Failed | Failed as % of Actual |
|---|---|---|---|---|---|---|
| Gradation | Min. tests specified | 208 | 217 | 104 | 4 | 1.8 |
| | Total tests | | 366 | | 9 | 2.5 |
| Density | Min. tests specified | 36 | 46 | 128 | 5 | 10.9 |
| | Total tests | | 150 | | 6 | 4.0 |

Note: Actual does not include retests.

South Dakota's requirements for gradation and density are near the average of those of the surrounding states.

**Gradation**

No change is recommended.

**Density**

No change is recommended.

## AC Paving

Table 8, on the next page, presents asphaltic paving aggregate gradation and density testing requirements for the Department and surrounding states.

**Table 8 — Surrounding States Test Requirements — AC Paving**

| State | Aggregate Gradation | Density |
|---|---|---|
| South Dakota | 1/1,200 tons | 1/1,000 tons |
| Iowa — Type A | 1/1,000 tons (at source)<br>3/lot (at plant) | As specified |
| Type B | 1/1,500 tons (at source)<br>3/lot (at plant) | As specified |
| Minnesota — QA specifications | 2/day/mix blend | 1,000 tons (minimum 2/day) |
| Specification 2331 | 1/day/mix | 1,000 tons |
| Montana — QA specifications | 1/600 tons | 1/600 tons |
| Non QA specifications | 1/5,000 tons | 1/1,000 feet of paver travel |
| Nebraska — Crushed gravel | 1/300 CY | Per specifications |
| Virgin aggregate | 1/1,000 tons | Per specifications |
| North Dakota | 1/1,000 tons (maximum 3 tests per day) | Per specifications |
| Wyoming | 1/5,000 tons | 1/300 tons or 5/lot |

As with the previous tests, Table 9, shown below, compares the Department's minimum testing criteria with its actual testing practices, and shows the number and percent of the tests that failed.

**Table 9 — Test Frequency Data Summary — AC Paving**

| Item/Test | Minimum Tests Specified or Total Tests | Minimum No. of Tests | Actual Tests | Actual as % of Minimum | No. of Tests Failed | Failed as % of Actual |
|---|---|---|---|---|---|---|
| Gradation | Min. tests specified | 259 | 353 | 136 | 28 | 7.9 |
| | Total tests | | 499 | | 28 | 5.6 |
| Liquid limit * | Min. tests specified | 18 | 24 | 133 | 0 | 0 |
| | Total tests | | 121 | | 0 | 0 |
| Plastic index * | Min. tests specified | 17 | 24 | 141 | 0 | 0 |
| | Total tests | | 49 | | 0 | 0 |
| Shale content * | Min. tests specified | 0 | 0 | | 0 | 0 |
| | Total tests | | 8 | | 0 | 0 |
| Density | Min. tests specified | 160 | 204 | 128 | 0 | 0 |
| | Total tests | | 466 | | 0 | 0 |

* Limited amounts of data were available.
Note: Actual does not include retests.

South Dakota's requirements for gradation and density for AC paving are near the average of those of the surrounding states.

**Gradation**

No change is recommended.

**Density**

No change is recommended.

## PCC Paving

Table 10 below presents course aggregate gradation, air content and slump testing criteria adopted by the Department and adjacent states for portland concrete paving.

**Table 10 — Surrounding States Test Requirements — PCC Paving**

| State | FA Gradation | CA Gradation | Air Content | Slump |
|---|---|---|---|---|
| South Dakota | 1/750 CY | 1/750 CY | 1/ 2 hours | 1/ 2 hours |
| Iowa | 1/1,500 tons (production) 3/lot (at plant) | 1/1,500 tons (production) 3/lot (at plant) | 1/1,000 CY for central mix 1/100 CY for transit mix | 1/1,000 CY for central mix 1/100 CY for transit mix |
| Minnesota | 1/500 CY (production) 2/day (at plant) | 1/500 CY (production) 2/day (at plant) | 1/300 CY (minimum 1/day) | 1/300 CY (minimum 1/day) |
| Montana | 1/750 CY | 1/750 CY | 1/100 CY (After 1st 3 loads) | 1/100 CY (After 1st 3 loads) |
| Nebraska | 1/100 CY | 1/100 CY | 3/day | Not listed |
| North Dakota | Continual | Continual | 1/2,000 SY (After 1st load, maximum 3 tests/day) | 1/2,000 SY (After 1st load, maximum 3 tests/day) |
| Wyoming | 1/5,000 tons | 1/5,000 tons | Not specified | Not specified |

The next table again compares the Department's current concrete pavement practices and resulting tests that failed. Comparisons for air content, slump and cylinder tests were not tabulated because the data were not readily available in the project summaries.

**Table 11 — Test Frequency Data Summary — PCC Pavement**

| Item/Test | Minimum Tests Specified or Total Tests | Minimum No. of Tests | Actual Tests | Actual as % of Minimum | No. of Tests Failed | Failed as % of Actual |
|---|---|---|---|---|---|---|
| Gradation - fine | Min. tests specified | 27 | 29 | 107 | 0 | 0 |
| | Total tests | | 86 | | 0 | 0 |
| Gradation - coarse | Min. tests specified | 34 | 34 | 100 | 1 | 1.0 |
| | Total tests | | 93 | | 3 | 3.2 |

Note: Actual does not include retests.

### Gradation

All adjacent states use the same testing frequencies for both fine and coarse aggregates. However some specify tests on the basis of cubic yards and others by tons. To convert the frequencies to the same base, a cubic foot of concrete was assumed to weigh 150 pounds or approximately 2 tons per cubic yard. The frequencies in cubic yards per test then are:

| | |
|---|---|
| Wyoming | 2,500 |
| **South Dakota** | **750** |
| Iowa | 750 |
| Montana | 750 |
| Minnesota | 500 |
| Nebraska | 100 |

Based on this analysis, no change in test frequencies for gradation analyses is recommended.

### Air Content and Slump

All of the agencies, including South Dakota, specify the same frequency for air content and slump. Again, a conversion is needed to compare the frequencies. For comparison purposes, it was assumed that a one-half mile of concrete, 8-inches thick and 24 feet wide (1,600 CY), is a typical 8-hour day's paving. On that basis, the minimum number of tests per day are:

| | |
|---|---|
| Iowa (central mix) | 1.6 |
| Nebraska | 3.0 |
| North Dakota | 3.5 |
| **South Dakota** | **4.0** |
| Minnesota | 5.3 |
| Montana | 16.0 |
| Iowa (transit mix) | 16.0 |

No change is recommended.

## *PCC Structures*

The following table presents portland concrete structure criteria for course aggregate gradation, air content and slump testing.

**Table 12 — Surrounding States Test Requirements — PCC Structures**

| State | FA Gradation | CA Gradation | Air Content | Slump |
|---|---|---|---|---|
| South Dakota | 1/100 CY | 1/100 CY | 1/2 hours | 1/2 hours |
| Iowa | 3 per lot | 3 per lot | 1/20 CY | 1/20 CY |
| Minnesota | 1/300 CY* | 1/300 CY* | 1-25 CY = 1 test<br>26-200 CY = 1/50 CY (minimum 2)<br>Over 200 = 1/75 CY (minimum 4) | 1-25 CY = 1 test<br>26-100 CY = 2 tests<br>Over 100 = 1/100 CY (minimum 2) |
| Montana | 1/125 CY | 1/125 CY | 1/100 CY | 1/100 CY |
| Nebraska | 1/100 CY | 1/100 CY | 1/day | As per contract |
| North Dakota | Not specified | Not specified | 1 each time a cylinder is cast (After 1st load) | 1 each time a cylinder is cast (After 1st load) |
| Wyoming | 1/500 CY | 1/500 CY | 1/25 CY | 1/25 CY |

* If also tested during production; 1/200 CY if not.

And the following table again compares the Department's current practice and results. As with PCC paving, air content, slump and cylinder tests were not tabulated.

**Table 13 — Test Frequency Data Summary — PCC Structures**

| Item/Test | Minimum Tests Specified or Total Tests | Minimum No. of Tests | Actual Tests | Actual as % of Minimum | No. of Tests Failed | Failed as % of Actual |
|---|---|---|---|---|---|---|
| Gradation - fine | Min. tests specified | 79 | 83 | 105 | 2 | 2.4 |
| | Total tests | | 133 | | 2 | 1.5 |
| Gradation - coarse | Min. tests specified | 67 | 70 | 104 | 2 | 2.9 |
| | Total tests | | 120 | | 5 | 4.2 |

Note: Actual does not include retests.

**Gradation**

As with PCC Paving, the requirements are the same for fine and coarse aggregates. The test frequencies, specified in cubic yards per test, are:

| | |
|---|---|
| **South Dakota** | **100** |
| Nebraska | 100 |
| Montana | 125 |
| Minnesota | 300 |
| Wyoming | 500 |

The Department has experienced a failed test rate of 1.5 percent for fine aggregate and 4.2 percent for coarse.

***<u>Recommendation No. 2-5:</u> Change the minimum test frequency for aggregate gradations for PC concrete for structures from 1 test per 100 CY to 1 test per 200 CY.***

This is about the average of the five states for which data were obtained.

**Air Content and Slump**

As with PCC paving, the frequency for air and slump tests is the same for nearly all adjacent states. Because of different units for test frequencies, the size of pour must be considered and the amount of time required to complete the pour must be estimated. For this purpose, it was assumed that typically a contractor would place 25 cubic yards per hour. The test frequencies, on that basis, are shown below as Table 14.

**Table 14 — Test Frequency Comparison — Air Content & Slump for PCC Structures**

| Size of Pour | | 25 CY | 100 CY | 250 CY |
|---|---|---|---|---|
| Hours per pour | | 1 | 4 | 10 |
| **State** | | **Tests per Pour** | | |
| Iowa | | 2 | 5 | 12 |
| Wyoming | | 1 | 4 | 10 |
| **South Dakota** | | **1** | **2** | **5** |
| Minnesota | Air content | 1 | 2 | 4 |
| | Slump | 1 | 2 | 3 |
| Montana | | 1 | 1 | 3 |
| Nebraska | | 1 | 1 | 1 |

The numbers of air and slump tests that failed were not tabulated. Except for Minnesota, the minimum number of air content and slump tests is the same. The test frequency for South Dakota is near the average of the surrounding states. No changes are recommended.

## Other Test Frequency Issues

Department procedures permit project engineers to request a reduction in the minimum test frequency requirements if project circumstances justify it. The provision as stated in the Materials Manual is:

> *When project quantities are too small to justify sampling and testing costs, or when small quantities of materials used will not have significant influence on performance, strength or durability of major items on construction, or when large quantities of material of known satisfactory history are used, a request may be made to the Materials and Surfacing Engineer, through the Region Materials Engineer, for permission to reduce or eliminate the Minimum Sample and Test Requirements.*

In practice, the project engineer must request the reduction and submit the reasons for the reduction through the area engineer. The area engineer then puts the request in writing to the regional materials engineer. The regional materials engineer confers with supervisors in the central laboratory. He then writes to the area engineer and project engineer either approving or rejecting the request. The process can be expedited through the use of E-mail or the telephone. The regional materials engineers and central materials engineers believe the process is working satisfactorily. A number of those interviewed in the field think the process takes too long.

Blanket approval may be given to eliminate shale tests, liquid limit and plasticity index tests for aggregates from ledge rock sources. However, the reduction of tests must still go through the request/approval procedure. Is it possible, since the source is usually known when the minimum test frequency requirements are determined, to automatically eliminate these unneeded tests to reduce the paperwork and time required for approval? Similarly, are fractured face tests needed for quarried material? Can these tests for sources that historically have always passed also be eliminated when the minimum test requirements are developed?

Currently, each project is treated individually as far as minimum test frequencies are concerned. Can stockpiles of aggregates be tested and approved for use on several projects to reduce the need for individual tests for each small project? This is especially needed for concrete aggregate tests for small bridge projects where the same source is used. The Materials Manual provides for accepting materials by transferring previously accepted material from another project. A Letter of Transfer (Form DOT-70) must document the transfer. Information collected during the field interviews indicates that this provision is not understood by many of the project engineers.

***Recommendation No. 2-6:* The procedures for setting the minimum test frequencies for projects and for requesting reductions in the minimums should be reviewed and revised, if necessary, to reduce the time required for approval.**

## Quality Control Testing

### Testing Assigned to Contractors

The traditional role of highway agencies in testing, and the need to increase the role of contractors is argued in an article in the June 1982 issue of Public Works (*3, page 14*):

*State highway agencies traditionally have assumed the responsibility for the tests and inspections necessary to assure conformance with the aggregate specifications. Occasionally, this has created serious problems. Legally, the responsibility for providing materials and products of the specified quality rests with the construction contractor. Whenever a State gets involved in the contractor's quality control activities, the State assumes an implicit liability for the quality of the product. In recognition of this, many States have imposed specific gradation control testing requirements upon the producer and the contractor.*

This is in keeping with the concepts promulgated by Dr. W. E. Deming, who is recognized as the father of quality assurance in Japan, of making producers responsible for quality control, and minimizing external quality control inspectors. Significant improvements have usually resulted from the implementation of this basic concept.

Few of the surrounding states require contractors to perform any testing for either quality or process control. In Iowa, contractors are responsible for aggregate gradation testing for asphalt and PC concrete, but not for testing of the mix. Contractors are required to have certified plant inspectors. Minnesota has a quality management program to certify plants. The requirement that contractors perform process control testing, and attain minimum quality assurance levels, is more widespread in other areas of the country.

South Dakota has taken a step in that direction. Currently, contractors are required to perform aggregate process control testing for AC paving, during the crushing process. Bid items for these tests are included in the contracts. Having a bid item for testing is a good transitional step, but ultimately quality control should be a contractor responsibility, and should be subsidiary to the item being produced. It was reported that contractors are paid for running P.I.s, when they are not needed, and in some cases where they are not actually run. This is related to the reduction of unneeded tests noted in Recommendation No. 2-6.

***Recommendation No. 2-7:** Assign production control testing of essentially all aggregates — especially base course, AC paving, PCC paving, and PCC for structures — to the producers, whether the material is crushed by suppliers or contractors.*

Contractors or suppliers should be responsible for controlling the quality of aggregates they produce, including conducting and documenting that minimum levels of quality control testing were done. The Department should be responsible for acceptance testing as the material is used. Because of limited staffing, a few project engineers have not performed tests on PCC pavement aggregates as they were produced. Instead, they relied on the producers' quality control testing and acceptance tests.

## Certified Plants and Technicians

Some states require that contractors' asphalt and PC concrete plants and that assigned testing technicians be certified. Minnesota certifies the plants but not the testing personnel. Iowa requires contractors to have certified plant inspector for PC concrete plants but does not certify plants.

One example where both plants and technicians are certified is the West Virginia Department of Transportation. The Department initiated a quality assurance program in 1976. The program requires that contractors provide and maintain a quality control system. (4, Page 34) A quality control plan must be submitted and approved for each project. The specifications provide that contractors are responsible for all quality control of:

- embankments and subgrade material;
- base courses;
- bituminous concrete;
- portland cement concrete paving; and
- portland cement concrete for structures.

Contractors must provide personnel who are qualified in the appropriate sampling and testing procedures. The Department developed procedures for examining and certifying contractor technicians in:

- aggregates;
- compaction;
- bituminous concrete;
- portland cement concrete.

Certification of Department personnel is provided for bituminous concrete, portland cement concrete, aggregate and bridge maintenance inspectors. Written and practical examinations are used to test applicants for certification. Study guides were developed to assist applicants to prepare for the examinations.

Department personnel are responsible for acceptance testing. They may either run separate tests or observe tests performed by contractor personnel.

Bituminous and portland cement concrete plants must be certified. Check lists are used to inspect plants for certification. A sample check list for inspection of a bituminous concrete drum plant is provided in Appendix E. Check lists are also available for bituminous concrete batch plants, bituminous concrete continuous plants and portland cement concrete plants.

## *Certifications*

Section 6.3 of the South Dakota Standard Specifications for Roads and Bridges, 1990 Edition, states:

> *.........The Contractor shall furnish certifications for all materials designated in the Contract or the Department's Materials Manual that will be accepted by certification. Unapproved materials shall not be used and will be subject to inspection, test, rejection and removal at no additional cost the Department. ..........*

Receipt of these materials certifications is a problem for nearly all regional materials engineers. Most of the surrounding states reported some problem getting contractors and suppliers to submit certifications, and most, as the Department does, make progress payments even if certifications have not been received. Final payments are withheld until all certifications have been received. Wyoming is an exception in that neither progress nor final payments are made until certifications are received. Section 700.01 of the 1987 Wyoming Standard Specifications provides:

> *.............Items manufactured and not controlled by job control samples and check samples, or which are tested by an authorized testing agency, shall be accompanied to the project with the manufacturers certification that the item conforms to the specifications. ...............*
>
> *In the case that an emergency condition exists, the engineer may allow the Contractor to incorporate an item or items into the work without required certifications...................Payment shall not be made for an item or items until all specification requirements have been met and the required certifications have been received by the Engineer.*

No material should be incorporated into the work unless it has been tested or certificates are submitted. If the engineer permits material to be incorporated into the work without the certifications, no payment should be made for the bid item involved until the certifications are received. The Department should not wait for the final payment process to withhold payment. The need for certifications and attention to the specifications must be emphasized at each pre-construction conference. A check list of certifications needed should be given to the contractor and the project engineer at that meeting.

> ***Recommendation No. 2-8:* Revise the standard specifications to require submission of certifications prior to incorporating materials into the work and prohibit making progress payments for any bid item until all certifications for that item are received.**

If certifications are to be of any value in ensuring that materials do meet the required specifications, a verification procedure is needed. (*5*) This procedure should provide for check tests to ensure that the supplier's quality control program is producing materials in compliance with the specifications.

## *Approved Products List*

The Department maintains a list of approved products. These approved products may be used by the contractors without their having to furnish a certificate of compliance. Products such as concrete admixtures, castings for drainage, paints, guard rail and treated wood are included on the list. The list also includes concrete mix designs for approved concrete producers throughout the State.

The approved products list includes approval of some concrete sources for mix designs, where aggregates have been previously tested and found to be consistently acceptable. Can previously tested quarries be included on the approved products list for other uses, such as base course or asphalt paving, with similar approval procedures?

Can the list of approved products be further expanded to reduce certifications?

## Quality Assurance Specifications

One objective of this study was to identify opportunities for the Department to expand its use of end-result or statistical specifications. Examples of end-result specifications that were identified in the study are summarized in this section. Because of the limited resources for completing the study, no effort was made to evaluate these specifications for use in South Dakota. Specifications from the New Jersey DOT were included with those of surrounding states because that state has earned a reputation of being a leader in the use of statistical specifications.

Currently, South Dakota's specifications provide for pay adjustments for deficiencies in PCC pavement thickness and surface roughness. The specifications provide for a bonus payment for very smooth PCC pavement. These are included with the other specifications in the examples that follow.

### Control of Aggregate Gradation

***Wyoming.*** This specification applies to the production of aggregates with requirements for grading — subbase, base or pavement. It is based on the average of five tests per lot and provides a pay factor from 75 percent to 105 percent for each lot. Material that has a pay factor below 75 percent is rejected.

### Control of Aggregate Gradation for Recycled Hot Plant Mix Bituminous Pavement

***Wyoming.*** This specification applies to the virgin aggregate added to the recycled material. It is similar to the specification for aggregate gradation above except that the percent of virgin material in the total mix is considered in establishing the pay factor. The pay factor varies from 83 percent to 103 percent.

### Aggregate Base Course Density

***New Jersey.*** Two methods are used: control strip and compaction acceptance testing. The second is a statistical specification. The base course is divided into lots of approximately 5,000 square yards or 1,000 cubic yards. Each lot is tested. Any lot that is determined to have more than 20 percent that does not meet 95 percent compaction, must be reworked, recompacted and retested. No adjustment in payment is made.

### PCC Pavement Thickness

***South Dakota.*** A deduction in payments is made for units of PCC pavements and shoulders that are deficient in thickness. One core is taken at a random location in each unit. Units of 8-inch thick pavement with deficient thicknesses of up to 1 inch are subject to proportional payments of 50 percent to 100 percent of the bid price, depending on the severity of the deficiency. Proportional payments for pavements more than 8 inches thick range from 55 percent to 100 percent. Shoulders deficient in thickness up to 1 inch are paid proportionally from 50 percent to 100 percent. Areas deficient in thickness greater than 1 inch must be evaluated by the engineer.

***Iowa.*** The pavement is cored by lot. Each area or lot is classified into one of 8 bands depending on the deviation of the cores from plan thickness. Payment ranges from 60 percent for band 7 to 105 percent for band 1. No payment is made for band 8. Pavements in band 8 may have to be removed and replaced.

***New Jersey.*** A lot consists of 15,000 square yards of surface area. Fifteen random cores are taken for each lot. The average thickness of the 15 cores must be equal to or in excess of the specified thickness and no more than two of the 15 cores can be deficient by more than 1/4 inch. If the average thickness is less than that specified, a formula is used to determine the payment reduction. If more than two cores are short by more than 1/4 inch, payment for the lot is reduced by 2 percent.

### PCC Pavement Surface Requirements

***South Dakota.*** The Department has two surface tolerance measures: ten-foot straightedge and profilograph. Either may be specified for a particular project.

Pavement surfaces tested with the ten-foot straightedge have a permissible longitudinal and transverse surface deviation of 1/8 inch in 10 feet. The permissible deviation for pavement used for rest areas, weigh stations, ramp entrances, shoulders and the like is 1/4 inch in 10 feet. Areas where the deviation exceeds the permissible deviation by not more than 3/8 inch will either be ground to bring the area within the tolerance or accepted without corrective action, at a reduced rate of payment, at the discretion of the engineer. Areas where the deviation exceeds the permissible deviation by more than 3/8 inch will be ground to bring the area within the tolerance, accepted without corrective action at a reduced rate of payment, or removed and replaced — at the discretion of the engineer. For deficient areas accepted without corrective action, the rates shown on the following page, will be deducted from the contract amount:

- ten dollars per square foot for areas where the maximum deviation exceeds the permissible deviation by not more than 1/8 inch;
- twenty dollars per square yard for areas where the maximum deviation exceeds the permissible deviation by more than 1/8 inch but not more than 3/8 inch; and
- thirty dollars per square yard for areas where the maximum deviation exceeds the permissible deviation by more than 3/8 inch.

When the profilograph is specified, two passes will be made in each driving lane, one in each wheel path. The contractor is required to provide the profilograph, operate it and furnish a profilogram to the Department for each day's run. The cost is incidental to the paving bid items. The Profile Index shall not exceed 10 inches per mile on areas to be tested. Driving lanes with an average Profile Index exceeding the tolerance by no more than 10 inches per mile may be corrected by grinding, or by accepting the affected area with a price reduction of one percent of the contract unit price for every inch above the value specified — at the discretion of the engineer. Driving lanes with an average Profile Index exceeding the tolerance by more than 10 inches per mile will be corrected by grinding, or by removing and replacing — at the discretion of the engineer. Individual bumps in excess of 0.3 inch shall be corrected by grinding, or removed and replaced at the discretion of the engineer. Bumps less than 1/4 inch in 10 feet may be accepted without correction. An incentive payment of one percent of the contract unit price will be made to the contractor for every inch the average Profile Index in any 0.1 mile segment is under five inches per mile. Surfaces cannot be improved by grinding to earn the incentive bonus.

***Iowa.*** The pavement smoothness specification applies to primary and interstate pavement surfaces for both PCC and AC pavements, as well as for bridge decks. Smoothness is tested with a 25-foot California profilograph. Testing is performed by the agency unless the contractor elects to furnish profilograph test results showing work is in compliance. Where it is approved to accept contractor test results, the agency performs only monitor testing. (6, Page 341-346)

The test results are evaluated. Corrections may be required for bumps, or smoothness, or both. All bumps exceeding 0.5 inch in a 25-foot distance must be corrected. The final profile index, following corrections, cannot exceed 15 inches per mile for interstate pavements (Chart A smoothness). For bridge decks and overlays, the profile index shall not exceed 60 inches per mile. For all other pavements, the index cannot exceed 36 inches per mile.

The contract bid price per square yard, for PCC pavement and pavement patching, and the contract price per ton for AC concrete and asphalt cement, are adjusted according to the following schedules, based on the final profile index:

**Chart A**

| Final Profile Index | Percent of Contract Unit Price |
|---|---|
| 0.0 - 15 | 100.0 |
| 15.1 - 18 | 98.0 |
| 18.1 - 21 | 94.5 |
| 21.1 - 24 | 91.0 |
| 24.2 - 27 | 87.5 |
| 27.1 - 30 | 84.0 |
| 30.1 - 33 | 80.5 |
| 33.1 - 36 | 77.0 |

**Chart B**

| Final Profile Index | Percent of Contract Unit Price |
|---|---|
| 0.0 - 30 | 100.0 |
| 30.1 - 40 | 95.0 |
| 40.1 - 50 | 90.0 |
| 50.1 - 60 | 80.0 |

Only the final surface course of AC concrete will be tested for smoothness. The corresponding price adjustment will apply to the full paving depth.

The contract price per cubic yard for structural concrete in new bridge decks, or the contract price per square yard for bridge deck overlays, is adjusted according to Chart B.

***Minnesota.*** The contractor is required to furnish and operate a California-type profilograph to test the smoothness of PCC pavements to determine corrective work needed. (7, Pages 215-218)(8, Page 24) Following any corrective work, the Department tests each lane of main line paving with its high-speed profilograph. A riding quality of 23.99 Root Mean Squared Acceleration (RMSA), or less, is considered acceptable. Sections or subsections that do not have an acceptable riding quality are accepted at the unit bid price, less a payment deduction as follows:

| Roughness (RMSA) | Price Reduction — Dollars/Square Yard |
|---|---|
| 24.00 - 25.99 | 0.25 |
| 26.00 - 27.99 | 0.75 |
| 28.00 - 29.99 | 1.25 |
| 30.00 - 31.99 | 2.00 |
| 32.00 and above | Remove and replace or plane texture |

A bonus is paid for exceptionally smooth pavement sections or subsections as follows:

| Roughness (RMSA) | Bonus — Dollars/Square Yard |
|---|---|
| 18.00 - 16.01 | 0.25 |
| 16.00 and below | 0.50 |

Price reductions or bonuses are not provided for AC paving smoothness.

*New Jersey.* The surface is tested with a 10-foot rolling straightedge that automatically marks the length of surface variations that exceed 1/8-inch in 10 feet. No more than 5 percent of each lot may exceed the 1/8-inch in 10 feet tolerance on new mainline pavement.

Surface tolerance lots are equal to the square yards placed in each production day. The surface tolerance is tested in the wheel paths. The percent of the lot that is defective is computed by dividing the length of defective areas (more than 1/8 inch in 10 feet) by the total length tested, and multiplying by 100. A sampling plan is specified which may require testing of 25 percent to 100 percent of the lot. Payment reductions of 0 to 5 percent are specified for defective percentages up to 13.9 percent. Lots with defective percentages of 14 percent or more may be removed and replaced or retested. If they remain in place, payment is reduced by 16 percent.

***Wyoming.*** Measurement of the surface roughness of concrete pavement is to be made with a California-type profilograph. Each days run is expected to have a Daily Average Profile Index (DAPI) of 7 inches per mile or less. All deviations in excess of 0.3 inches in 25 feet must be removed. Incentive payments are made for daily pavement runs where the DAPI is less than 7 inches. A second special provision provides for a DAPI of 15 inches for use on city streets.

## PC Concrete Strength

*New Jersey.* Test cylinders are made and tested. If the cylinders fail, the pay adjustment is computed by formula, provided that no individual test falls below the retest limit. If that happens, the concrete represented by the failing test may be cored. If the cores fail, the contractor can remove and replace the material at no cost to the state or, if it is approved, leave the material in place and accept a 50-percent pay reduction.

## Asphalt Concrete Mixtures

*New Jersey.* Tolerances are specified for deviations from the job mix formula, asphalt content, aggregate passing the No. 8 or No. 200 sieves, and nonconformance to stability requirements. Reductions in payments vary depending on the extent of the deviations.

## AC Pavement Thickness and Density

***Iowa.*** The pavement is cored and the cores are tested for density and thickness. The payment schedule for the Quality Index — Density ranges from 75 percent to 100 percent. The payment schedule for the Quality Index — Thickness similarly ranges from 75 percent to 100 percent.

***Minnesota.*** Minnesota provides two methods for control of compaction: the control strip method density and specified density.

Under the control strip method, acceptance is normally made in lots equal to the number of tons of mix placed in each lift on each production day. Each lot is divided into 5 sublots of approximately equal area. Production of less than 500 tons may be combined with the next day's production to form a lot. One density test is made with a nuclear testing device at randomly selected locations in each sublot. The relative density for each test is determined by dividing the site density by the appropriate mean control strip density and multiplying by 100. The mean and the range of the relative densities of the five sublots are determined and inserted into the following equation to determine the quality level of each lot.

Quality Level = Mean Relative Density - (0.60 X Range)

If the quality level of any lot is less than 95.5, payment for the bituminous mixture will be reduced as follows:

| Quality Level | Pay Factor (% of Contract Price) All Mixtures |
|---|---|
| 95.5 or higher | 100 |
| 94.5 to 95.4 | 97.5 |
| 93.5 to 94.4 | 95 |
| 92.5 to 93.4 | 90 |
| 91.5 to 92.4 | 80 |
| 91.4 or lower | Disposition determined by Engineer |

Where specified density is required, each lift is to be compacted to not less than 95 percent of the Marshall density. The contractor takes core samples under the supervision of the Engineer for testing by the Department. At least one sample is taken for each 1,000 tons, or fraction, in each course. Areas with failing densities cannot be accepted at the contract unit price but, instead of being removed and replaced, are accepted at a reduced price as shown in the table below:

| Field Density (% of Marshall Density) | Pay Factor (% of Contract Price) |
|---|---|
| 95.0 or higher | 100 |
| 94.0 to 94.9 | 99 |
| 93.0 to 93.9 | 97.5 |
| 92.0 to 92.9 | 95 |
| 91.0 to 91.9 | 92.5 |
| 90.0 to 90.9 | 87.5 |
| Less than 90.0 | Remove and replace |

In addition to the above specifications, the 1991 Minnesota Supplemental Specifications provide for quality assurance specifications for plant mixed bituminous pavement. Under this specification, lots are selected, as mentioned above, to represent a day's production, and each lot is divided into five sublots. Two cores are taken at random locations in each sublot by the contractor. (Companion cores are taken at three of the coring locations, as selected by the Engineer, for testing by the Department to verify contractor test results.) The contractor tests the cores in the presence of the Engineer. The density must be 91 percent of the maximum specific gravity based on the grand average of the five sublot averages, with no individual sublot average below 89 percent of the maximum specific gravity. The maximum specific gravity value, for calculating the percentage density, is the average value of all tests conducted the same day the lot was placed and compacted. Payment for compaction of the completed pavement is by lot based on the maximum specific gravity obtained, using these pay factors:

| Mean of 10 cores as % of Maximum Specific Gravity | Pay Factor A (% of Contract Price) |
|---|---|
| 91.0 % or greater | 100 |
| 90.0 % to 90.9 | 99 |
| 89.0 % to 89.9 | 97.5 |
| 88.0 % to 88.9 | 95 |
| 87.0 % to 87.9 | 92.5 |
| Less than 87 % | 70 % if it is allowed to remain in place |

| Lowest Mean of Any Sublot Average | Pay Factor B (% of Contract Price) |
|---|---|
| 89.0 % or greater | 100 |
| 88.0 % to 88.9 | 99 |
| 87.0 % to 87.9 | 98 |
| 86.0 % to 86.9 | 97 |
| 85.0 % to 85.9 | 96 |
| Less than 85 % | 80 % if it is allowed to remain in place |

Total Pay Factor = (Pay Factor A) X (Pay Factor B)

***New Jersey.*** Fifteen cores are taken in each lot and the thicknesses are compared with the specified thickness, and the acceptance testing limit. From this a QL is computed. QL = the average lot thickness minus the thickness testing limit divided by the average range. A reduction in payment is made, depending on the QL, from none to 50 percent. Any pavement that does not qualify for at least 50 percent payment must be removed and replaced, or overlaid.

### Air Voids Acceptance Plan

***New Jersey.*** Compaction of AC pavement is measured by the percent of air voids instead of regular densities. Five cores are taken at random locations from each lot (approximately 5,000 square yards). Statistical methods are used to determine the percent of the lot that is defective. Pay adjustments are made in accordance with a formula.

### Quality Assurance for South Dakota

Gradually, the use of quality assurance specifications is increasing nationally as more states utilize them. The major advantage of QA specifications is that the responsibility for quality is assigned to those responsible for production — the contractors and producers. The use of penalties and bonuses motivate contractors to improve quality and ultimately, to take more pride in quality work. In the long run, contractors who pay attention to quality rarely have work rejected or have to re-do work.

Contractors must staff to provide the expertise to perform the QA sampling and testing. This is not a particularly difficult problem for larger contracting firms. It may be for small contractors, although they can take advantage of consulting engineering firms, to provide this service. Still, the use of QA specifications on most small projects is not warranted.

***Recommendation No. 2-9:* *The Department should expand its use of end-result and statistical specifications, especially on larger projects.***

## Inspection

### Earthwork

A major concern identified in the initial interviews is the role of grading inspectors and density testers. On many projects the grading inspector also serves as the density inspector. Where densities are tested with the balloon or sand cone methods, the inspector must leave the grade for the field laboratory long enough to run the tests, which may be a significant portion of the day. Thus there is no inspector on the grade while the tests are being run.

This practice was confirmed during our visits to projects. Many of the grading projects had only one inspector for grading and density testing. Others had a full-time grading inspector and a density tester. Usually the density tester also inspected the pipe installations. Is a full-time grading inspector needed? In our opinion, a grading inspector is needed essentially full-time to ensure that the contractor's grading operation is carried out uniformly so that randomly taken moisture and density tests truly represent actual compaction. There are two options for accomplishing this:

1. always assign a grading inspector and a density tester to each project — at least for major earthwork projects; or
2. take advantage of testing procedures which allow the grading inspector to remain on the grade while taking moisture and density tests.

Where the nuclear gauge can be used, the grading inspector can take the densities and remain on the grade nearly all of the time, once the gauge is calibrated. However, calibration requirements deter the use of the nuclear gauge on all small projects. Testing Procedure SD 114 provides that ten tests be taken, as follows, to calculate the density correction for the nuclear gauge:

- ten gauge moisture tests,
- ten gauge density tests,
- ten oven-dry moisture tests, and
- ten sand-cone or balloon density tests. (*9*)

Although the procedure does not address how often the density correction for a gauge must be made, the practice is to require it on every project. Consequently, it is practical to use the nuclear gauge only on major grading projects.

The Department's calibration procedure is one of the accepted methods approved by AASHTO. (*10, pages 917-919*) The AASHTO procedure also provides for calibration with blocks of known density. The AASHTO procedure does not specify how frequently that calibration curves should be checked — whether it should be once per project or once per season. For the backscatter method, users are cautioned to check the calibration curves for testing materials that are distinctly different from material types previously tested.

The review of practices in surrounding states showed mixed use of the nuclear gauge for earthwork moisture and density testing.

- Iowa uses nuclear gauges some on soils. Gauges are calibrated annually in the central lab and are correlated for moisture in the field.
- Minnesota uses sand cones and nuclear gauges for earthwork. They do not correlate between the two methods.

- Montana uses nuclear gauges for all density testing. Sand cones or balloons are used only when a nuclear gauge is not available. They do not correlate gauges with either of the other methods.
- Nebraska does not use nuclear gauges for earthwork.
- North Dakota uses the balloon method for earthwork although their experience with nuclear gauges indicated that it was accurate, if the direct-transmission mode was used.
- Wyoming uses the sand cone for earthwork.

Another practice that permits the grading inspector to take the moisture/density tests and remain on the grade is followed in Michigan. To ensure that the inspector does not have to leave the grade, pickups are equipped with self-contained density kits that include all equipment needed to conduct the tests. No field laboratories are used. Early kits included a two-burner propane stove for drying samples. The stoves have been replaced with Speedy moisture meters in most kits. Present day kits include a volumeter and a Speedy and are supplemented with a nuclear gauge. A list of equipment furnished in density kits is shown in Appendix C. The Department now has 76 nuclear gauges. They are used for most earthwork moisture and density tests. Although all gauges may be operated in either the backscatter or direct-transmission mode, only the direct-transmission mode is used for earthwork testing.

To be effective, grading inspectors must spend essentially all of their time on the grade. More efficient use can be made of grading inspectors if they also take the moisture/density tests — so long as it does not take them away from the grade for any length of time.

***Recommendation No. 2-10:* The Department should revise its procedure to permit correlation to be used on adjacent projects, to take advantage of the faster testing capability of nuclear gauges on more projects, while allowing the grading inspector to remain on the grade.**

It should be noted that the same gauge would be required for the correlation to be valid.

***Recommendation No. 2-11:* Vehicles should be equipped with self-contained density kits. These kits should include either Speedy moisture meters, or stoves for drying samples, so grading inspectors can perform complete tests without the need for a field laboratory.**

It was observed that the installation of storm sewers was a continuing operation — trenching, pipe placement and backfilling were all underway at the same time. Any time that a density test was taken, backfilling had to stop to permit the inspector to take the test. The use of nuclear gauges can reduce the time required for the test. Quicker tests inconvenience the contractor less so inspectors would be less likely to skimp on tests.

### Record Samples

Record earthwork samples must be taken every 500 feet on the finished grade for submission to the central laboratory for testing. These tests include liquid limit, plasticity index and soil classification. The purpose of these tests is to provide a historical record of the actual soils in the finished subgrade. There is a perception by some field engineers that these samples are taken to check the design of the surfacing section. The surfacing is frequently placed before the results of the tests are known, especially on projects where surfacing is included in the grading contract. The need for these samples was questioned.

## *Pipe Inspection*

Inspection of the installation and backfill of pipes, storm sewers, water lines and other underground facilities is normally performed on a part-time spot inspection basis. As noted earlier, earthwork density testing and pipe inspection are frequently assigned to the same technician. It appeared, on some of the projects visited, that inspection of pipe installation and backfill was marginal because of the limited number of inspectors. Because any settlements around underground installations are reflected in the driving lanes, this is not the place to skimp on inspection or testing.

## *Weighing Material*

Most, if not all, of the contractors who win the larger AC paving projects have plants with automatic scales. The use of automatic scales should eliminate the need for a weigher, although one automatic plant was observed where the contractor demanded that the weigher hand tickets to the truck drivers. The weigher, a seasonal employee, tore the weigh ticket from the printer, looked up the spread on a chart and wrote it on the ticket, and then handed it to the truck drivers. The checker could have used the same chart when he received the ticket.

On large asphalt paving projects the plant inspector is kept quite busy running gradation tests, sampling asphalt cement as it is delivered, running Marshalls where they are required, watching the plant operations, etc. Where production is high, the weigher should be assigned as a helper to the plant inspector to assist with the sampling, testing and inspection. While this would result in no reduction in staffing, it would be a better use of staff.

> ***Recommendation No. 2-12:** Automatic scales and ticket printers should be required for all AC paving projects with quantities above a preset limit. Specifications should be revised so Department weighers are not required. To encourage competition from contractors with older plants, automatic scales should not be required for small projects.*

Consideration should also be given to paying for cushion course and subbase by in-place cubic yards to eliminate the need for the weigher and checker.

## *Payment for Watering*

Measurement and documentation of the use of water for earthwork, cushion courses, subbase and base are difficult. Inspectors have little choice but to accept the word of the water truck drivers as to the number of loads hauled each day. The South Dakota 1990 Standard Specifications provide for payment of water for earthwork, subbase, base course, gravel cushion and gravel surfacing. Should water for these items be made subsidiary to other bid items and eliminated as a separate bid item to reduce the inspectors' work load?

A review of specifications from adjacent states concerning payment for water provided the following information:

- In the 1984 Iowa Standard Specifications, water is an incidental item for earthwork when compaction with moisture and density control or moisture control is specified in the 1984 Iowa Standard Specifications. If neither is specified, water for earthwork is a separate pay item but it is not for base courses.
- The 1987 Wyoming Standard Specifications provide for payment for water for earthwork, aggregate subbase and base courses.

- The 1987 Montana Standard Specifications provide for payment for water for maintenance of traffic and detours, but water for embankment, roadbeds and surfacing aggregates is incidental to other pay items.
- The 1991 Minnesota Supplemental Specifications changed the description of watering to eliminate payment for water used in conjunction with compacting soil or aggregates. Only water used for dust control is now eligible for payment.

Specifications from other adjacent states were not available.

The 1988 Minnesota Standard Specifications were similar to those currently in use in Wyoming. The more recent Supplemental Specifications eliminate payment for water except for dust control. It appears that, except for Wyoming, the trend is towards making water an incidental item for earthwork and base courses, and providing payment only when used for dust control.

Documentation of water usage is currently handled by the grading inspector as a secondary duty. Elimination of water as a pay item will not change the amount of time required for inspection but it would free the inspector for more important inspection items.

***Recommendation No. 2-13:*** ***Water used for earthwork, cushion courses, subbases, and base courses should be incidental to the bid items and not paid separately. Payment should be continued for water used to control dust to ensure the safety of the public.***

### Concrete Plants

CEMMS planning standards for the staffing of concrete plants is based on having two people at the plant, probably a tester and a plant inspector. We had no opportunity to observe the staffing at a concrete plant, but in our discussions it appeared that testing was a part-time function, and that a plant inspector was assigned only when there was a pour. This is a logical way to staff. No change is recommended.

## Staking

The major objective of this study was to review testing and inspection requirements. However, staking activities do require manpower. Any manpower made available by reducing the requirements for staking can be utilized for other work including inspection and testing.

### Final Cross Sections

It appears that pay quantities for earthwork on most major projects, are determined from final cross sections. Some, mostly small projects, are set up for earthwork to be paid as plan quantity. Staked quantities are used as the basis for payment on a few projects. Section 120.4, Method of Measurement, of the 1990 South Dakota Standard Specifications provides, in part, that:

> *Accepted quantities of excavation will be measured in its original position by cross sectioning. The area excavated will include overbreakage or slides not due to carelessness of the Contractor. Where it is impractical to measure material by this method, acceptable methods involving three dimensional measurements or measurements in the hauling vehicle may be used.*
>
> *With written agreement between the Contractor and the Department, excavation which conforms to the staked lines and grades may be computed using original cross sections and staked sections.*

*When specified, plan quantity will be the measurement for payment, provided the project is constructed to the lines and grades specified. Measurements will not be made except those necessary to determine that the work has been performed in conformance with the plans and to measure changes which increase or decrease quantities. Such areas will be measured, differences in quantities computed and deductions or additions made.*

Taking final cross sections requires extra manpower and cannot be completed until the earthwork is completed. Computation of final quantities can be started much earlier if payment is based on staked quantities. No computations are needed for payment of plan quantities unless there are changes to plan quantities.

Because final cross sections are taken after the project is complete, usually in the late fall, the savings in man-hours will not be of any significant help in increasing the manpower available for inspection and testing. However, it will increase manpower availability for completing final estimates and preliminary surveys.

***Recommendation No. 2-14*: All projects should be set up to pay for earthwork by either (1) staked quantities plus or minus changes or (2) plan quantity.**

Final cross sections will still be required to determine borrow pit quantities, of course.

A section from Section 203.09, Method of Measurement, from the 1987 Montana Standard Specifications may be of use in revising the South Dakota specifications.

***(A) Excavation.*** *The quantities, in cubic yards, of unclassified excavation, unclassified borrow, special borrow, unclassified channel excavation, street excavation, and muck excavation for which payment will be made will be the staked quantities calculated in accordance with Article 109.01.*

*Remeasurements will be taken only: (1) in areas of slides not attributable to the fault of the Contractor; (2) in areas where excavation outside the staked lines and grades was authorized by the Engineer; (3) in unstaked areas such as borrow areas, muck excavations, subexcavations, and in other unstaked excavations authorized by the Engineer. These areas of excavation and borrow will be measured in the original position by cross section the area excavated; and (4) if a disagreement occurs over the accuracy of quantities computed from the staked lines and grades, either party to the contract may request remeasurement of specific areas of the work.*

Section 109.01 states:

*In computing volumes of excavation, the average end area method or other acceptable methods will be used.*

## Assignment of Staking to Contractors

Most construction staking is performed by Department forces. Currently, any staking that cannot be done by Department forces is assigned to consultants. Department procedures are designed to permit hiring consultants with very short notice.

The states adjacent to South Dakota perform nearly all staking with in-house forces. Iowa and Minnesota have assigned staking to contractors on a few selected projects. North Dakota plans to require contractors to do more staking. Contractor staking is used to a greater extent in other parts of the country. Making construction staking a contractor responsibility has some of the same advantages of assigning QC testing to contractors — it puts the responsibility for staking on those who use the stakes. It encourages contractors to be innovative in providing and saving the necessary stakes.

Despite the prevailing practices in the region, consideration should be given to having contractors provide their own stakes for selected items, at least on projects where Department personnel are in very short supply. Items such as staking for PCC paving, grade control for subgrades and structure staking could be assigned to contractors. The inspectors would maintain control by spot checking. Many of the personnel currently assigned to survey crews would then be available for inspection and testing assignments.

***Recommendation No. 2-15:* The Department should assign staking to contractors for selected activities and projects where it is difficult for the Department to provide survey personnel, either because of location or staffing shortages.**

## Field Office

Currently, project engineers prepare a draft of the weekly progress reports and bi-weekly progress estimates manually. A clerk in the area office key punches this information to produce the completed reports for distribution. For engineers trained in the use of the computer, it would be easier to enter the information directly rather than writing it out long hand. The clerk should still process and distribute the completed reports. Screen formats for the computers would make entering the data easier for both the project engineers and clerks. Project engineers without computer expertise could continue with the manual preparation of these reports until they learn to use computers.

The use of PCs can reduce the level of effort required for preparing reports, estimates and quantity computations. The prices of PCs are dropping rapidly. While these findings alone may not justify computer purchases, an argument we find compelling was presented in some field interviews. Younger engineers typically have computer training. Moreover, they equate computer availability with progressive, modern organizations. If many national studies can be believed, as we think they can, recruiting and retaining engineers and technicians will be even more difficult in the next ten years than it has in the past ten. Providing these personnel with the modern tools of the trade may become a critical issue.

***Recommendation No. 2-16:* It is recommended that a program to equip field project offices with personal computers be initiated. Training and software must be provided with the computers.**

## Staffing

Staffing levels for field construction were obtained as of June 1989 and April 1991. A comparison of staffing as of those dates is shown on the next page as Figure 5.

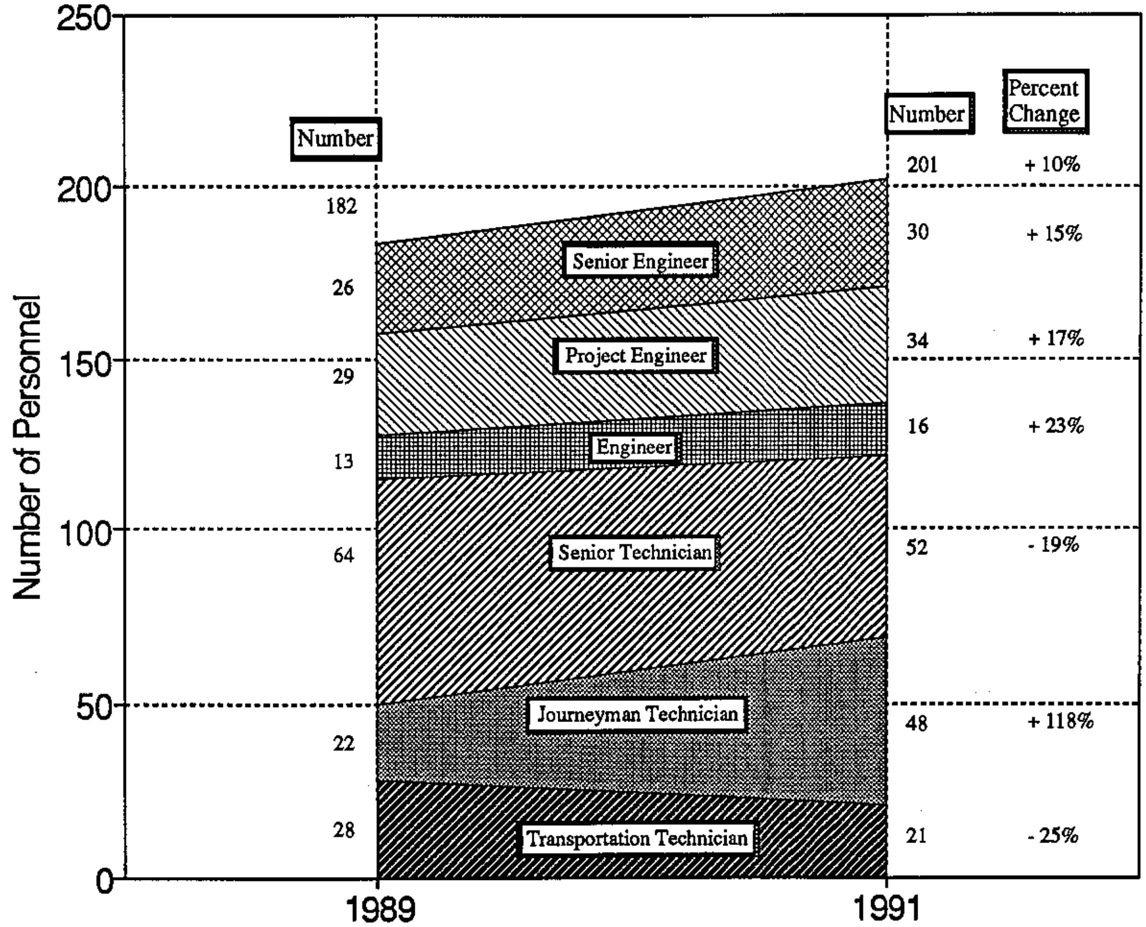
Overall there was a significant loss of experienced personnel — 19 percent reduction — in the senior technician classification. The number of journeyman technicians increased even more in an effort to compensate for the loss of experience at the higher level. While the significant loss in the numbers of senior technicians is a matter of concern, the growth in the number of field engineers is encouraging and a circumstance not many agencies have been able to realize in recent years.

In the course of the study, these field observations were made:

- No projects were visited which appeared to be over staffed. However, some were marginally staffed.

**Figure 5 -- Construction Staffing**

**June 1989 and April 1991**




- No major problems were identified which could be attributed to lack of adequate staff.
- The practice of hiring college students for summer work leaves most projects short handed in mid-August when they return to school. In some instances, replacements must be recruited which increases the training problem.
- The work loads in the regions vary significantly from year to year. One year they may be short-handed and the next they may be looking for work. These fluctuations further complicate staffing of construction projects. Can the work loads of the regions be considered in setting the letting schedules? A minor change in the letting date of a few months, one way or the other, could make a significant difference in balancing staffing with the work load.

## *Use of Consultants for CEI*

The use of consultants to supplement Department forces for construction engineering is increasing. The trend, in terms of percent of total contract payments and percent of contract payments for work done by consultants, is shown in Figure 6 on Page 38.

Trends shown in this graph are supported by the data presented in Table 15 on the next page. They show that payments to consultants for construction engineering increased from six percent of total engineering costs, in 1988, to nearly one quarter of the total in 1991. The experience gained in working with consultants over the past four years may prove invaluable in the future, if work load trends increase as dramatically as expected, and if employement ceilings, either by administrative actions or inabilities to compete effectively in the market place, are experienced.

**Figure 6 — CE Cost Trends**

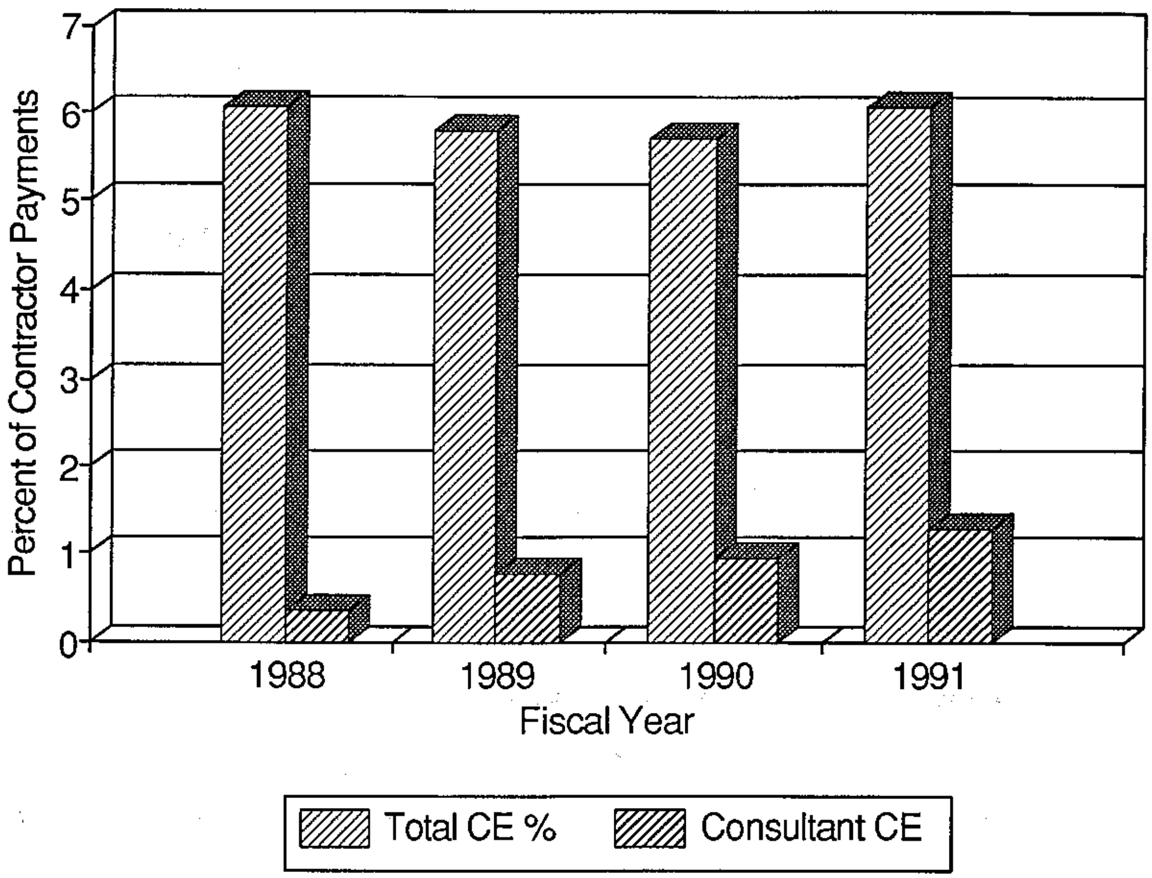



**Table 15 — CE Cost Trend Data**

| Fiscal Year | Payments to Contractors ($ millions) | Total CE Costs ($ millions) | CE Costs as % of Payments to Contractors | Payments to Consultants for CE ($ millions) | Consultant Payments as % of Total CE |
|---|---|---|---|---|---|
| 1988 | 92.871 | 5.608 | 6.00 | 0.335 | 6.0 |
| 1989 | 119.732 | 6.922 | 5.78 | 0.926 | 13.4 |
| 1990 | 113.941 | 6.489 | 5.70 | 1.083 | 16.7 |
| 1991 | 120.616 | 7.301 | 6.05 | 1.555 | 21.3 |

The total construction engineering costs of 6 percent or less are lower than most states where the Consultant has checked them. They are quite reasonable considering the limited amount of testing and staking that have been assigned to contractors. The increased use of consultants has not increased the total CE costs.

## *Training*

The following courses applicable for field construction personnel are listed in the Department's training catalog. (*11*) Most were prepared and are conducted by Department personnel.

| Classroom Courses: | Duration | Manual Available |
|---|---|---|
| • Aggregate and concrete testing | 3 or 4 days | Materials Manual |
| • Asphalt inspection | 1 day | X |
| • Basic welding | 4 days | |
| • Concrete paving | 4 days | X |
| • Concrete plants | 4 days | X |
| • Earthwork | 4 days | |
| • Nuclear gauge operation & operation certification | 1 day | |
| • Portland cement concrete materials | 1.5 days | |
| • Roadside development and erosion control | 4 days | |
| • Structures | 4 days | X |
| • Total station | 3 days | |

Usually only permanent employees attend these courses because of the time required for completion and the time of year that they are offered.

| Self-Instructional Manuals, Videotapes and Booklets: | Mode | Duration |
|---|---|---|
| • Pipe installation | Text/Manual | 16 hours |
| • Basic mathematics | Text | 40 hours |
| • Construction mathematics | Text | 40 hours |
| • Highway plan reading | Text | 60 hours |
| • Survey I | Text | 32 hours |
| • Survey II | Text | 32 hours |
| • Weighing | Text | 8 hours |
| • Checker's guidelines | Text | 1 hour |
| • Concrete control and test | Text | 1 hour |
| • Inspector's job guide for highway and street construction | Booklet | |
| • Sign and delineator | Text | 4 hours |
| • Principles of construction of hot-mix asphalt pavements | Text | 40 hours |

Seasonal employees could be more effective if training were available for the specific activity they are assigned. Some areas use the Department's training workbooks to train these employees when there is time, but most receive only on-the-job training in part because the subjects covered by the workbooks are limited to those listed above. Employees must get hands-on experience to be fully trained. However, the learning curve can be shortened if employees are given more formal training. The use of self-help videotapes and workbooks reduce the amount of time permanent staff members need to devote to training.

> *Recommendation No. 2-17:* ***Because of its reliance on seasonal employees, the Department should develop or utilize existing training materials to better train these employees to perform the specific tasks they will be assigned.***

Implementation of this recommendation will reduce reliance on on-the-job training and provide more uniform training consistent with desired practices. Training of seasonal employees should be limited to the specific tasks they will be assigned and, if possible, precede their assignment to the field. It is possible that evening training sessions could be held at some points around the state prior to the advent of the construction season. Payment for attending the training sessions may be required, but it is possible that payments could be made at minimum rates. Effective implementation will require high levels of coordination among field supervisors and trainers conducting the sessions.

### Construction Manual

The Department relies on policy memorandums to inform field construction personnel of construction policies. A construction manual is needed to provide guidance for new engineers and technicians as well as to serve as a current ready reference for all field construction personnel. The use of consultants for construction engineering and inspection has increased significantly in the last few years. A construction manual would also provide guidance to consultant personnel to help ensure that projects are administered in accordance with Department policies.

***Recommendation No. 2-18: A construction manual should be developed for use as a ready reference by field engineers and technicians.***

Typically, construction manuals include such information as that listed in the outline below.

General Information

- Department Organization
- Personnel Practices and Polices
- Code of Ethics
- Public Relations
- Relations with the Contractor

Preconstruction Administration

- Plans, Specifications and Special Provisions
- Documentation Requirements
- Traffic Control
- Preconstruction Conference

Contract Administration

- Contract Time
- Change Orders
- Contract Claims Procedure
- Progress Estimates
- Final Payments

Construction Staking

- Staking Procedures
- Preliminary Staking
- Construction Staking

Inspection and Testing

- Earthwork
- Base Courses
- Pipe Culverts
- Major Structures
- AC Paving
- PCC Paving
- Traffic Control
- Incidental Construction
- Temporary Erosion Control

Sample Construction Forms

Useful Tables and Charts

Glossary

The construction manual should supplement the standard specifications or any existing manuals that are available to field construction engineers — and should not duplicate them. For example, the manuals and texts listed under Training as available may provide sufficient guidance that many of the topics under Inspection and Testing can be omitted.

# Chapter Three

# Staffing Analysis

Two analyses are presented in the chapter: current staffing practices and staffing impacts of the proposed recommendations.

## Current Staffing

An analysis of Department records was made to evaluate staffing of field construction projects.

### Model Projects

The work load tabulations showed that construction and resurfacing project-types accounted for nearly 80 percent of the field construction staff man-hours. Consequently, selection of projects for the analysis was confined to those two project types.

Thirty-one new construction projects and twelve resurfacing projects were selected with the assistance of the Construction Division for the analysis. These projects are listed in Tables D-1 and D-2 in Appendix D. Only projects that were completely finaled were included in the analysis to ensure that all man-hours and final quantities were included in the computations. Projects from all four regions were included for each project type. There were four new construction projects from Region 1, and nine from each of the other three regions, and three resurfacing projects from each region. Modifiers were applied in estimating the manpower needs for five of the construction projects as shown in Table D-1. No modifiers were used for any of the resurfacing projects selected.

The data collected for each activity on each project included:

- planned man-hours;
- actual man-hours reported;
- planned quantities; and
- final quantities.

Only projects for which all of these data were available were included in the analysis.

### Paradox Model

Because of the ease of manipulating data, Paradox 3.5 data base software was used to model the data in preference to spread sheet software. The Paradox files and formats for the projects analyzed will be provided to the Department for use in future analyses.

### Standards Evaluation

A comparison of actual reported data with that planned for each activity and project was made. The comparisons are presented in Appendix D. (There were so few construction projects with modifiers that the results were of little use. Therefore, the comparisons for these projects were omitted from this report.)

In evaluating the standards, consideration must be given to actual field conditions and practices. Experience shows that, on the average, construction engineering management systems can be used effectively to predict staffing needs for regions or a state. These systems are less reliable for individual projects and even less reliable for individual activities on those projects. There are many variables that the project engineer cannot control — particularly contractor productivity and weather.

In addition, the ways that the project staff operate and how they charge time affect the evaluation. For example, project engineers[1] are, for the most part, working supervisors. They inspect paving, run survey crews, check undercuts and prepare progress estimates among other activities. This is appropriate. Most are assigned only one or two projects at a time and have time to perform some activities other than project management. Yet, all of the project engineers that were interviewed charge all of their time to one activity — project management. They felt that separating the man-hours by activity was too much trouble and unnecessary. Consequently, while the total man-hours charged to a project may be correct, the man-hours charged to individual activities are not. The Department should not discourage project engineers from being working supervisors by requiring unnecessary paperwork. However, the accuracy of the data reported to CEMMS can be improved if time is reported to the activity the engineers actually perfom.

---

[1] For purposes of this discussion, the term "project engineer" as used here includes both senior engineers and project engineers.

## Construction Projects

A sample analysis for Activity 01, Roadway Layout Staking, is shown in Table 16 below.

**Table 16 — Sample Standards Analysis**

**Project Type:** Construction, No Modifiers
**Activity:** 05 Earthwork Inspection
**Unit of Measure:** 10,000 Cubic Yards

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/ Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 4.4 | 11 | 48 | 423 | 4.4 | 96.1 | 874 |
| 033Y | 5.0 | 11 | 55 | 87 | 2.5 | 34.8 | 316 |
| 0474 | 100.4 | 11 | 1,104 | 1,091 | 107.9 | 10.1 | 92 |
| 2085 | 39.3 | 11 | 432 | 416 | 43..8 | 9.5 | 86 |
| 2626 | 21.9 | 11 | 241 | 183 | 21.7 | 8.4 | 77 |
| 0440 | 150.1 | 11 | 1,651 | 1,283 | 162.9 | 7.9 | 72 |
| 0442 | 108.9 | 11 | 1,198 | 950 | 122.4 | 7.8 | 71 |
| 163W | 113.1 | 11 | 1,244 | 539 | 118.9 | 4.5 | 41 |
| 1251 | 116.7 | 11 | 1,284 | 542 | 122.5 | 4.4 | 40 |
| Total | 659.8 | 11 | 7,257 | 5,514 | 707.0 | 7.8 | 71 |
| (Weighted Average) | | | | | | | |
| Total* | 420.6 | 11 | 4,626 | 3,923 | 458.7 | 8.6 | 78 |

* With 2 highs & 2 lows omitted

To account for quantity changes during construction in making the analysis, the actual man-hours per unit were computed by dividing the actual man-hours charged by the final number of work quantity units. Units such as roadway miles typically do not change. However, in the example above, the total earthwork quantities increased from the original plan quantity of 659.8 cubic yards to 707 cubic yards, a 7 percent change. A comparison of the actual man-hours with the planned number of units shows 8.4 man-hours per unit. However, final quantity comparisons show 7.8 man-hours per unit. As noted above, the actual man-hours per unit normally vary significantly from the standard for some activities on some projects. To eliminate some of the bias caused by this problem, a second calculation without the extreme high and low values was made for most activities.

A comparison of the actual man-hours per unit with the standards for all activities for new construction projects is presented in Table 17 on the next page. The adjusted man-hours per unit (without the highs and lows) are also listed in the table. The total actual man-hours used is ten percent higher than planned man-hours for the projects in the sample. If the planned man-hours are adjusted for the changes in quantities, the actual man-hours are only 4 percent above plan. Overall, the standards are accurately predicting total staffing needs for the way the Department is currently staffing projects. However, a review of the table indicates that the actual man-hours per unit varied

## Table 17 -- Analysis of CEMMS Standards -- Construction Projects with No Modifiers

| Code | Activity | No. of Proj. | Unit of Measure | Standard M-Hrs per Unit | Actual M-Hrs per Actual Unit | Actual as % of Planned | Actual M-Hrs/Actual Unit w/o Highs/Lows | Adjusted as % of Planned |
|---|---|---|---|---|---|---|---|---|
| 01 | Layout Staking | 9 | Roadway Mile | 105 | 93.5 | 89 | 102 | 97 |
| 02 | X-Sect/Slope Stake | 10 | Roadway Mile | 145 | 151.5 | 104 | 118 | 81 |
| 03 | Grade Control | 8 | Roadway Mile | 86 | 85.7 | 100 | 83 | 97 |
| 04 | Stake Minor Struct | 8 | Roadway Mile | 25 | 17.5 | 70 | N/A | N/A |
| 05 | Earthwork Inspection | 9 | 10,000 CY | 11 | 7.8 | 71 | 8.6 | 78 |
| 06 | Testing | 9 | 10,000 CY | 7 | 7.1 | 101 | 6.9 | 99 |
| 07 | Minor Str Inspection | 8 | Roadway Mile | 25 | 32.2 | 129 | 25.8 | 103 |
| 08 | Earthwork Office | 10 | Roadway Mile | 60 | 27.6 | 46 | 33.6 | 56 |
| 11 | Line/Grade Control | 4 | Roadway Mile | 125 | 165.6 | 132 | N/A | N/A |
| 12 | Untreated Agg Insp | 12 | 1,000 Tons | 5 | 6.4 | 129 | 6.7 | 134 |
| 13 | Test Untreated Agg | 11 | 1,000 Tons | 3 | 3.4 | 112 | 3.9 | 131 |
| 16 | Weigh Agg Matls | 11 | 1,000 Tons | 5 | 9.2 | 184 | 7.2 | 145 |
| 17 | Office Agg/Paving | 11 | 1,000 Tons | 2 | 1.3 | 65 | N/A | N/A |
| 21 | Asph Paving Insp | 7 | 1,000 Tons | 13 | 35.5 | 273 | 26.0 | 200 |
| 22 | Asph Plant Insp | 6 | 1,000 Tons | 13 | 24.8 | 191 | 16.2 | 125 |
| 31 | PCC Paving Insp | 5 | 1,000 SY | 7 | 608 | 97 | N/A | N/A |
| 32 | PCC Plant Insp | 5 | 1,000 SY | 4 | 4.1 | 103 | N/A | N/A |
| 41 | Struct/Box Staking | 14 | Bent | 10 | 10.9 | 109 | 10.4 | 104 |
| 42 | Struct/Box Insp | 17 | 100 SY | 60 | 70.4 | 117 | 63.3 | 105 |
| 43 | PCC Plant Insp - Str | 17 | 100 SY | 8 | 14.3 | 179 | 10.8 | 134 |
| 44 | Office - Struct/Box | 5 | 100 SY | 5 | 5.1 | 102 | N/A | N/A |
| 51 | Stake Misc Items | 18 | Roadway Mile | 25 | 30.8 | 123 | 24.5 | 98 |
| 52 | Insp Misc Items | 22 | Roadway Mile | 75 | 90.2 | 120 | 63.0 | 84 |
| 53 | Office - Misc Items | 14 | Roadway Mile | 15 | 12.6 | 84 | 14.7 | 98 |
| 71 | General Office | 25 | % Insp MH | 8% | 11% | 138 | 11.6% | 146 |
| 72 | Project Management | 24 | % MH 01-71 | 15% | 15% | 97 | 13.6% | 90 |
| 73 | Standby | 7 | % MH 01-71 | 0.1% | 0.5% | 476 | 0.2% | 229 |
| 74 | Travel | 22 | % Stk/Insp MH | 14.4% | 14.6% | 101 | 12.8% | 88 |

significantly from the standard for a number of activities. Activities for which there were significant underruns include:

- 02, Cross sectioning and slope staking,
- 05, Earthwork inspection,
- 08, Earthwork office work, and
- 52, Inspection of miscellaneous items.

These activities overran:

- 12, Untreated aggregate inspection,
- 13, Testing untreated aggregates,
- 16, Weighing aggregate materials,
- 21, Asphalt paving inspection,
- 22, Asphalt plant inspection,
- 43, PCC plant inspection for structures, and
- 71, General office work.

Activity 73, Standby, overran significantly as far as the percentage is concerned but the total man-hours is not significant.

**Resurfacing Projects**

A comparison of planned and actual man-hours per unit for resurfacing projects, similar to that for new construction projects, is presented in Table 18 on the next page. The total man-hours used on the selected projects were within two tenths of one percent of that planned. As with the analysis for construction-type projects, the actual man-hours for some individual activities varied significantly from plan.

Surfacing activities for which there were significant underruns include:

- 12, Untreated aggregate inspection,
- 17, Office work for aggregate and paving,
- 22, Asphalt plant inspection, and
- 52, Inspection of miscellaneous items.

These activities overran:

- 13, Untreated aggregate inspection,
- 13, Testing untreated aggregates,
- 16, Weighing aggregate materials, and
- 51, Staking miscellaneous items.

## Table 18 -- Analysis of CEMMS Standards -- Resurfacing Projects with No Modifiers

| Code | Activity | No. of Proj. | Unit of Measure | Standard M-Hrs per Unit | Actual M-Hrs per Actual Unit | Actual as % of Planned | Actual M-Hrs/Actual Unit w/o Highs/Lows | Adjusted as % of Planned |
|---|---|---|---|---|---|---|---|---|
| 11 | Line/Grade Control | 10 | Roadway Mile | 12 | 13.2 | 110 | 11.5 | 96 |
| 12 | Untreated Agg Insp | 7 | 1,000 Tons | 6 | 5.2 | 87 | 5.3 | 88 |
| 13 | Test Untreated Agg | 9 | 1,000 Tons | 4 | 5.8 | 145 | 6.6 | 165 |
| 16 | Weigh Agg Matls | 7 | 1,000 Tons | 5 | 7.7 | 155 | 6.7 | 135 |
| 17 | Office Agg/Paving | 9 | 1,000 Tons | 1 | 1.0 | 97 | 0.7 | 65 |
| 21 | Asph Paving Insp | 11 | 1,000 Tons | 13 | 13.2 | 101 | 13.2 | 101 |
| 22 | Asph Plant Insp | 11 | 1,000 Tons | 13 | 9.5 | 73 | N/A | N/A |
| 51 | Stake Misc Items | 7 | Roadway Mile | 2 | 3.6 | 179 | 2.9 | 146 |
| 52 | Insp Misc Items | 10 | Roadway Mile | 10 | 8.3 | 83 | 7.9 | 79 |
| 53 | Office - Misc Items | 6 | Roadway Mile | 1 | 2.8 | 276 | 1.6 | 160 |
| 71 | General Office | 10 | % Insp MH | 8% | 0.14 | 177 | 11.5% | 95 |
| 72 | Project Management | 11 | % MH 01-71 | 15% | 0.19 | 126 | 16.2% | 108 |
| 73 | Standby | 5 | % MH 01-71 | 0.1% | 0.031 | 3,057 | 1.2% | 1,191 |
| 74 | Travel | 9 | % Stk/Insp MH | 15% | 0.115 | 76 | 13.4% | 89 |
| 75 | Training | 1 | % MH 01-71 | 0.1% | 0.001 | 76 | 0.08% | 76 |

## *Draft Inspection, Staking and Administrative Guidelines*

On the basis of this analysis, it appears that, overall, the CEMMS planning standards for new construction and resurfacing projects are projecting the total manpower needs very closely. It also appears that standards for some activities should be reviewed. Suggested standards for construction and resurfacing project types are presented in Tables 19 and 20 respectively. The data indicated that staffing was fairly uniform in all regions. There was no pattern showing most projects in one region exceeding the standards or those in another region underrunning.

***Recommendation No. 3-1:*** ***The data and the analysis of the standards should be reviewed by a panel of Department employees who are familiar with the projects included in the analysis and understand any circumstances that might affect the staffing or the validity of the reported man-hours. It may be necessary to add data for additional projects to the data base to get an adequate sample for some activities.***

To implement this recommendation, it is suggested that a standards panel be selected to periodically review all standards used in CEMMS. Normally, the panel should be required to meet only once a year. The panel should include representatives from all four regions as well as from the central office construction staff. A six to eight member panel is suggested. Panel members should include senior, project and area engineers and possible a regional engineer. Panel membership should rotate on a two- to three-year cycle. A key central construction staff member should serve as chairperson.

## *Use of CEMMS*

Field personnel make very little use of CEMMS. It is perceived as another unrealistic head office report of little importance to the field. It is definitely not viewed as a management tool for anyone below the regional level. Some project engineers do not even know what it is. Would more field involvement in the planning and staffing elements of the system improve the accuracy and acceptance of the system?

Some regional engineers do use CEMMS to help balance work and staffing between areas. It can also be used to help select projects for assignment to consultants for CEI.

***Recommendation No. 3-2:*** ***Field construction engineers and senior technicians should receive training in manpower management and the use of CEMMS.***

The training should include such topics as:

- the purpose and use of the Department's Construction Engineering Manpower Management System;
- the manpower planning process and the use of planning standards;
- how the accuracy of reporting is reflected in updating the planning standards; and
- manpower management techniques, including items such as work scheduling principles, primary and secondary assignments, and the most productive crew sizes for each activity.

The advantages of conducting this training include:

- improved reporting accuracy which should result in realistic standards;
- a better understanding of management of manpower; and
- an increased awareness of the need for versatile technicians and the need for cross training to achieve versatility.

**Table No. 19 — Suggested Standards — Construction Projects with No Modifiers**

| Code | Activity | Unit of Measure | Standard Man-Hrs per Unit | Actual Man Hrs/Actual Unit | Adjusted as % of Standard | Suggested Standard |
|---|---|---|---|---|---|---|
| 01 | Layout Staking | Roadway Mile | 105 | 101.5 | 97 | 105 |
| 02 | X-Sect/Slope Stake | Roadway Mile | 145 | 117.7 | 81 | 120 |
| 03 | Grade Control | Roadway Mile | 86 | 83.4 | 97 | 86 |
| 04 | Stake Minor Struct | Roadway Mile | 25 | 17 | 70 | 17 |
| 05 | Earthwork Insp | 10,000 CY | 11 | 8.6 | 78 | 9 |
| 06 | Testing - Earthwork | 10,000 CY | 7 | 6.9 | 99 | 7 |
| 07 | Minor Struct Insp | Roadway Mile | 25 | 25.8 | 103 | 25 |
| 08 | Earthwork Office | Roadway Mile | 60 | 33.6 | 56 | 35 |
| 11 | Line/Grade Control | Roadway Mile | 125 | 166 | 132 | 165 |
| 12 | Untreated Agg Insp | 1,000 Tons | 5 | 6.7 | 134 | 7 |
| 13 | Test Untreated Agg | 1,000 Tons | 3 | 3.9 | 131 | 4 |
| 16 | Weigh Agg Matls | 1,000 Tons | 5 | 7.2 | 145 | 7 |
| 17 | Office Agg/Paving | 1,000 Tons | 2 | 1.3 | 65 | 1.3 |
| 21 | AC Paving Insp | 1,000 Tons | 13 | 26.0 | 200 | 26 |
| 22 | AC Plant Insp | 1,000 Tons | 13 | 16.2 | 125 | 16 |
| 31 | PCC Paving Insp | 1,000 SY | 7 | 6.8 | 97 | 7 |
| 32 | PCC Plant Insp- Pvg | 1,000 SY | 4 | 4.1 | 103 | 4 |
| 41 | Struct/Box Staking | Bent | 10 | 10.4 | 104 | 10 |
| 42 | Struct/Box Insp | 100 SY | 60 | 63.3 | 105 | 60 |
| 43 | PCC Plant Insp-Str | 100 SY | 8 | 10.8 | 134 | 10 |
| 44 | Office - Struct/Box | 100 SY | 5 | 5.1 | 102 | 5 |
| 51 | Stake Misc Items | Roadway Mile | 25 | 24.5 | 98 | 25 |
| 52 | Insp Misc Items | Roadway Mile | 75 | 63.0 | 84 | 65 |
| 53 | Office - Misc Items | Roadway Mile | 15 | 14.7 | 98 | 15 |
| 71 | General Office | % Insp MH | 8% | 11.6% | 146 | 11% |
| 72 | Project Management | % MH 01-71 | 15% | 13.6% | 90 | 14% |
| 73 | Standby | % MH 01-71 | 0.1% | 0.2% | 229 | 0.2% |
| 74 | Travel | % Stk/Insp MH | 14.4% | 12.8% | 88 | 14.4% |

**Table No. 20 — Suggested Standards — Resurfacing Projects with No Modifiers**

| Code | Activity | Unit of Measure | Standard Man-Hrs per Unit | Actual Man Hrs/Actual Unit | Adjusted as % of Standard | Suggested Standard |
|---|---|---|---|---|---|---|
| 11 | Line/Grade Control | Roadway Mile | 12 | 11.5 | 96 | 12 |
| 12 | Untreated Agg Insp | 1,000 Tons | 6 | 5.3 | 88 | 6 |
| 13 | Test Untreated Agg | 1,000 Tons | 4 | 6.6 | 165 | 6 |
| 16 | Weigh Agg Matls | 1,000 Tons | 5 | 6.7 | 135 | 6 |
| 17 | Office Agg/Paving | 1,000 Tons | 1 | 0.7 | 65 | 1 |
| 21 | AC Paving Insp | 1,000 Tons | 13 | 13.2 | 101 | 13 |
| 22 | AC Plant Insp | 1,000 Tons | 13 | 9.5 | 73 | 10 |
| 51 | Stake Misc Items | Roadway Mile | 2 | 2.9 | 146 | 3 |
| 52 | Insp Misc Items | Roadway Mile | 10 | 7.9 | 79 | 8 |
| 53 | Office - Misc Items | Roadway Mile | 1 | 1.6 | 160 | 1.5 |
| 71 | General Office | % Insp MH | 8% | 11.5% | 95 | 8% |
| 72 | Project Management | % MH 01-71 | 15% | 16.2% | 108 | 15% |
| 73 | Standby | % MH 01-71 | 0.1% | 1.2% | 1,191 | 0.2% |
| 74 | Travel | % Stk/Insp MH | 15% | 13.4% | 89 | 15% |
| 75 | Training | % MH 01-71 | 0.1% | 0.08% | 76 | 0.1% |

## Staffing Impacts of Proposed Recommendations

Some of the recommendations will have major impacts on staffing needs; others will have little or no impact. The recommendations from Chapter Two are repeated here for the convenience of the reader. The impact on staffing was estimated by applying the changes in staffing needs to the actual man-hours and the actual units for the analysis of the selected new construction projects without modifiers.

### Impacts of Individual Recommendations

***Recommendation No. 2-1:*** ***It is recommended that the Department continue to provide materials and borrow sources as it has in the past rather than specifying contractor furnished sources for all projects.***

This recommendation confirms a current practice so it has no impact on staffing.

***Recommendation No. 2-2:*** ***Eliminate the zone requirements for embankment density testing, and change the minimum requirement to 1 density test per 12-inch layer per one-half mile of all embankment construction.***

The excavation quantities on the nine new construction projects totaled 7 million cubic yards. The roadway miles totaled 54.5. The average is about 130,000 cubic yards per roadway mile. If shrink is neglected, this closely corresponds with the embankment quantity for the average fill height of 9 feet in Table 4 on Page 14. In that table, the current number of tests per one-half mile is four.

The proposed frequency increases the minimum number of tests to nine, or five additional tests per one-half mile of roadway, or ten tests per roadway mile. (If a fill height of seven feet to allow for shrink were selected, the impact would be slightly less.) If it is assumed that each test will require one man-hour, an additional 545 man-hours would be required for density testing on the model projects to implement the recommendation. (Ten tests per roadway mile times one hour per test times 54.5 roadway miles equals 545 man-hours.) There were 4,986 man-hours charged to Activity 06, Testing for Earthwork, Minor Drainage and Utilities, on the model projects. The additional 545 man-hours represents a 10.9 percent increase in manpower requirements for Activity 06 and 0.5 percent increase to the total of 108,164 man-hours that were charged to all of the new construction model projects.

Moisture/density tests can be performed in much less time with nuclear gauges. Increased use of nuclear gauges would help offset the staffing requirements of the increased testing frequency.

***Recommendation No. 2-3:** Use the same minimum test frequency for embankment moisture tests as that for density testing.*

This change will not affect staffing.

***Recommendation No. 2-4:** Revise the specification to provide an upper limit of 2 points above optimum as the maximum permissible moisture limit for embankments.*

This change will not affect staffing.

***Recommendation No. 2-5:** Change the minimum test frequency for aggregate gradations for PC concrete for structures from 1 test per 100 CY to 1 test per 200 CY.*

To determine the effect of this recommendation on staffing needs, a comparison of the two frequencies was made using the quantities from the new construction model projects. For purposes of this analysis, it was assumed that 42 percent of the concrete was fine aggregate and 58 percent was coarse. All other ingredients were excluded from the analysis. The results are shown in Table 21 on the next page. It was assumed that each test would take one-half of a man-hour.

Implementation of the recommendation would reduce the number of tests by 40 percent. This would represent a 1.6 percent reduction in man-hours for Activity 43, PCC Plant Inspection for Structures, and a 0.02 percent overall reduction.

**Table 21 — Effect of Decreasing Testing Frequency for Aggregate for Structural Concrete**

| PCEMS Number | Quantity of Concrete CY | Estimated Quantity of Fine Aggregate | Estimated Quantity of Coarse Aggregate | Minimum No. of Tests 1/100 CY Each Aggregate | Minimum No. of Tests 1/200 CY Each Aggregate | Actual Man-Hours Charged to Act. 43 | Potential Savings in Man-Hours |
|---|---|---|---|---|---|---|---|
| 033Y | 8 | 84 | 117 | 3 | 2 | 22 | 0.5 |
| 0285 | 41 | 17 | 24 | 2 | 2 | 20 | 0.0 |
| 0440 | 322 | 135 | 187 | 4 | 2 | 100 | 1.0 |
| 0474 | 554 | 233 | 321 | 7 | 4 | 42 | 1.5 |
| 035Y | 35 | 15 | 20 | 2 | 2 | 2 | 0.0 |
| 063W | 170 | 71 | 99 | 2 | 2 | 2 | 0.0 |
| 061W | 996 | 418 | 578 | 11 | 6 | 8 | 2.5 |
| 034Y | 42 | 18 | 24 | 2 | 2 | 22 | 0.0 |
| J237 | 771 | 234 | 447 | 8 | 5 | 158 | 1.5 |
| 259Y | 242 | 102 | 140 | 4 | 2 | 206 | 1.0 |
| 1352 | 828 | 348 | 480 | 8 | 5 | 31 | 1.5 |
| 163W | 1,210 | 508 | 702 | 14 | 7 | 198 | 3.5 |
| 2365 | 912 | 383 | 529 | 10 | 5 | 217 | 2.5 |
| 024Y | 120 | 50 | 70 | 2 | 2 | 153 | 0.0 |
| 266Y | 123 | 52 | 71 | 2 | 2 | 36 | 0.0 |
| 265Y | 102 | 43 | 59 | 2 | 2 | 11 | 0.0 |
| 620X | 400 | 168 | 232 | 5 | 3 | 26 | 1.0 |
| J204 | 2,146 | 901 | 1245 | 23 | 12 | 85 | 5.5 |
| 260Y | 791 | 332 | 459 | 9 | 5 | 138 | 2.0 |
| Total | | | | 120 | 72 | 1,477 | 24.0 |
| % | | | | | 60 | | 1.6 |

***Recommendation No. 2-6:*** ***The procedures for setting the minimum test frequencies for projects and for requesting reductions in the minimums should be reviewed and revised to reduce the time required for approval.***

This change will not affect staffing.

***Recommendation No. 2-7:*** ***Assign production control testing of essentially all aggregates — especially base course, AC paving, PCC paving, and PCC for structures — to the producers, whether the material is crushed by suppliers or contractors.***

The Department currently requires producers of aggregates for AC paving to perform the process control testing. The minimum testing frequency for process control testing for other aggregates as specified in the Materials Manual is that needed to maintain control. In practice, inspectors frequently take split samples to check the suppliers' quality control tests. While assigning all process control testing of aggregates to the contractors or suppliers will reduce the staffing requirements for

Department employees somewhat, the savings in man-hours is not expected to be significant. CEMMS does not separately identify man-hours spent on production control testing for these items.

***<u>Recommendation No. 2-8</u>: Revise the standard specifications to require submission of certifications prior to incorporating materials into the work and prohibit making progress payments until all certifications are received.***

In the long run, implementation of this recommendation should reduce the time spent in obtaining certificates, but the reduction in actual man-hours is not expected to be significant.

***<u>Recommendation No. 2-9</u>: The Department should expand its use of end-result and statistical specifications, especially on larger projects.***

It is not expected that implementation of this recommendation will result in any significant change in staffing needs, at least in the near future.

***<u>Recommendation No. 2-10</u>: The Department should revise its procedure to permit correlation curves to be used on adjacent projects, to take advantage of the faster testing capability of nuclear gauges on more projects, while allowing the grading inspector to remain on the grade.***

***<u>Recommendation No. 2-11</u>: Vehicles should be equipped with self-contained density kits. These kits should include either Speedy moisture meters, or stoves for drying samples, so grading inspectors can perform complete tests without the need for a field laboratory.***

Either of these methods would allow the grading inspector to remain on the grade nearly full time and still accomplish the necessary testing. Correlating the nuclear gauge for soils changes will require the same time as it now does. Grading inspectors frequently inspect other items, such as fence and pipe installation, when they have another inspector available to run moisture/density tests. Because of this and insufficient data as to how frequently a grading and density inspector are both assigned, no estimate of potential savings was made.

***<u>Recommendation No. 2-12</u>: Automatic scales and ticket printers should be required for all AC paving projects with quantities above a preset limit. Specifications should be revised so Department weighers are not required. To encourage competition from contractors with older plants, automatic scales should not be required for small projects.***

On larger asphalt paving projects, the plant inspector needs assistance to keep up with the testing and observe plant operations. Those currently assigned as weighers could provide this help. Therefore, it is not expected that this recommendation will result in any reduction in staffing on major projects. (Assigning junior inspectors to assist experienced plant inspectors can also provide excellent training opportunities.)

***<u>Recommendation No. 2-13</u>: Water used for earthwork, cushion courses, subbases, and base courses should be incidental to those items and not paid separately. Payment should be continued for water used for dust control to ensure the safety of the public.***

While this would result in a slight reduction in paperwork and record keeping, a grading inspector will still be required essentially full-time.

***<u>Recommendation No. 2-14</u>: All projects should be set up to pay for earthwork by either (1) staked quantities plus or minus changes or (2) plan quantity.***

The base planning standard in CEMMS for Activity 02, Cross sectioning and Slope Staking, for the Construction Contract Type provides 32 man-hours per roadway mile for final cross sectioning roadways. That is about 30 percent of the total base standard for the activity. An additional 20 man-hours is provided for cross sectioning borrow pits, undercuts, topsoil piles, and the like. Thirty-two man-hours per roadway mile is the equivalent of 21 percent of the man-hours charged to Activity 02 on the Type A projects (new construction without modifiers) which were included in our analysis of CEMMS data. On a typical project, elimination of final cross sectioning would represent a 1.6 percent saving in the total man-hours.

***Recommendation No. 2-15:*** ***Assign staking to contractors for selected activities and projects where it is difficult for the Department to provide survey personnel, either because of location or staffing shortages.***

Because of the uncertainty as to how many projects or activities that might be assigned to contractors, no estimate of savings in man-hours was attempted.

***Recommendation No. 2-16:*** ***It is recommended that a program to equip field project offices with personal computers be initiated.***

Initially, while engineers and technicians are learning to use PCs and the necessary software, no savings can be expected. As they become proficient, the time required for correspondence, progress estimates and the like will be reduced. No estimate of costs or future savings was attempted.

***Recommendation No. 2-17:*** ***Because of its reliance on seasonal employees, the Department should develop or utilize existing training materials to better train these employees to perform the specific tasks they will be assigned.***

No estimate of the effect on staffing can be made.

***Recommendation No. 2-18:*** ***Develop a construction manual for use as a ready reference by field engineers and technicians.***

The availability of a construction manual should provide engineers and technicians with guidance in approved Department practices and procedures to improve compliance and reduce errors. However, no reduction in staffing can be expected.

## Summary of Recommendation Impacts

An estimate of the effect that all of the recommendations will have on staffing is summarized in Table 22. Only the recommendations for which estimated staffing changes were made are included in the summary.

**Table 22 — Summary of Recommendation Impacts**

| Recommendation | Activity Affected | Percent Change in Man-Hours by Activity | Percent Change in Man-Hours for New Construction Projects |
|---|---|---|---|
| 2-2 | 06-Testing — Earthwork, et al | + 11 | + 0.50 |
| 2-5 | 43-PCC Plant insp- structures | - 2 | - 0.02 |
| 2-14 | 02-Cross section/slope stake | - 21 | - 1.64 |
| 2-15 | 11-Line/grade control aggregate/paving | - 1 | - 0.04 |
| Total | | | - 1.20 |

The impact of the recommendations on the staffing needs is significant for some activities while the total impact of all of the recommendations on staffing is relatively minor. This is not unexpected considering the staffing levels for construction and the construction engineering costs. Nevertheless, the Department should implement these recommendations to effectively administer construction projects.

## Chapter Four

# Conclusions

A brief summary of the research, major conclusions and recommendations is presented in this chapter followed by recommendations for further research.

## Research

### Literature Search

The literature search produced relatively few references with specific application to this study. Those that were of use are listed under References at the end of this chapter.

Research conducted in the early 1980s, entitled "Cost Effectiveness in Sampling and Testing Programs," addressed the need for rational ways to determine the number of tests needed to ensure quality construction. A computer program was developed in that study that provides a good overall methodology for determining the cost effectiveness of testing frequencies for asphalt paving. However, the necessary research to determine the relationships between tests and pavement performance was not funded.

### Work Load

From the analysis of the construction work load, it was clear that the major project types are new construction and resurfacing. Construction-type projects represented 55 percent of the payments to contractors for the years 1985 through 1989 and about 67 percent of the planned construction expenditures for the period from 1990 through 1994. Resurfacing represented 24 percent and 19 percent during these same time periods. A number of major reconstruction projects were classified as new construction. Had this not occurred, the reconstruction project type may have been more significant.

Because of the significance of construction and resurfacing, the research team concentrated its efforts on these two project types in selecting projects for analysis and field visits.

### Activity Significance

An analysis was made of the man-hours charged to all project types through the Department's Construction Engineering Manpower Management System. Twenty of the 35 CEMMS activities accounted for 90 percent of the man-hours charged to all project types. Nearly 30 percent of the man-hours were charged to three activities — project management and coordination, inspection of miscellaneous items, and structure and box culvert inspection.

## Conclusions

### Designated Materials Sources

The Department locates aggregate and borrow sources for most projects. The general exception is for locations where the only available aggregate sources are quarries. It was questioned if this practice should continue or if contractor-furnished material should be specified. The man-hours spent investigating materials and borrow sources and securing options were reviewed for the past three years. The time spent on all three activities statewide averaged 3.5 person-years per year. Considering that each contractor would have to locate material or borrow on all projects they wanted to bid, it is recommended that the Department continue to locate aggregate and borrow sources.

### Acceptance Testing

South Dakota has developed minimum test frequencies requirements for most field tests — as do nearly all state highway and transportation agencies. This minimum represents the fewest tests normally required to ensure that quality work is achieved by the contractors. It is expected that additional tests will be taken when materials problems are found. The minimum may be reduced under special circumstances unique to a project upon request by the project and area engineers.

The number of acceptance tests actually taken was compared with the minimum requirements for selected tests on a sample of projects. The objectives for the analysis were to determine if the minimum frequencies were attained, and if the number of tests taken greatly exceeded the minimum. It was found that, typically, field construction personnel are taking slightly more than the minimum number of tests unless there are problems. Then additional tests are taken. In addition, the Department's minimum test frequencies were compared with those of the six surrounding states.

The percentage of tests that failed was also reviewed. These percentages appeared reasonable for all of the tests reviewed.

From these analyses, it is recommended that the frequency be increased for embankment moisture and density tests, and be decreased for aggregate gradations for PC concrete for structures. Changes to simplify the procedure for reducing the minimum frequency are also recommended.

### Quality Control Testing

The Department requires the contractors to perform the process control testing for asphalt paving aggregates. Few of the surrounding states require contractors to perform any testing. The practice is much more prevalent in other sections of the country. About two-thirds of the states currently use contractor quality control testing, according to a recent national survey. (*12*)

Despite the limited use of contractor QC testing in the region, it is recommended that the Department assign process control testing for all aggregate production to the responsible contractors or suppliers. The major advantage of requiring contractors to perform the process control testing is that doing so assigns the responsibility for quality to the producers — those who can best control quality.

### Certifications

Construction personnel reported that obtaining materials certifications from contractors and suppliers requires an excessive amount of time of the regional materials engineers, and delays project completions. Department policies permit the use of material prior to receiving the certifications.

And progress payments are made even though the certifications have not been received. Final payments are withheld until the certifications are received.

The contractors should take the responsibility for ensuring that certifications are provided when they are needed instead of putting the burden on the Department employees. To accomplish this, it is recommended that the specifications be revised to prohibit incorporation of materials into the work or to make progress payments for the bid items involved until the appropriate certifications have been received.

### Quality Assurance Specifications

Performance-based, end-result or statistical specifications all refer to quality assurance specifications. About one-third of the states use some end-result specifications. The Department uses this type of specification to encourage contractors to meet thickness and smoothness tolerances for PCC pavements. All of the surrounding states use some end-result specifications. On the basis of the experience of other agencies, the Department should expand the use of end-result specifications to cover additional items.

### Earthwork Inspection

On many earthwork projects, the grading inspector also has the responsibility for moisture/density testing. On projects where densities are taken with the balloon or sand cone methods, the inspector must leave the grade to complete the tests in the field laboratory. Under these circumstances, the grading inspector may be away from the grade for a large portion of the day. On other projects, a density tester may also be available. The density tester usually inspects culvert installations as well as running the moisture/density tests.

Because of current correlation procedures, it is only economical to use nuclear gauges on large earthwork projects — those that require well over ten density tests for each soil change. The use of nuclear gauges for earthwork in the surrounding states is mixed — from exclusive use of the nuclear gauge to never using it.

The grading inspector can perform the moisture/density tests and watch the grading operation if he is equipped to complete the tests without leaving the grade. This can be accomplished by:

- revising the correlation procedure to permit the use of correlation curves on adjacent projects to take better advantage of the speed of the nuclear gauge; and
- equipping vehicles with self-contained density kits which include either Speedy moisture meters or stoves for drying samples to eliminate the need for the field laboratory.

### Weighing Material

Most large asphalt plants are equipped with automatic scales that print weigh tickets. A Department weigher should not be needed. However, at one plant the weigher was tearing the ticket from the automatic printer and handing it to the truck drivers. He would have been of more use assisting the plant inspector.

The Department should revise its specifications to require automatic scales and ticket printers on all asphalt paving projects above a preset limit. The specifications should also preclude the need for an agency weigher.

## *Staking*

Department specifications provide for determination of excavation quantities from final cross sections, staked lines and grades, or plan quantity. Payment by plan quantity is usually specified only on urban and small rural projects. Staked quantities may be used if the contractor agrees. Excavation quantities for most projects are determined from final cross sections.

Final cross sections cannot be taken until the project nears completion. This delays computation of final pay quantities until the end of the project. The determination of quantities on the basis of staked quantities plus or minus changes would allow computation of final quantities at a much earlier stage of the project. In addition, the time spent by survey crews in taking final cross sections would be substantially decreased. Where changes in excavation limits are necessary, that area can be restaked or final cross sectioned.

## *Assignment of Staking to Contractors*

Of those agencies responding to a national survey, nearly three-fourths currently require contractors to perform at least a portion of the construction staking. (*12*) Few of the surrounding states generally assign construction staking to contractors. Despite this regional prevailing practice, the Department should consider assigning staking to contractors, on selected projects, so survey personnel can be assigned to inspection and testing activities.

## *Staffing*

One objective of this study is to identify ways to improve the efficiency of current employees in construction. While there are some areas, such as reducing the testing frequencies and eliminating the need for final cross sections for earthwork, where efficiency can be improved, these changes will have a relatively minor impact on the total work load. In the consultant's opinion, construction is certainly not overstaffed for its current work load. Personnel are being used very effectively on most projects.

According to information provided by ARTBA (American Road and Transportation Builders Association), the annual federal aid allocations to South Dakota are expected to be about $110 million under the new surface transportation bill. That compares with $89 million in FY 1991 — an increase of 24 percent. State matching funds must increase as well. Department records show that funding for construction in the five-year period from FY 1987 through 1991 averaged $84 million per year. Funding for the next six years is estimated to average $115.8 million per year — a 37.8 percent increase (without the federal lands funds or demonstration projects included in the new bill). (*13*) Since inflation is relatively low now, this indicates a significant increase in construction for the Department. To handle this increase, the Department has these options:

- increase in-house staffing and conduct the necessary training;
- increase the use of consultants for construction engineering and inspection,
- require the contractors to perform more of the QC testing and staking, or
- some combination of all of the above.

The last option is the most logical. It avoids adding personnel who may have to be laid off if work loads decrease in the future, and takes advantage of the capabilities of South Dakota consultants and contractors.

### Seasonal Employees

The Department utilizes seasonal employees to supplement its permanent staff during the construction season. The majority of seasonal employees are college students and many are engineering students. Most leave the Department to return to college in mid-August. Frequently, replacements must be recruited to complete the construction season. Nearly all training is on-the-job. Seasonal employees can be more effective in their assigned tasks if they receive more formal training. Training for seasonals should be confined to orientations and the specific tasks to be assigned.

### Construction Manual

The Department relies on policy memorandums to inform construction personnel of current policies and decisions. As more senior engineers and technicians retire, those with less experience must take their places. A construction manual is needed as a reference to guide field engineers and technicians.

### CEMMS

The planning standards for the Construction Division's Construction Engineering Manpower Management System (CEMMS) were reviewed. Actual reported man-hours were compared with the planning standards for all activities for construction and resurfacing project types. Overall, the planning standards predict the total staffing needs very well. However, the standards for some activities should be reviewed and adjusted. This should be accomplished through the appointment of a standards panel which would meet periodically to review, refine and improve the standards.

CEMMS is used very little in the field. Area, senior and project engineers do not view it as a useful management tool. Many do not know what it is supposed to accomplish. They have little input into manpower planning for their assigned projects. Because CEMMS reports are not viewed as useful, little effort is made to ensure that time is reported accurately to individual activities.

An effort is needed to revitalize CEMMS to enhance its use in the field. To accomplish this, the Construction Division should:

- revise the planning process so field engineers are involved in estimating the manpower needs for their assigned projects;
- review the planning standards periodically to ensure that they are realistic for current Department practices; and
- develop and conduct training in manpower management and the use of CEMMS for field engineers.

## Further Research

The need to establish the relationship between tests and the performance of materials incorporated into highway facilities was recognized many years ago. This need has been addressed by researchers for specific materials over the years but attaining conclusive results, as to which tests predict how materials will perform, has proven elusive. Nevertheless, research to define that relationship should continue.

# References

1 Von Quintus, H. L., Raubut, J. B., Kennedy, T. W., and Jordahl, P. R., *Cost Effectiveness of Sampling and Testing Programs — Executive Summary,* Federal Highway Administration, Washington , D.C. (April 1986) 24 pages

2 Von Quintus, H. L., Raubut, J. B., Kennedy, T. W., and Jordahl, P. R., *Cost Effectiveness of Sampling and Testing Programs,* Federal Highway Administration, Washington, D.C. (April 1986) 362 pages

3 Kopac, Peter A., Fernandez, Jose I., Forster, Stephen W., and Mitchell, Terry M., *Aggregate Gradation Control: Part I — An Analysis of Current Aggregate Gradation Control Programs,* Public Works (June 1982) Pages 13-24

4 *Standard Specifications Roads and Bridges,* West Virginia Department of Highways, Charleston, West Virginia (1982) 913 pages

5 Smith, Nathan L., Jr., NCHRP Synthesis 102, *Material Certification and Material-Certification Effectiveness,* Transportation Research Board, Washington, D.C. (November 1983) 17 pages

6 *Standard Specifications for Highway and Bridge Construction,* Iowa Department of Transportation, Ames, Iowa (1984) 807 pages

7 *Standard Specifications for Construction,* Minnesota Department of Transportation, St. Paul, Minnesota (1988) 914 pages

8 *Supplemental Specifications to the 1988 Standard Specifications for Construction,* Minnesota Department of Transportation, St. Paul, Minnesota (January 2, 1991) 125 pages

9 *Materials Manual,* South Dakota Department of Transportation, Pierre, South Dakota (March 1991)

10 *Standard Specifications for Transportation Materials and Methods of Sampling and Testing,* American Association of State Highway and Transportation Officials, Washington, D.C. (August 1986) 1275 pages

11 *Training Catalog,* South Dakota Department of Transportation, Pierre, South Dakota (1991-1992) 82 pages

12 *Innovative Contracting Practices,* TRR 386, Transportation Research Board, Washington, D.C. (December 1991) Page 14

13 Howard, Richard L., *A Presentation on the Intermodal Surface Transportation Efficiency Act of 1991 to the House Transportation Committee of the South Dakota Legislature,* South Dakota Department of Transportation, Pierre, South Dakota (January 28, 1992) Page 11

14 *Density Control Handbook—A Guide to Density Testing of Soils and Bituminous Mixtures,* Michigan Department of Transportation, Lansing, Michigan (September 1991) 142 pages

The following references were used to verify testing frequency data and end-result specifications but are not specifically referenced in the text.

*Standard Specifications for Road and Bridge Construction,* Montana Department of Highways, Helena, Montana (January 1, 1987) 667 pages

*Materials Manual of Test Procedures,* Montana Department of Highways, Helena, Montana (April 1, 1991)

*Materials Sampling — Volume II,* Nebraska Department of Roads, Lincoln, Nebraska (June 1983)

Weed, Richard M., *Statistical Specification Development,* New Jersey Department of Transportation, Trenton, NJ. (December 1982) 315 pages

*Standard Specifications for Roads and Bridges,* South Dakota Department of Transportation, Pierre, South Dakota (1990) 554 pages

Weed, Richard M., *Unbiased Graduated Pay Schedules,* TRR 745, Transportation Research Board, Washington, D.C., (1980) Pages 23-28

*Standard Specifications for Road and Bridge Construction,* Wyoming Highway Department, Cheyenne, Wyoming (1987) 737 pages

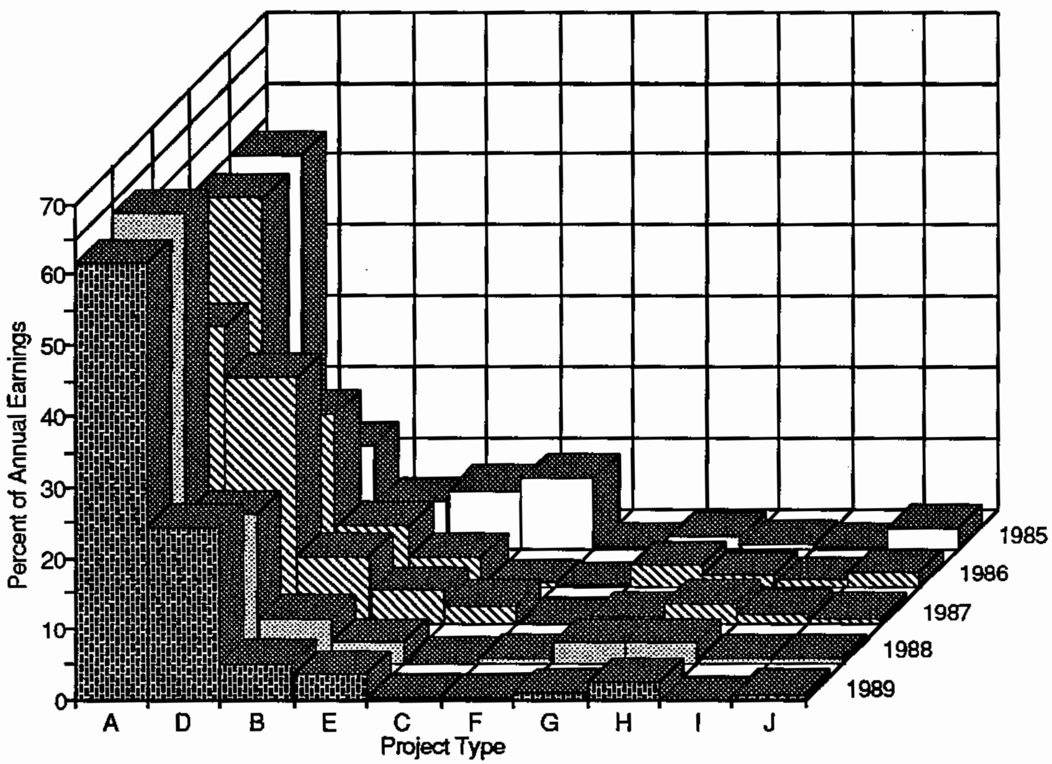
*Field Testing Manual,* Wyoming Highway Department, Cheyenne, Wyoming (February 1989)

*Appendix A*

# Work Load Analysis

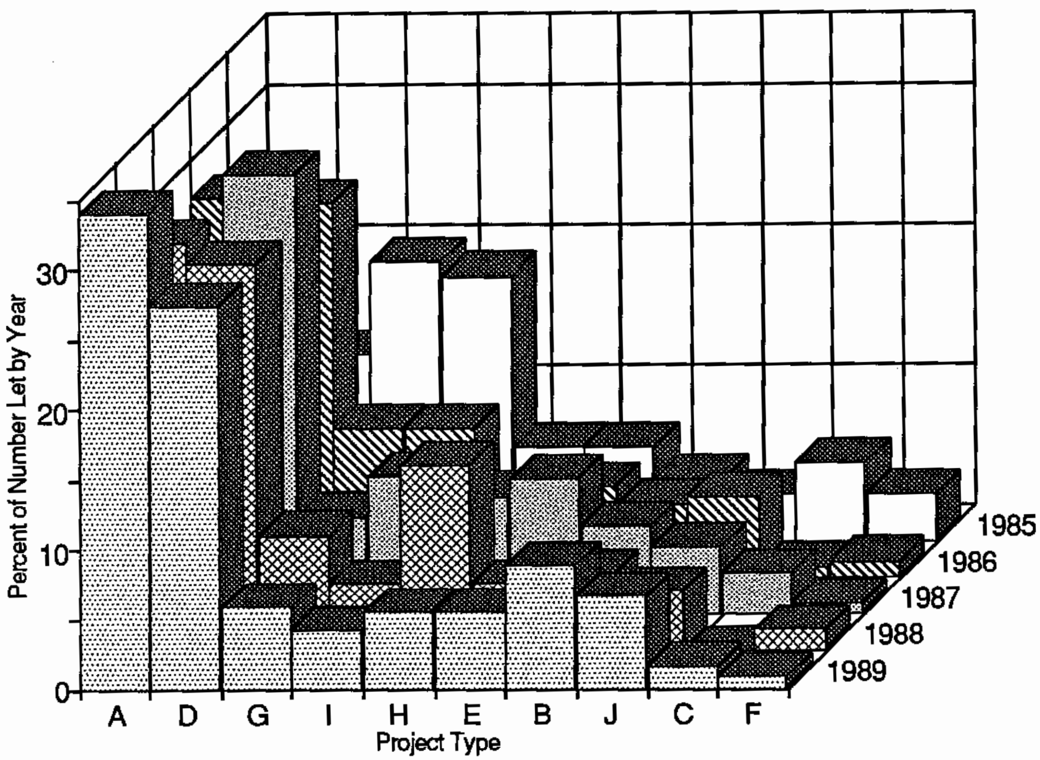
The three figures included in this appendix supplement the discussion on construction work load which begins on Page 4 of this report.

# Figure A-1 — Contractor Earnings: 1985 through 1989



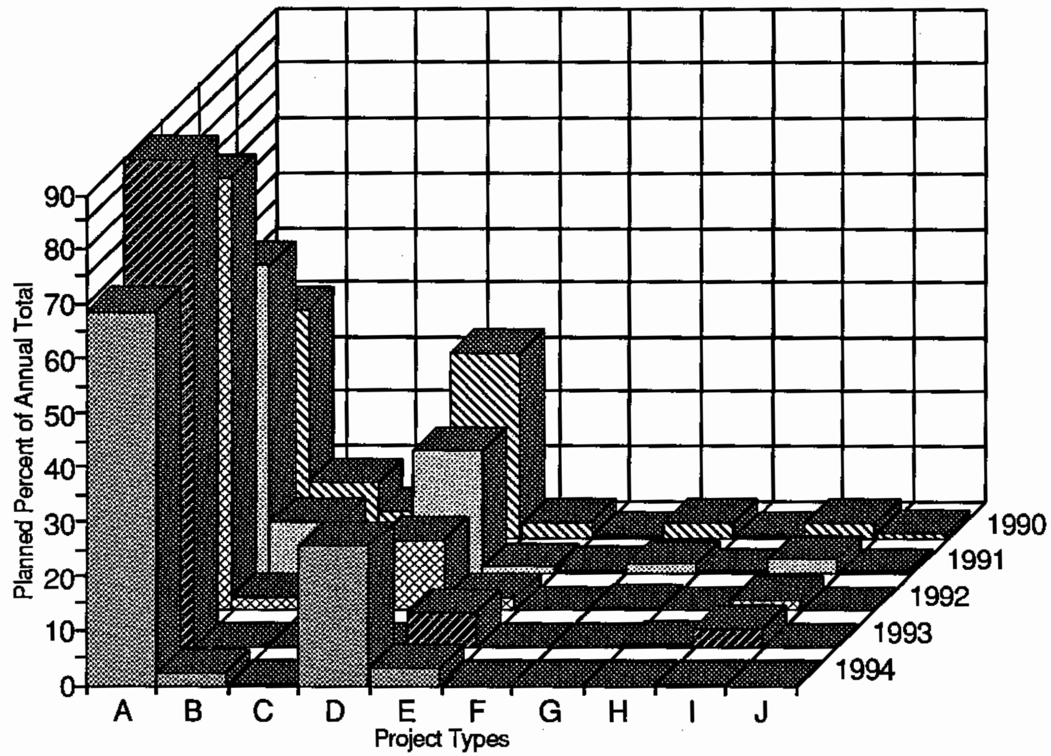

| | Project Types | Average Annual Percent of Total |
|---|---|---|
| A | Construction | 55 |
| B | Reconstruction | 7 |
| C | Widening and Resurfacing | 3 |
| D | Resurfacing | 24 |
| E | Bridge Repair | 5 |
| F | Intersection Improvement | 0 |
| G | Safety and Traffic Control | 2 |
| H | Miscellaneous | 2 |
| I | Unique | 1 |
| J | Aggregate Stockpiles | 1 |
| | | 100 |

## Figure A-2 — Percent of Number of Projects Awarded: 1985 through 1989




| | Project Types | Average Annual Percent of Total |
|---|---|---|
| A | Construction | 25 |
| B | Reconstruction | 6 |
| C | Widening and Resurfacing | 2 |
| D | Resurfacing | 25 |
| E | Bridge Repair | 7 |
| F | Instersection Improvement | 2 |
| G | Safety and Traffic Control | 10 |
| H | Miscellaneous | 8 |
| I | Unique | 10 |
| J | Aggregate Stockpiles | 5 |
| | | 100 |

# Figure A-3 — Work Load Plan: 1990 through 1994




| | Project Types | Average Annual Percent of Total |
|---|---|---|
| A | Construction | 67 |
| B | Reconstruction | 5 |
| C | Widening and Resurfacing | 2 |
| D | Resurfacing | 19 |
| E | Bridge Repair | 3 |
| F | Intersection Improvement | 0 |
| G | Safety and Traffic Control | 1 |
| H | Miscellaneous | 0 |
| I | Unique | 2 |
| J | Aggregate Stockpiles | 0 |
| | | 100 |

*Appendix B*

# *Activity Analyses*

Analyses to determine the significant activities for each project type were made. All data were taken from Construction Engineering Manpower Management System (CEMMS) records. The analyses which summarizes all project types is in Figure 2 on Page 8. Analyses for Construction and Resurfacing project types are shown in Figures 3 and 4, Pages 9 and 10. The analyses for all other project types are presented in this appendix.

The definitions of the CEMMS activities are included here for easy reference followed by the analyses.

## *Individual Planning Activity Definitions*

**Code** **Description**

**Earthwork**

01 ROADWAY LAYOUT STAKING. Staking for road layout includes locating or re-establishing control points, staking or restaking centerline, establishing reference lines, and elevation control; staking for clearing, grubbing, tree removal and miscellaneous items; right of way staking; and staking for all utility relocation and construction. FIELD WORK ONLY.

02 CROSS SECTIONING AND SLOPE STAKING. Re-establishing centerline, slope staking, cross sectioning and final measurements for roadway earthwork. Includes cross sectioning of borrow pits, undercut areas and channel changes. FIELD WORK ONLY.

03 GRADE CONTROL -- SUBGRADE. Re-establishing centerline, setting off-set stakes, and establishing grade for roadway excavation, embankment and granular subbase. FIELD WORK ONLY.

04 MINOR DRAINAGE STRUCTURE STAKING. Layout, staking, and final measurement for all subsurface drainage, including pipes, underdrains, storm sewers, headwalls and other related drainage facilities. Does not include box culverts. FIELD WORK ONLY.

05 EARTHWORK INSPECTION. All earthwork inspection, including topsoil removal, stockpiling and placing inspection; slope shaping and grade inspection; and subbase placement inspection. Includes clearing and grubbing, tree removal, building and structures relocation or demolition, relocation of all utilities and new utility construction of water lines, electrical cables, sanitary sewers, and other removal items. Excludes moisture and density testing. FIELD WORK AND FIELD DOCUMENTATION ONLY.

06 TESTING -- EARTHWORK, MINOR DRAINAGE, UTILITIES. Density and moisture determination tests on earthwork, minor drainage and utility construction.

| Code | Description |
|---|---|

07 MINOR DRAINAGE STRUCTURE INSPECTION. Inspection for installation of pipes, underdrains, storm sewers, headwalls, manholes, catch basins and other related minor drainage structures. Includes inspection of installation -- location, trench width, bedding, placement and joints; inspection of forms and reinforcing steel; and inspection of backfill. Includes gradation testing for backfill material, all field and plant concrete testing and plant inspection. FIELD WORK AND FIELD DOCUMENTATION ONLY.

08 EARTHWORK -- OFFICE. All office work necessary to prepare for road layout staking, minor drainage facilities, utility relocation, clearing and grubbing, tree removal, other removal items, and traffic control during construction. Also includes preparation of slope stake books, grade books, sketches and the computation and preparation of final quantities for earthwork items.

**Aggregate**

11 LINE/GRADE CONTROL -- AGGREGATE CONSTRUCTION/PAVING. Resetting reference lines, setting offset stakes, setting grades, staking and final measurements for all aggregate construction and paving courses. FIELD WORK ONLY.

12 UNTREATED AGGREGATE CONSTRUCTION INSPECTION. Inspection of untreated aggregate bases and surface courses. Includes subbase shaping (fine grading of subbase) and depth inspection in preparation for aggregate placing; computing and checking yield; checking and inspecting aggregate placing, shaping, width, depth and crown. Excludes testing. FIELD WORK AND FIELD DOCUMENTATION ONLY.

13 TESTING -- UNTREATED AGGREGATE CONSTRUCTION. Field testing for untreated aggregate bases or surface courses at the aggregate source and on the roadway. Includes gradation, moisture and density tests.

14 TREATED AGGREGATE CONSTRUCTION INSPECTION. Inspection of asphalt, cement or lime treated bases. Includes subbase shaping (fine grading of subbase) and depth inspection in preparation for base placement; computing and checking yield; checking and inspecting treated base placing, shaping, width, depth and crown. Excludes plant inspection and testing. FIELD WORK AND FIELD DOCUMENTATION ONLY.

15 TESTING -- TREATED AGGREGATE CONSTRUCTION. Field testing for treated bases including moisture and density tests, plant inspection and gradation.

16 WEIGH AGGREGATE CONSTRUCTION MATERIALS. Scale inspection and weighing of aggregates for treated or untreated aggregate base and surface construction.

17 OFFICE WORK -- AGGREGATE CONSTRUCTION/PAVING. All office work in the preparation of field books, checking accumulation sheets, checking documentation, and preparation of final quantities for aggregate construction, asphalt paving and concrete paving.

**Asphalt Paving**

21 ASPHALT PAVING INSPECTION. Roadway inspection of asphalt paving operations. Includes checking grade preparation (fine grading and trimming); inspection of contractor's equipment, priming, joints, mix placement, mix temperature, rolling, non-skid surface treatment, computing and checking yield and checking asphalt materials. Includes field testing on the roadway. FIELD WORK AND FIELD DOCUMENTATION ONLY.

| Code | Description |
| --- | --- |

22 ASPHALT PLANT INSPECTION. All plant testing, weighing and inspection for asphalt paving operations. Includes aggregate gradation tests, extraction tests, plant calibration checks, and inspecting methods of storing and stockpiling materials.

**PCC Paving**

31 PORTLAND CEMENT CONCRETE PAVING INSPECTION. Roadway inspection of portland cement concrete paving operations. Includes checking grade preparation (fine grading and trimming), inspection of forms condition and placement, inspection of methods of storing and handling materials, inspection of contractor's equipment, inspection of installation of transfer devices, inspection of steel placement and concrete placement -- includes finishing, edging, curing, straight-edging, grinding, sawing and joint installation. Includes field concrete testing on the roadway. FIELD WORK AND FIELD DOCUMENTATION ONLY.

32 PCC PLANT -- PAVING. All plant testing and inspection for concrete paving operations. Includes aggregate gradation and moisture determination tests.

33 JOINT REPAIR PROJECT INSPECTION. Inspection of joint repair operations. Includes layout of pavements to be removed; and the inspection of sawing of joints, subgrade preparation and placement of concrete or asphalt pavement. FIELD WORK AND FIELD DOCUMENTATION ONLY.

**Structure/Box Culvert**

41 STRUCTURE STAKING. All layout of structures with a clear span of 20 feet or more and box culverts. Includes staking excavation limits, staking foundation piles, setting pile cut-offs, staking substructure lines and establishing grades, taking beam elevations and laying out deck lines and grades. FIELD WORK ONLY.

42 STRUCTURE INSPECTION. Inspection of structures with a span of 20 feet or more and box culverts. Includes inspection of structures excavation and backfill, inspecting piling operations, inspecting reinforcing and structural steel placement, inspecting substructure and superstructure concrete placement, and inspecting project cleanup. Includes all field testing and materials control at structure site. FIELD WORK AND FIELD DOCUMENTATION ONLY.

43 PCC PLANT -- STRUCTURE. All plant testing and inspection when the output of the plant is being used for the construction of structures with a clear span of 20 feet or more and box culverts. Includes aggregate gradation and moisture determination tests.

44 STRUCTURE -- OFFICE. Office work in quantity computations, field book preparation, checking documentation, deck grade computations, and preparation of final quantities for structures with a clear span of 20 feet or more and box culverts.

**Miscellaneous**

51 STAKING MISCELLANEOUS ITEMS. Staking for curb, gutter, sodding, seeding, erosion control, guardrail, fence, permanent signs, delineators, riprap, striping, final trim and all other items not identified in other activities. Includes all staking on smaller projects such as landscaping, intersection improvements (50 actual work day limit), and safety and traffic control.

| Code | Description |
|---|---|

52 INSPECTION OF MISCELLANEOUS ITEMS. All inspection, testing and final measurement for curb, gutter, sodding, seeding, erosion control, guardrail, fence, permanent signs, delineators, riprap, striping, final trim and all other items not identified in other activities. Includes all inspection on smaller projects such as landscaping, intersection improvements (50 actual work day limit), and safety and traffic control.

53 OFFICE WORK FOR MISCELLANEOUS ITEMS. Office work in the preparation of field books, checking documentation and preparation of final quantities for curb, gutter, sodding, seeding, erosion control, guardrail, fence, permanent signs, delineators, riprap, striping, final trim and all other items not identified in other activities. Includes all office work on projects such as landscaping, intersection improvements (50 actual work day limit), and safety and traffic control.

**Special Feature**

61 SPECIAL FEATURE STAKING. Staking of major features unique to the projects. Includes all staking for rest area facilities such as buildings, wells, flow chambers and pump houses; also staking for barriers, tunnels, retaining walls, and other specialty contract items. Includes staking on unique projects. FIELD WORK ONLY.

62 SPECIAL FEATURE INSPECTION. Inspection of major features unique to the projects. Includes all inspection for rest area facilities such as buildings, wells, flow chambers and pump houses; also barriers, tunnels, retaining walls, and other specialty items. Includes inspection of unique projects.

63 SPECIAL FEATURE -- OFFICE. Office work for major features unique to the projects. Includes all office work for rest area facilities such as buildings, wells, flow chambers and pump houses; also barriers, tunnels, retaining walls, and other special contract items.

**General**

71 GENERAL OFFICE WORK. General office work in establishing and maintaining files and record keeping systems; preparation of reports, final "As Constructed" plans, time sheets, bi-weekly progress reports, estimates, CCO's and maintaining the office.

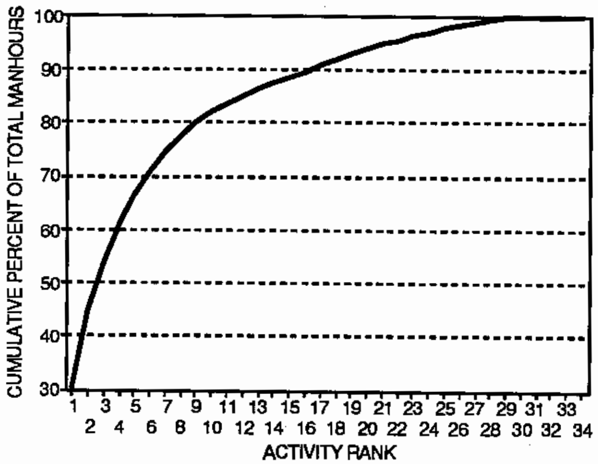
72 PROJECT MANAGEMENT AND COORDINATION. Project management relative to supervision of surveying, inspection and office activities; meeting with representatives of other divisions and agencies, contractors, landowners or the public; personnel management; manpower evaluations; training; and other project management.

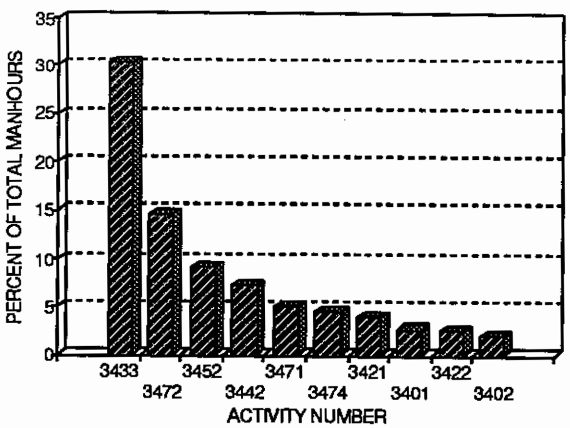
73 STANDBY (HOURLY EMPLOYEES ONLY). All non-productive time spent while waiting for the contractor to commence or resume work, waiting for the weather to improve so work may commence or resume.

74 TRAVEL (HOURLY EMPLOYEES ONLY). Travel time equal to or greater than one hour per person per day.

75 TRAINING. Includes only on-the-job training for a specific project. (Example: Training of a scale man. If one man is weighing and a second man in the scalehouse is just learning by observation, the second man would use this function and charge it to the project he is training for.)

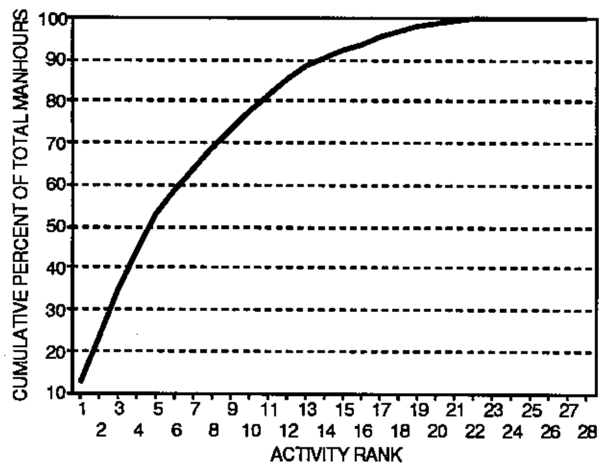
# Figure B-1 — Type B: Reconstruction

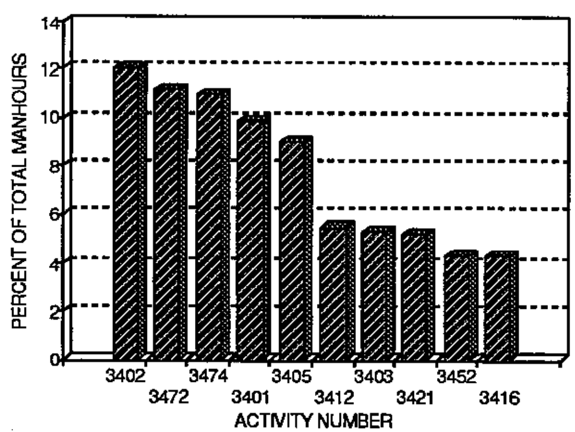



| Rank | Act No | Activity Name | Manhours | Percent of Total Manhours |
|---|---|---|---|---|
| 1 | 3433 | JCT REP PROJ INSP | 32998 | 30 |
| 2 | 3472 | PROJECT MGMT & COORD | 15821 | 15 |
| 3 | 3452 | INSPECT MISC ITEMS | 9988 | 9 |
| 4 | 3442 | STRUCT/BOX INSPECT | 7847 | 7 |
| 5 | 3471 | GENERAL OFFICE WORK | 5545 | 5 |
| 6 | 3474 | TRAVEL | 4970 | 5 |
| 7 | 3421 | ASPHALT PAV INSPECT | 4288 | 4 |
| 8 | 3401 | ROADWAY LAYOUT STAKE | 2935 | 3 |
| 9 | 3422 | ASPHLT PLANT INSPECT | 2779 | 3 |
| 10 | 3402 | X-SECT & SLOPE STAKE | 2101 | 2 |
| 11 | 3416 | WEIGH AGG MATERIALS | 1792 | 2 |
| 12 | 3451 | STAKING MISC ITEMS | 1521 | 1 |
| 13 | 3453 | OFFICE WRK MISC ITEM | 1438 | 1 |
| 14 | 3412 | UNTREAT AGG INSPECT | 1273 | 1 |
| 15 | 3411 | LINE/GRADE CONTROL | 1194 | 1 |
| 16 | 3407 | MINOR STRUCT INSPECT | 1172 | 1 |
| 17 | 3413 | TESTING--UNTREAT AGG | 1135 | 1 |
| 18 | 3408 | EARTHWORK--OFFICE | 1100 | 1 |
| 19 | 3405 | EARTHWORK INSPECTION | 1091 | 1 |
| 20 | 3475 | TRAINING | 1053 | 1 |
| | | TOTAL MANHOURS | 108791 | |

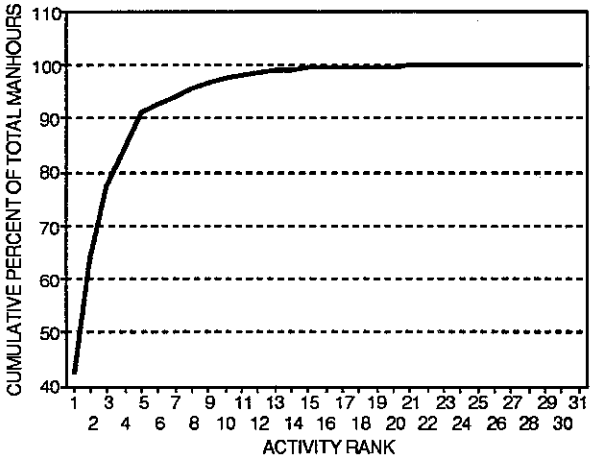
# Figure B-2 — Type C: Widening and Resurfacing

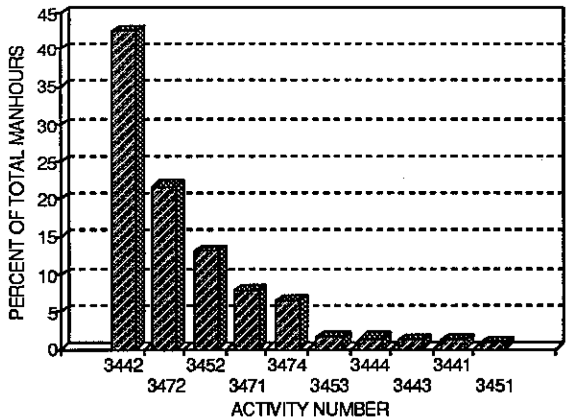



| Rank | Act No | Activity Name | Manhours | Percent of Total Manhours |
|---|---|---|---|---|
| 1 | 3402 | X-SECT & SLOPE STAKE | 5561 | 12 |
| 2 | 3472 | PROJECT MGMT & COORD | 5162 | 11 |
| 3 | 3474 | TRAVEL | 5080 | 11 |
| 4 | 3401 | ROADWAY LAYOUT STAKE | 4560 | 10 |
| 5 | 3405 | EARTHWORK INSPECTION | 4172 | 9 |
| 6 | 3412 | UNTREAT AGG INSPECT | 2519 | 5 |
| 7 | 3403 | GRADE CNTRL–SUBGRAD | 2448 | 5 |
| 8 | 3421 | ASPHALT PAV INSPECT | 2376 | 5 |
| 9 | 3452 | INSPECT MISC ITEMS | 1996 | 4 |
| 10 | 3416 | WEIGH AGG MATERIALS | 1993 | 4 |
| 11 | 3471 | GENERAL OFFICE WORK | 1855 | 4 |
| 12 | 3408 | EARTHWORK--OFFICE | 1701 | 4 |
| 13 | 3422 | ASPHLT PLANT INSPECT | 1566 | 3 |
| 14 | 3406 | TEST-STRUCT,EARTH,UT | 927 | 2 |
| 15 | 3451 | STAKING MISC ITEMS | 756 | 2 |
| 16 | 3417 | OFFICE WORK-AGG/PAV | 725 | 2 |
| 17 | 3413 | TESTING–UNTREAT AGG | 720 | 2 |
| 18 | 3453 | OFFICE WRK MISC ITEM | 600 | 1 |
| 19 | 3407 | MINOR STRUCT INSPECT | 585 | 1 |
| 20 | 3404 | MINOR STRUCT STAKING | 357 | 1 |
| | | TOTAL MANHOURS | 46259 | |

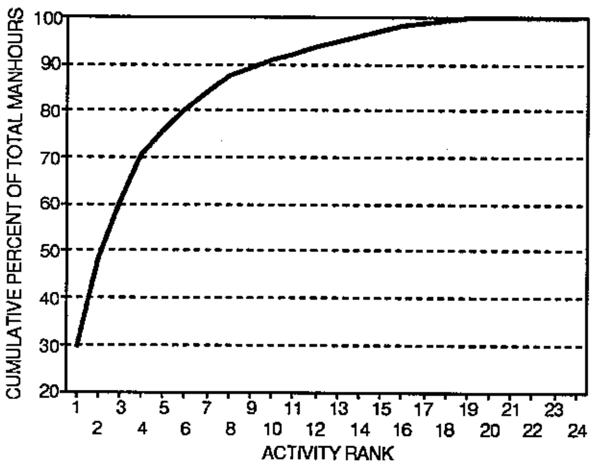
# Figure B-3 — Type E: Bridge Repair

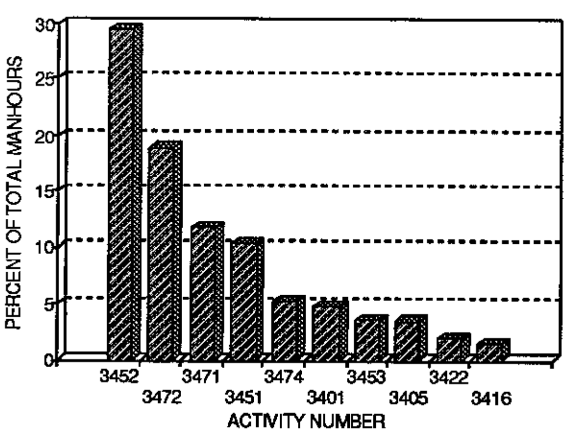



| Rank | Act No | Activity Name | Manhours | Percent of Total Manhours |
|---|---|---|---|---|
| 1 | 3442 | STRUCT/BOX INSPECT | 31036 | 43 |
| 2 | 3472 | PROJECT MGMT & COORD | 15800 | 22 |
| 3 | 3452 | INSPECT MISC ITEMS | 9473 | 13 |
| 4 | 3471 | GENERAL OFFICE WORK | 5632 | 8 |
| 5 | 3474 | TRAVEL | 4656 | 6 |
| 6 | 3453 | OFFICE WRK MISC ITEM | 1056 | 1 |
| 7 | 3444 | STRUCT/BOX OFFICE | 955 | 1 |
| 8 | 3443 | PCC PLANT--INSPECT | 945 | 1 |
| 9 | 3441 | STRUCT/BOX CVRT STAK | 843 | 1 |
| 10 | 3451 | STAKING MISC ITEMS | 692 | 1 |
| 11 | 3431 | PCC PAVE INSPECTION | 501 | 1 |
| 12 | 3432 | PCC PLANT--PAVING | 417 | 1 |
| 13 | 3421 | ASPHALT PAV INSPECT | 251 | 0 |
| 14 | 3413 | TESTING--UNTREAT AGG | 157 | 0 |
| 15 | 3422 | ASPHLT PLANT INSPECT | 134 | 0 |
| 16 | 3402 | X-SECT & SLOPE STAKE | 95 | 0 |
| 17 | 3417 | OFFICE WORK-AGG/PAV | 64 | 0 |
| 18 | 3416 | WEIGH AGG MATERIALS | 58 | 0 |
| 19 | 3473 | STANDBY | 29 | 0 |
| 20 | 3408 | EARTHWORK--OFFICE | 28 | 0 |
| | | TOTAL MANHOURS | 72957 | |

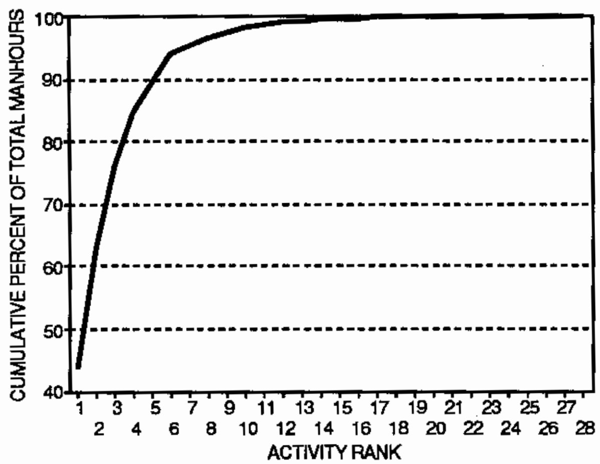
# Figure B-5 — Type G: Safety and Traffic Control

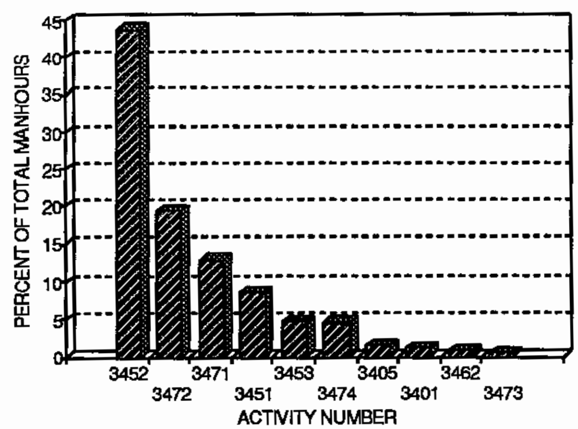



| Rank | Act No | Activity Name | Manhours | Percent of Total Manhours |
|---|---|---|---|---|
| 1 | 3452 | INSPECT MISC ITEMS | 2634 | 29 |
| 2 | 3472 | PROJECT MGMT & COORD | 1689 | 19 |
| 3 | 3471 | GENERAL OFFICE WORK | 1059 | 12 |
| 4 | 3451 | STAKING MISC ITEMS | 919 | 10 |
| 5 | 3474 | TRAVEL | 465 | 5 |
| 6 | 3401 | ROADWAY LAYOUT STAKE | 420 | 5 |
| 7 | 3453 | OFFICE WRK MISC ITEM | 323 | 4 |
| 8 | 3405 | EARTHWORK INSPECTION | 314 | 4 |
| 9 | 3422 | ASPHLT PLANT INSPECT | 167 | 2 |
| 10 | 3416 | WEIGH AGG MATERIALS | 133 | 1 |
| 11 | 3412 | UNTREAT AGG INSPECT | 120 | 1 |
| 12 | 3411 | LINE/GRADE CONTROL | 118 | 1 |
| 13 | 3421 | ASPHALT PAV INSPECT | 111 | 1 |
| 14 | 3402 | X-SECT & SLOPE STAKE | 109 | 1 |
| 15 | 3406 | TEST-STRUCT,EARTH,UT | 92 | 1 |
| 16 | 3403 | GRADE CNTRL--SUBGRAD | 91 | 1 |
| 17 | 3413 | TESTING--UNTREAT AGG | 56 | 1 |
| 18 | 3408 | EARTHWORK--OFFICE | 46 | 1 |
| 19 | 3417 | OFFICE WORK-AGG/PAV | 40 | 0 |
| 20 | 3442 | STRUCT/BOX INSPECT | 12 | 0 |
| | | TOTAL MANHOURS | 8941 | |

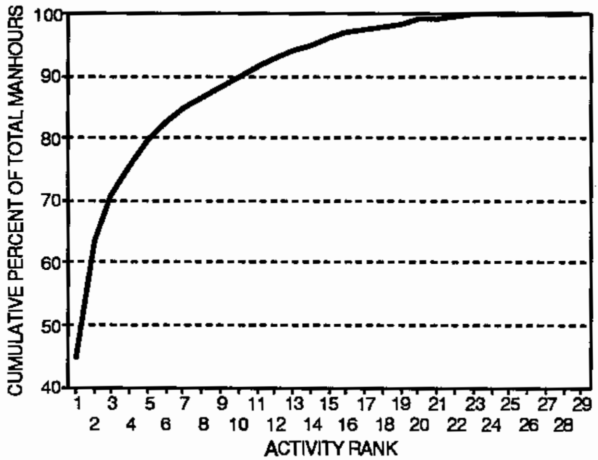
# Figure B-5 — Type G: Safety and Traffic Control

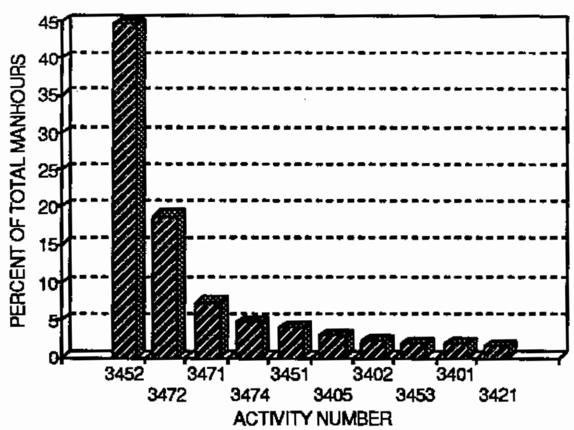



| Rank | Act No | Activity Name | Manhours | Percent of Total Manhours |
|---|---|---|---|---|
| 1 | 3452 | INSPECT MISC ITEMS | 16073 | 44 |
| 2 | 3472 | PROJECT MGMT & COORD | 7152 | 19 |
| 3 | 3471 | GENERAL OFFICE WORK | 4739 | 13 |
| 4 | 3451 | STAKING MISC ITEMS | 3159 | 9 |
| 5 | 3453 | OFFICE WRK MISC ITEM | 1689 | 5 |
| 6 | 3474 | TRAVEL | 1666 | 5 |
| 7 | 3405 | EARTHWORK INSPECTION | 590 | 2 |
| 8 | 3401 | ROADWAY LAYOUT STAKE | 446 | 1 |
| 9 | 3462 | SPECIAL FEAT INSPECT | 307 | 1 |
| 10 | 3473 | STANDBY | 190 | 1 |
| 11 | 3408 | EARTHWORK--OFFICE | 185 | 1 |
| 12 | 3422 | ASPHLT PLANT INSPECT | 146 | 0 |
| 13 | 3442 | STRUCT/BOX INSPECT | 105 | 0 |
| 14 | 3411 | LINE/GRADE CONTROL | 55 | 0 |
| 15 | 3431 | PCC PAVE INSPECTION | 55 | 0 |
| 16 | 3402 | X-SECT & SLOPE STAKE | 43 | 0 |
| 17 | 3404 | MINOR STRUCT STAKING | 25 | 0 |
| 18 | 3432 | PCC PLANT--PAVING | 20 | 0 |
| 19 | 3417 | OFFICE WORK-AGG/PAV | 19 | 0 |
| 20 | 3412 | UNTREAT AGG INSPECT | 17 | 0 |
| | | TOTAL MANHOURS | 36730 | |

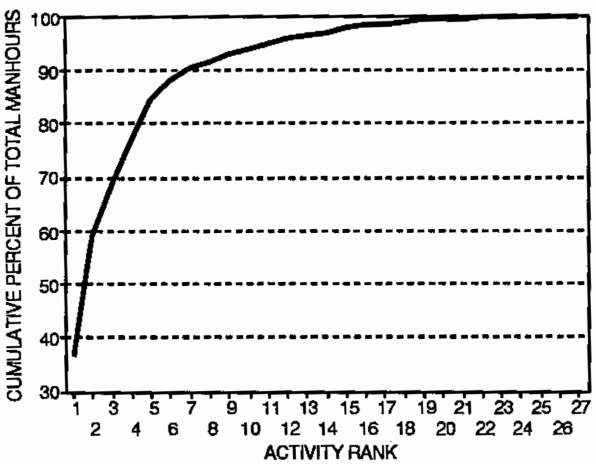
# Figure B-6 — Type H: Miscellaneous

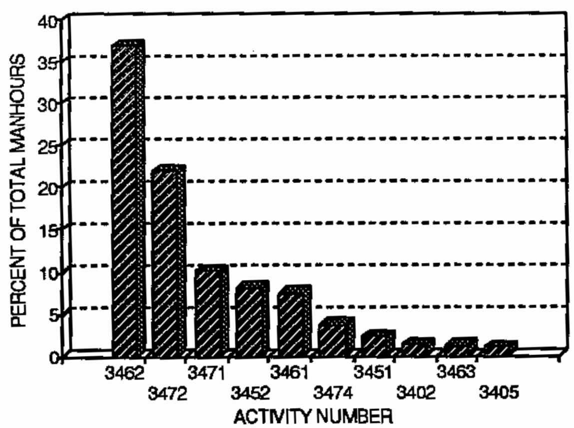



| Rank | Act No | Activity Name | Manhours | Percent of Total Manhours |
|---|---|---|---|---|
| 1 | 3452 | INSPECT MISC ITEMS | 19705 | 45 |
| 2 | 3472 | PROJECT MGMT & COORD | 8363 | 19 |
| 3 | 3471 | GENERAL OFFICE WORK | 3229 | 7 |
| 4 | 3474 | TRAVEL | 2143 | 5 |
| 5 | 3451 | STAKING MISC ITEMS | 1749 | 4 |
| 6 | 3405 | EARTHWORK INSPECTION | 1275 | 3 |
| 7 | 3402 | X-SECT & SLOPE STAKE | 986 | 2 |
| 8 | 3453 | OFFICE WRK MISC ITEM | 804 | 2 |
| 9 | 3401 | ROADWAY LAYOUT STAKE | 787 | 2 |
| 10 | 3421 | ASPHALT PAV INSPECT | 706 | 2 |
| 11 | 3408 | EARTHWORK--OFFICE | 685 | 2 |
| 12 | 3442 | STRUCT/BOX INSPECT | 662 | 1 |
| 13 | 3412 | UNTREAT AGG INSPECT | 477 | 1 |
| 14 | 3407 | MINOR STRUCT INSPECT | 475 | 1 |
| 15 | 3411 | LINE/GRADE CONTROL | 461 | 1 |
| 16 | 3462 | SPECIAL FEAT INSPECT | 407 | 1 |
| 17 | 3413 | TESTING--UNTREAT AGG | 228 | 1 |
| 18 | 3403 | GRADE CNTRL--SUBGRAD | 219 | 0 |
| 19 | 3406 | TEST-STRUCT,EARTH,UT | 197 | 0 |
| 20 | 3443 | PCC PLANT--INSPECT | 194 | 0 |
| | | TOTAL MANHOURS | 44262 | |

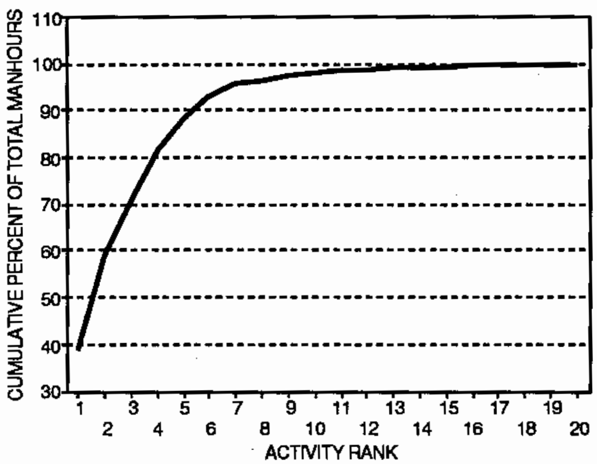
# Figure B-7 — Type I: Unique

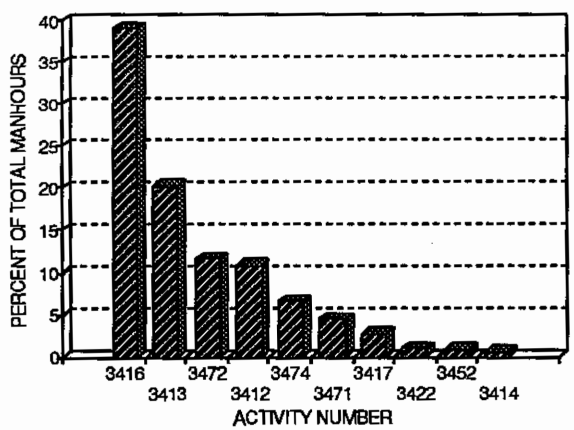



| Rank | Act No | Activity Name | Manhours | Percent of Total Manhours |
|---|---|---|---|---|
| 1 | 3462 | SPECIAL FEAT INSPECT | 8144 | 37 |
| 2 | 3472 | PROJECT MGMT & COORD | 4819 | 22 |
| 3 | 3471 | GENERAL OFFICE WORK | 2245 | 10 |
| 4 | 3452 | INSPECT MISC ITEMS | 1763 | 8 |
| 5 | 3461 | SPECIAL FEAT STAKING | 1628 | 7 |
| 6 | 3474 | TRAVEL | 815 | 4 |
| 7 | 3451 | STAKING MISC ITEMS | 495 | 2 |
| 8 | 3402 | X-SECT & SLOPE STAKE | 311 | 1 |
| 9 | 3463 | SPECIAL FEAT--OFFICE | 266 | 1 |
| 10 | 3405 | EARTHWORK INSPECTION | 254 | 1 |
| 11 | 3401 | ROADWAY LAYOUT STAKE | 207 | 1 |
| 12 | 3412 | UNTREAT AGG INSPECT | 164 | 1 |
| 13 | 3421 | ASPHALT PAV INSPECT | 158 | 1 |
| 14 | 3453 | OFFICE WRK MISC ITEM | 144 | 1 |
| 15 | 3416 | WEIGH AGG MATERIALS | 113 | 1 |
| 16 | 3422 | ASPHLT PLANT INSPECT | 106 | 0 |
| 17 | 3408 | EARTHWORK--OFFICE | 102 | 0 |
| 18 | 3403 | GRADE CNTRL--SUBGRAD | 63 | 0 |
| 19 | 3413 | TESTING--UNTREAT AGG | 56 | 0 |
| 20 | 3411 | LINE/GRADE CONTROL | 48 | 0 |
| | | TOTAL MANHOURS | 22037 | |

# Figure B-8 — Type J: Aggregate Stockpiles




| Rank | Act No | Activity Name | Manhours | Percent of Total Manhours |
|---|---|---|---|---|
| 1 | 3416 | WEIGH AGG MATERIALS | 5822 | 39 |
| 2 | 3413 | TESTING--UNTREAT AGG | 3014 | 20 |
| 3 | 3472 | PROJECT MGMT & COORD | 1751 | 12 |
| 4 | 3412 | UNTREAT AGG INSPECT | 1624 | 11 |
| 5 | 3474 | TRAVEL | 984 | 7 |
| 6 | 3471 | GENERAL OFFICE WORK | 659 | 4 |
| 7 | 3417 | OFFICE WORK-AGG/PAV | 417 | 3 |
| 8 | 3422 | ASPHLT PLANT INSPECT | 165 | 1 |
| 9 | 3452 | INSPECT MISC ITEMS | 131 | 1 |
| 10 | 3414 | TREATED AGG INSPECT | 87 | 1 |
| 11 | 3473 | STANDBY | 51 | 0 |
| 12 | 3461 | SPECIAL FEAT STAKING | 45 | 0 |
| 13 | 3415 | TESTING--TREATED AGG | 44 | 0 |
| 14 | 3475 | TRAINING | 29 | 0 |
| 15 | 3402 | X-SECT & SLOPE STAKE | 28 | 0 |
| 16 | 3451 | STAKING MISC ITEMS | 21 | 0 |
| 17 | 3453 | OFFICE WRK MISC ITEM | 21 | 0 |
| 18 | 3433 | JCT REP PROJ INSP | 20 | 0 |
| 19 | 3411 | LINE/GRADE CONTROL | 18 | 0 |
| 20 | 3408 | EARTHWORK--OFFICE | 14 | 0 |
| | | TOTAL MANHOURS | 14945 | |

*Appendix C*

# ***Density Kit Equipment***

## ***Michigan Department of Transportation***
## ***Equipment Furnished in Density Kits***[1]

1 -- 200 Series Volumeter
1 -- Box of spare balloons
1 -- Base plate for volumeter
2 -- 2,000-gram weights and one box of 1 to 1,000-gram weights
1 -- 5-kilo capacity balance
1 -- Standard Proctor rammer
1 -- Proctor mold
1 -- Strike-off bar
1 -- Michigan cone with stopper
2 -- 10 by 10-inch pans
1 -- Large 12-inch spoon
1 -- One-point cone chart
1 -- One-point T-99 chart
1 -- 1/2-gallon plastic water bottle
1 -- 1/2-gallon plastic carbide jug
1 -- "Speedy" Moisture Tester Kit
1 -- 4-inch spatula
1 -- Density Handbook
1 -- 8 by 8 by 10-inch wooden pounding block
1 -- 18 by 18-inch screen with 1/4-inch mesh
1* -- Nuclear gauge and support equipment
1* -- Michigan Modified Marshall set-up
1* -- Michigan Modified T-180 set-up

* Truck mounted kit may be supplemented with a Nuclear Moisture-Density gauge, Michigan Modified Marshall or Michigan Modified T-180 equipment.

**Additional Equipment Needed When a Stove is Used**

1 -- 1 additional set of 1 to 1,000-gram weights
1 -- 2-kilo capacity balance weighing to 1/10 of a gram
1 -- 2-burner LP bottled gas stove and tank
4 -- 16-ounce moisture cans
1 -- Pair of crucible tongs

[1] Pages 141-142, Density Control Handbook (_14_)

# Appendix D

# Standards Analyses

This appendix includes the following items to supplement the discussions in Chapter Three, Staffing Analyses:

- a listing -- PCEMS number, project description and modifiers -- of the projects selected for making the analyses;
- summary comparisons of planned and actual man-hours per unit for each activity for new construction and resurfacing project types; and
- the standards analyses for each activity for each of the two project types.

There were few new construction projects and no resurfacing projects in the sample where modifiers had been applied so these analyses are limited to projects without modifiers.

## *Model Projects*

**Table D-1 -- Model Projects --Resurfacing**

| PCEMS Number | Project Description |
|---|---|
| 1264 | AC Pavement |
| 2676 | AC Pavement |
| 3068 | AC Pavement |
| 3073 | AC Pavement |
| 3082 | AC Pavement |
| 3083 | AC Pavement |
| J205 | AC Pavement |
| J219 | AC Pavement |
| J227 | AC Pavement |
| J228 | AC Pavement |
| J258 | AC Pavement |
| J263 | AC Pavement |

**Table D-2 -- Model Projects -- New Construction**

| PCEMS Number | Project Description | Modifiers Traffic | Urban | Mountains |
|---|---|---|---|---|
| 131Y | Grading/Base/PCC Pavement | X | X | |
| 1302 | Grading/Base/AC Pvt/PCC Pvt/Structures | | X | |
| J204 | Grading/Base/Structures | | X | |
| 52A2 | Grading/Base/PCC Pavement | | | X |
| 598X | Grading/Base/AC Pavement/PCC Pavement | | | X |
| 024Y | Structures | | | |
| 0285 | Structures | | | |
| 033Y | Grading/Structures | | | |
| 034Y | Structures | | | |
| 035Y | Structures | | | |
| 0410 | Base/AC Pavement/PCC Pavement | | | |
| 0440 | Grading/Base/Structures | | | |
| 0442 | Grading/Base | | | |
| 0474 | Grading/Base/Structures | | | |
| 061W | Structures | | | |
| 063W | Structures | | | |
| 1251 | Grading/Base/AC Pavement | | | |
| 1352 | Structures | | | |
| 163W | Grading/Base/Structures | | | |
| 2085 | Grading/Base/AC Pavement | | | |
| 2365 | Structures | | | |
| 259Y | Structures | | | |
| 260Y | Structures | | | |
| 2626 | Grading/Base/AC Pavement | | | |
| 2656 | Base/AC Pavement/PCC Pavement | | | |
| 265Y | Structures | | | |
| 266Y | Structures | | | |
| 2959 | Base/AC Pavement/PCC Pavement | | | |
| 2983 | Base/AC Pavement/PCC Pavement | | | |
| 620X | Structures | | | |
| J237 | Grading/Base/PCC Pavement/Structures | | | |

## Table D-3 -- Analysis of CEMMS Standards -- Construction Projects with No Modifiers

| Code | Activity | No. of Proj. | Unit of Measure | Total Planning Units | Standard M-Hrs per Unit | Planned Man-Hours | Actual Units | Actual Man-Hours | Actual M-Hrs per Actual Unit | Actual as % of Planned |
|---|---|---|---|---|---|---|---|---|---|---|
| 01 | Layout Staking | 9 | Roadway Mile | 54.5 | 105 | 5,706 | 54.5 | 5,094 | 93.5 | 89 |
| 02 | X-Sect/Slope Stake | 10 | Roadway Mile | 55.5 | 145 | 7,982 | 55.5 | 8,408 | 151.5 | 104 |
| 03 | Grade Control | 8 | Roadway Mile | 53.5 | 86 | 4,601 | 53.5 | 4,583 | 85.7 | 100 |
| 04 | Stake Minor Struct | 8 | Roadway Mile | 53.5 | 25 | 1,326 | 53.5 | 935 | 17.5 | 70 |
| 05 | Earthwork Inspection | 9 | 10,000 CY | 659.8 | 11 | 7,257 | 707.0 | 5,514 | 7.8 | 71 |
| 06 | Testing | 9 | 10,000 CY | 659.8 | 7 | 4,619 | 707.0 | 4,986 | 7.1 | 101 |
| 07 | Minor Str Inspection | 8 | Roadway Mile | 53.5 | 25 | 1,316 | 53.5 | 1,723 | 32.2 | 129 |
| 08 | Earthwork Office | 10 | Roadway Mile | 55.5 | 60 | 3,287 | 55.5 | 1,532 | 27.6 | 46 |
| 11 | Line/Grade Control | 4 | Roadway Mile | 40.4 | 125 | 5,052 | 40.4 | 6,691 | 165.6 | 132 |
| 12 | Untreated Agg Insp | 12 | 1,000 Tons | 664.6 | 5 | 3,325 | 663.1 | 4,269 | 6.4 | 129 |
| 13 | Test Untreated Agg | 11 | 1,000 Tons | 572.8 | 3 | 1,719 | 576.6 | 1,940 | 3.4 | 112 |
| 16 | Weigh Agg Matls | 11 | 1,000 Tons | 657.2 | 5 | 3,288 | 655.5 | 6,034 | 9.2 | 184 |
| 17 | Office Agg/Paving | 11 | 1,000 Tons | 999.6 | 2 | 1,998 | 1,051.8 | 1,372 | 1.3 | 65 |
| 21 | Asph Paving Insp | 7 | 1,000 Tons | 45.5 | 13 | 592 | 44.9 | 1,594 | 35.5 | 273 |
| 22 | Asph Plant Insp | 6 | 1,000 Tons | 42.1 | 13 | 548 | 41.7 | 1,033 | 24.8 | 191 |
| 31 | PCC Paving Insp | 5 | 1,000 SY | 707.1 | 7 | 4,949 | 716.8 | 4,862 | 608 | 97 |
| 32 | PCC Plant Insp | 5 | 1,000 SY | 707.1 | 4 | 2,829 | 716.8 | 2,960 | 4.1 | 103 |
| 41 | Struct/Box Staking | 14 | Bent | 55.0 | 10 | 550 | 55.0 | 599 | 10.9 | 109 |
| 42 | Struct/Box Insp | 17 | 100 SY | 87.4 | 60 | 5,244 | 87.4 | 6,150 | 70.4 | 117 |
| 43 | PCC Plant Insp - Str | 17 | 100 SY | 87.4 | 8 | 699 | 87.4 | 1,254 | 14.3 | 179 |
| 44 | Office - Struct/Box | 5 | 100 SY | 34.2 | 5 | 171 | 34.2 | 174 | 5.1 | 102 |
| 51 | Stake Misc Items | 18 | Roadway Mile | 58.9 | 25 | 1,466 | 58.9 | 1,815 | 30.8 | 123 |
| 52 | Insp Misc Items | 22 | Roadway Mile | 64.9 | 75 | 4,828 | 64.9 | 5,857 | 90.2 | 120 |
| 53 | Office - Misc Items | 14 | Roadway Mile | 47.9 | 15 | 708 | 47.9 | 602 | 12.6 | 84 |
| 71 | General Office | 25 | % Insp MH | 41,955.0 | 8% | 3,356 | 48,672.0 | 5,380 | 11% | 138 |
| 72 | Project Management | 24 | % MH 01-71 | 70,974.0 | 15% | 10,648 | 78,482.0 | 11,432 | 15% | 97 |
| 73 | Standby | 7 | % MH 01-71 | 37,248.0 | 0.1% | 38 | 44,981.0 | 214 | 0.5% | 476 |
| 74 | Travel | 22 | % Stk/Insp MH | 67,893.0 | 144.% | 9,808 | 76,464.0 | 11,157 | 14.6% | 101 |
| | **Total** | | | | | **97,910** | | **108,164** | | **110** |

## Table D-4 -- Analysis of CEMMS Standards -- Resurfacing Projects with No Modifiers

| Code | Activity | No. of Proj. | Unit of Measure | Total Planning Units | Standard M-Hrs per Unit | Planned Man-Hours | Actual Units | Actual Man-Hours | Actual M-Hrs per Actual Unit | Actual as % of Planned |
|---|---|---|---|---|---|---|---|---|---|---|
| 11 | Line/Grade Control | 10 | Roadway Mile | 99.7 | 12 | 1,196 | 99.7 | 1,315 | 13.2 | 110 |
| 12 | Untreated Agg Insp | 7 | 1,000 T | 46.0 | 6 | 276 | 42.5 | 221 | 5.2 | 87 |
| 13 | Test Untreated Agg | 9 | 1,000 Tons | 47.7 | 4 | 191 | 42.5 | 247 | 5.8 | 145 |
| 16 | Weigh Agg Matls | 7 | 1,000 Tons | 46.0 | 5 | 231 | 42.5 | 329 | 7.7 | 155 |
| 17 | Office Agg/Paving | 9 | 1,000 Tons | 347.3 | 1 | 349 | 353.4 | 344 | 1.0 | 97 |
| 21 | Asph Paving Insp | 11 | 1,000 Tons | 334.8 | 13 | 4,354 | 346.7 | 4,569 | 13.2 | 101 |
| 22 | Asph Plant Insp | 11 | 1,000 Tons | 334.8 | 13 | 4,354 | 346.7 | 3,287 | 9.5 | 73 |
| 51 | Stake Misc Items | 7 | Roadway Mile | 44.9 | 2 | 90 | 44.9 | 161 | 3.6 | 179 |
| 52 | Insp Misc Items | 10 | Roadway Mile | 64.0 | 10 | 640 | 64.0 | 533 | 8.3 | 83 |
| 53 | Office - Misc Items | 6 | Roadway Mile | 35.2 | 1 | 35 | 34.2 | 97 | 2.8 | 276 |
| 71 | General Office | 10 | % Insp MH | 9,802.0 | 8% | 783 | 8,633.0 | 1,220 | 14% | 177 |
| 72 | Project Management | 11 | % MH 01-71 | 12,922.0 | 15% | 1,939 | 12,435.0 | 2,356 | 19% | 126 |
| 73 | Standby | 5 | % MH 01-71 | 5,216.0 | 0.1% | 5 | 5,169.0 | 158 | 3.1% | 3,057 |
| 74 | Travel | 9 | % Stk/Insp MH | 9,500.0 | 15% | 1,426 | 8,410.0 | 964 | 11.5% | 76 |
| 75 | Training | 1 | % MH 01-71 | 4,471.0 | 0.1% | 1 | 1,314.0 | 1 | 0.1% | 76 |
| | **Total** | | | | | **15,780** | | **15,802** | | **100** |

Project Type: Construction, No Modifiers

Activity: 01 Roadway Layout Staking
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 1251 | 1.4 | 105 | 147 | 435 | 1.4 | 311 | 296 |
| 259Y | 1.0 | 105 | 105 | 300 | 1.0 | 300 | 286 |
| 2085 | 1.8 | 105 | 171 | 299 | 1.8 | 166 | 158 |
| 0440 | 18.7 | 105 | 1,964 | 2,034 | 18.7 | 109 | 104 |
| 163W | 7.8 | 105 | 819 | 776 | 7.8 | 99 | 95 |
| 2626 | 2.0 | 105 | 210 | 197 | 2.0 | 99 | 94 |
| 0474 | 8.7 | 105 | 914 | 654 | 8.7 | 75 | 72 |
| 0442 | 12.1 | 105 | 1,271 | 371 | 12.1 | 31 | 29 |
| J237 | 1.0 | 105 | 105 | 28 | 1.0 | 28 | 27 |
| Total | 54.5 | 105 | 5,706 | 5,094 | 54.5 | 93 | 89 |
| (Weighted Average) | | | | | | | |
| Total* | 39.0 | 105 | 4,078 | 3,960 | 39.0 | 102 | 97 |

* With 2 highs & 2 lows omitted

Activity: 02 Cross-Section and Slope Stake
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 163W | 7.8 | 145 | 1,131 | 2,600 | 7.8 | 333 | 230 |
| 2085 | 1.8 | 145 | 194 | 561 | 1.8 | 312 | 215 |
| 1251 | 1.4 | 145 | 203 | 202 | 1.4 | 144 | 100 |
| 0440 | 18.7 | 145 | 2,712 | 2,575 | 18.7 | 138 | 95 |
| 0474 | 8.7 | 145 | 1,262 | 1,159 | 8.7 | 133 | 92 |
| 2626 | 2.0 | 145 | 290 | 266 | 2.0 | 133 | 92 |
| 0442 | 12.1 | 145 | 1,755 | 895 | 12.1 | 74 | 51 |
| 033Y | 1.0 | 145 | 145 | 68 | 1.0 | 68 | 47 |
| 259Y | 1.0 | 145 | 145 | 56 | 1.0 | 56 | 39 |
| J237 | 1 | 145 | 145 | 26 | 1.0 | 26 | 18 |
| Total | 55.5 | 145 | 7,982 | 8,408 | 55.5 | 151 | 104 |
| (Weighted Average) | | | | | | | |
| Total* | 43.9 | 145 | 6,367 | 5,165 | 43.9 | 118 | 81 |

* With 2 highs & 2 lows omitted

## Standards Analysis

**Project Type:** Construction, No Modifiers

**Activity:** 03 Grade Control -- Subgrade
**Unit of Measure:** Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 1 | 86 | 86 | 207 | 1.0 | 207 | 241 |
| 1251 | 1.4 | 86 | 120 | 163 | 1.4 | 116 | 135 |
| 0442 | 12.1 | 86 | 1,041 | 1,226 | 12.1 | 101 | 118 |
| 2085 | 1.8 | 86 | 155 | 170 | 1.8 | 94 | 110 |
| 163W | 7.8 | 86 | 671 | 645 | 7.8 | 83 | 96 |
| 0474 | 8.7 | 86 | 748 | 705 | 8.7 | 81 | 94 |
| 0440 | 18.7 | 86 | 1,608 | 1,328 | 18.7 | 71 | 83 |
| 2626 | 2.0 | 86 | 172 | 139 | 2.0 | 70 | 81 |
| Total (Weighted Average) | 53.5 | 86 | 4,601 | 4,583 | 53.5 | 86 | 100 |
| Total* | 52.5 | 86 | 4,515 | 4,376 | 52.5 | 83 | 97 |

* With 1 high & 0 lows omitted

**Activity:** 04 Minor Structure Staking
**Unit of Measure:** Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 1251 | 1.4 | 25 | 35 | 36 | 1.4 | 26 | 103 |
| 163W | 7.8 | 25 | 195 | 170 | 7.8 | 22 | 87 |
| 0474 | 8.7 | 25 | 218 | 180 | 8.7 | 21 | 83 |
| 2085 | 1.8 | 25 | 32 | 34 | 1.8 | 19 | 76 |
| 0440 | 18.7 | 25 | 468 | 318 | 18.7 | 17 | 68 |
| 2626 | 2.0 | 25 | 50 | 31 | 2.0 | 16 | 62 |
| 0442 | 12.1 | 25 | 303 | 156 | 12.1 | 13 | 52 |
| J237 | 1 | 25 | 25 | 10 | 1.0 | 10 | 40 |
| Total (Weighted Average) | 53.5 | 25 | 1,326 | 935 | 53.5 | 17 | 70 |

Standards Analysis

Project Type: Construction, No Modifiers

Activity: 05 Earthwork Inspection
Unit of Measure: 10,000 Cubic Yards

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 4.4 | 11 | 48 | 423 | 4.4 | 96.1 | 874 |
| 033Y | 5.0 | 11 | 55 | 87 | 2.5 | 34.8 | 316 |
| 0474 | 100.4 | 11 | 1,104 | 1,091 | 107.9 | 10.1 | 92 |
| 2085 | 39.3 | 11 | 432 | 416 | 43.8 | 9.5 | 86 |
| 2626 | 21.9 | 11 | 241 | 183 | 21.7 | 8.4 | 77 |
| 0440 | 150.1 | 11 | 1,651 | 1,283 | 162.9 | 7.9 | 72 |
| 0442 | 108.9 | 11 | 1,198 | 950 | 122.4 | 7.8 | 71 |
| 163W | 113.1 | 11 | 1,244 | 539 | 118.9 | 4.5 | 41 |
| 1251 | 116.7 | 11 | 1,284 | 542 | 122.5 | 4.4 | 40 |
| Total | 659.8 | 11 | 7,257 | 5,514 | 707.0 | 7.8 | 71 |
| (Weighted Average) | | | | | | | |
| Total* | 420.6 | 11 | 4,626 | 3,923 | 458.7 | 8.6 | 78 |

* With 2 highs & 2 lows omitted

Activity: 06 Testing -- Structures, Earthwork, Utilities
Unit of Measure: 10,000 Cubic Yards

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 4.4 | 7 | 31 | 168 | 4.4 | 38.2 | 545 |
| 033Y | 5.0 | 7 | 35 | 72 | 2.5 | 28.8 | 411 |
| 2085 | 39.3 | 7 | 275 | 635 | 43.8 | 14.5 | 207 |
| 163W | 113.1 | 7 | 792 | 1,109 | 118.9 | 9.3 | 133 |
| 0474 | 100.4 | 7 | 703 | 882 | 107.9 | 8.2 | 117 |
| 0440 | 150.1 | 7 | 1,051 | 949 | 162.9 | 5.8 | 83 |
| 1251 | 116.7 | 7 | 817 | 659 | 122.5 | 5.4 | 77 |
| 0442 | 108.9 | 7 | 762 | 480 | 122.4 | 3.9 | 56 |
| 2626 | 21.9 | 7 | 153 | 32 | 21.7 | 1.5 | 21 |
| Total | 659.8 | 7 | 4,619 | 4,986 | 707.0 | 7.1 | 101 |
| (Weighted Average) | | | | | | | |
| Total* | 628.5 | 7 | 4,400 | 4,714 | 678.4 | 6.9 | 99 |

* With 2 highs & 1 low omitted

Standards Analysis

Project Type: Construction, No Modifiers

Activity: 07 Minor Structure Inpsection
Unit of Measure: Roadway Mile

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 1 | 25 | 25 | 233 | 1.0 | 233.0 | 932 |
| 2085 | 1.8 | 25 | 22 | 257 | 1.8 | 142.8 | 571 |
| 2626 | 2.0 | 25 | 50 | 180 | 2.0 | 90.0 | 360 |
| 1251 | 1.4 | 25 | 35 | 85 | 1.4 | 60.7 | 243 |
| 0474 | 8.7 | 25 | 218 | 228 | 8.7 | 26.2 | 105 |
| 0442 | 12.1 | 25 | 303 | 234 | 12.1 | 19.3 | 77 |
| 163W | 7.8 | 25 | 195 | 98 | 7.8 | 12.6 | 50 |
| 0440 | 18.7 | 25 | 468 | 408 | 18.7 | 1.1 | 5 |
| Total (Weighted Average) | 53.5 | 25 | 1,316 | 1,723 | 53.5 | 32.2 | 129 |
| Total* | 32.0 | 25 | 801 | 825 | 32.0 | 25.8 | 103 |

* With 2 highs & 1 low omitted

Activity: 08 Earthwork -- Office
Unit of Measure: Roadway Mile

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 259Y | 1.0 | 60 | 60 | 83 | 1.0 | 83.0 | 138 |
| 2085 | 1.8 | 60 | 65 | 105 | 1.8 | 58.3 | 97 |
| 1251 | 1.4 | 60 | 84 | 75 | 1.4 | 53.6 | 89 |
| 0440 | 18.7 | 60 | 1,122 | 778 | 18.7 | 41.6 | 69 |
| 0474 | 8.7 | 60 | 522 | 189 | 8.7 | 21.7 | 36 |
| 163W | 7.8 | 60 | 468 | 150 | 7.8 | 19.2 | 32 |
| J237 | 1.0 | 60 | 60 | 16 | 1.0 | 16.0 | 27 |
| 2626 | 2.0 | 60 | 120 | 27 | 2.0 | 13.5 | 23 |
| 033Y | 1.0 | 60 | 60 | 11 | 1.0 | 11.0 | 18 |
| 0442 | 12.1 | 60 | 726 | 98 | 12.1 | 8.1 | 13 |
| Total (Weighted Average) | 55.5 | 60 | 3,287 | 1,532 | 55.5 | 27.6 | 46 |
| Total* | 42.4 | 60 | 2,501 | 1,423 | 42.4 | 33.6 | 56 |

* With 0 highs & 2 lows omitted

Project Type: Construction, No Modifiers

Activity: 11 Line/Grade Control
Unit of Measure: Roadway Mile

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 2983 | 13.9 | 125 | 1,738 | 2,905 | 13.9 | 209.0 | 167 |
| 2656 | 8.7 | 125 | 1,088 | 1,543 | 8.7 | 177.4 | 142 |
| 0442 | 12.1 | 125 | 1,513 | 1,528 | 12.1 | 126.3 | 101 |
| 0410 | 5.7 | 125 | 713 | 715 | 5.7 | 125.4 | 100 |
| Total (Weighted Average) | 40.4 | 125 | 5,052 | 6,691 | 40.4 | 165.6 | 132 |

Activity: 12 Untreated Aggregate Inpsection
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 7.4 | 5 | 37 | 91 | 7.6 | 12.0 | 239 |
| 0440 | 114.0 | 5 | 570 | 1,251 | 136.0 | 9.2 | 184 |
| 2626 | 22.3 | 5 | 112 | 195 | 23.8 | 8.2 | 164 |
| 1251 | 34.7 | 5 | 174 | 263 | 35.4 | 7.4 | 149 |
| 2656 | 12.5 | 5 | 63 | 99 | 14.1 | 7.0 | 140 |
| 0442 | 149.8 | 5 | 749 | 1,045 | 154.2 | 6.8 | 136 |
| 0474 | 71.8 | 5 | 359 | 439 | 71.4 | 6.1 | 123 |
| 163W | 91.8 | 5 | 459 | 516 | 86.5 | 6.0 | 119 |
| 0410 | 13.6 | 5 | 68 | 75 | 13.1 | 5.7 | 115 |
| 2959 | 40.3 | 5 | 202 | 172 | 38.2 | 4.5 | 90 |
| 2085 | 63.2 | 5 | 316 | 113 | 51.7 | 2.2 | 44 |
| 2983 | 43.2 | 5 | 216 | 10 | 31.1 | 0.3 | 6 |
| Total (Weighted Average) | 664.6 | 5 | 3,325 | 4,269 | 663.1 | 6.4 | 129 |
| Total* | 614.0 | 5 | 3,072 | 4,168 | 624.4 | 6.7 | 134 |

* With 1 high & 1 low omitted

Standards Analysis

Project Type: Construction, No Modifiers

Activity: 13 Testing -- Untreated Aggregate
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 0410 | 13.6 | 3 | 41 | 92 | 13.1 | 7.0 | 234 |
| 0474 | 71.8 | 3 | 215 | 433 | 71.4 | 6.1 | 202 |
| 0440 | 114.0 | 3 | 342 | 742 | 136.0 | 5.5 | 182 |
| 2656 | 12.5 | 3 | 38 | 59 | 14.1 | 4.2 | 139 |
| 1251 | 34.7 | 3 | 104 | 142 | 35.4 | 4.0 | 134 |
| 2959 | 40.3 | 3 | 121 | 104 | 38.2 | 2.7 | 91 |
| 2085 | 63.2 | 3 | 190 | 136 | 51.7 | 2.6 | 88 |
| 2983 | 43.2 | 3 | 130 | 43 | 31.1 | 1.4 | 46 |
| J237 | 7.4 | 3 | 22 | 10 | 7.6 | 1.3 | 44 |
| 2626 | 22.3 | 3 | 67 | 27 | 23.8 | 1.1 | 38 |
| 0442 | 149.8 | 3 | 449 | 152 | 154.2 | 1.0 | 33 |
| Total (Weighted Average) | 572.8 | 3 | 1,719 | 1,940 | 576.6 | 3.4 | 112 |
| Total* | 315.3 | 3 | 947 | 1,236 | 314.1 | 3.9 | 131 |

* With 2 highs & 2 lows omitted

Activity: 16 Weigh Aggregate Materials
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 0440 | 114.0 | 5 | 570 | 2,268 | 136.0 | 16.7 | 334 |
| 2085 | 63.2 | 5 | 316 | 745 | 51.7 | 14.4 | 288 |
| 2983 | 43.2 | 5 | 216 | 308 | 31.1 | 9.9 | 198 |
| 1251 | 34.7 | 5 | 174 | 303 | 35.4 | 8.6 | 171 |
| 0442 | 149.8 | 5 | 749 | 1,224 | 154.2 | 7.9 | 159 |
| 2656 | 12.5 | 5 | 63 | 106 | 14.1 | 7.5 | 150 |
| 2959 | 40.3 | 5 | 202 | 221 | 38.2 | 5.8 | 116 |
| 163W | 91.8 | 5 | 459 | 456 | 86.5 | 5.3 | 105 |
| 2626 | 22.3 | 5 | 112 | 120 | 23.8 | 5.0 | 101 |
| 0410 | 13.6 | 5 | 68 | 44 | 13.1 | 3.4 | 67 |
| 0474 | 71.8 | 5 | 359 | 239 | 71.4 | 3.3 | 67 |
| Total (Weighted Average) | 657.2 | 5 | 3,288 | 6,034 | 655.5 | 9.2 | 184 |
| | 543.2 | 5 | 2,718 | 3,766 | 519.5 | 7.2 | 145 |

* With 2 highs & 0 lows omitted

Project Type: Construction, No Modifiers

Activity: 17 Office Work -- Aggregate/Paving
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 0410 | 72.7 | 2 | 145 | 265 | 72.1 | 3.7 | 184 |
| 2983 | 160.6 | 2 | 321 | 261 | 148.3 | 1.8 | 88 |
| 0440 | 114.0 | 2 | 228 | 207 | 136.0 | 1.5 | 76 |
| 2656 | 91.2 | 2 | 182 | 142 | 100.0 | 1.4 | 71 |
| 2085 | 75.5 | 2 | 151 | 80 | 65.8 | 1.2 | 61 |
| 1251 | 43.6 | 2 | 87 | 48 | 39.9 | 1.2 | 60 |
| 163W | 91.8 | 2 | 184 | 89 | 86.5 | 1.0 | 51 |
| 2959 | 147.2 | 2 | 294 | 142 | 145.3 | 1.0 | 49 |
| 2626 | 31.0 | 2 | 62 | 27 | 32.3 | 0.8 | 42 |
| 0474 | 22.2 | 2 | 44 | 45 | 71.4 | 0.6 | 32 |
| 0442 | 149.8 | 2 | 300 | 66 | 154.2 | 0.4 | 21 |
| Total (Weighted Average) | 999.6 | 2 | 1,998 | 1,372 | 1051.8 | 1.3 | 65 |

Activity: 21 Asphalt Paving Inpsection
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 2983 | 3.4 | 13 | 44 | 508 | 3.2 | 158.8 | 1,221 |
| 0410 | 1.1 | 13 | 14 | 50 | 1.1 | 45.5 | 350 |
| 2656 | 7.6 | 13 | 99 | 315 | 9.5 | 33.2 | 255 |
| 2085 | 12.3 | 13 | 160 | 375 | 14.1 | 26.6 | 205 |
| 2959 | 3.5 | 13 | 46 | 93 | 4.0 | 23.3 | 179 |
| 1251 | 8.9 | 13 | 116 | 104 | 4.5 | 23.1 | 178 |
| 2626 | 8.7 | 13 | 113 | 149 | 8.5 | 17.5 | 135 |
| Total (Weighted Average) | 45.5 | 13 | 592 | 1,594 | 44.9 | 35.5 | 273 |
| Total* | 42.1 | 13 | 548 | 1,086 | 41.7 | 26.0 | 200 |

* With 2 highs & 0 lows omitted

Standards Analysis

Project Type: Construction, No Modifiers

Activity: 22 Asphalt Plant Inpsection
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 0410 | 1.1 | 13 | 14 | 48 | 1.1 | 43.6 | 336 |
| 2085 | 12.3 | 13 | 160 | 555 | 14.1 | 39.4 | 303 |
| 2656 | 7.6 | 13 | 99 | 218 | 9.5 | 22.9 | 177 |
| 2959 | 3.5 | 13 | 46 | 74 | 4.0 | 18.5 | 142 |
| 1251 | 8.9 | 13 | 116 | 64 | 4.5 | 14.2 | 109 |
| 2626 | 8.7 | 13 | 113 | 74 | 8.5 | 8.7 | 67 |
| Total (Weighted Average) | 42.1 | 13 | 548 | 1,033 | 41.7 | 24.8 | 191 |
| Total* | 28.7 | 13 | 374 | 430 | 26.5 | 16.2 | 125 |

* With 2 highs & 0 lows omitted

Activity: 31 PCC Pavement Inspection
Unit of Measure: 1,000 Square Yards

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 13.9 | 7 | 97 | 139 | 14.0 | 9.9 | 142 |
| 0410 | 116.0 | 7 | 812 | 1,067 | 115.7 | 9.2 | 132 |
| 2959 | 206.9 | 7 | 1,448 | 1,750 | 206.2 | 8.5 | 121 |
| 2656 | 142.3 | 7 | 996 | 1,082 | 152.9 | 7.1 | 101 |
| 2983 | 228.0 | 7 | 1,596 | 824 | 228.0 | 3.6 | 52 |
| Total (Weighted Average) | 707.1 | 7 | 4,949 | 4,862 | 716.8 | 6.8 | 97 |

Project Type: Construction, No Modifiers

Activity: 32 PCC Plant -- Paving
Unit of Measure: 1,000 Square Yards

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 2983 | 228.0 | 4 | 912 | 996 | 228.0 | 4.4 | 109 |
| 2959 | 206.9 | 4 | 828 | 896 | 206.2 | 4.3 | 109 |
| 2656 | 142.3 | 4 | 569 | 601 | 152.9 | 3.9 | 98 |
| 0410 | 116.0 | 4 | 464 | 423 | 115.7 | 3.7 | 91 |
| J237 | 13.9 | 4 | 56 | 44 | 14.0 | 3.1 | 79 |
| Total (Weighted Average) | 707.1 | 4 | 2,829 | 2,960 | 716.8 | 4.1 | 103 |

Activity: 41 Structure/Box Culvert Staking
Unit of Measure: Bent

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 163W | 6.0 | 10 | 60 | 142 | 6.0 | 23.7 | 237 |
| 0285 | 3.0 | 10 | 30 | 62 | 3.0 | 20.7 | 207 |
| 2365 | 6.0 | 10 | 60 | 102 | 6.0 | 17.0 | 170 |
| 063W | 2.0 | 10 | 20 | 27 | 2.0 | 13.5 | 135 |
| 061W | 4.0 | 10 | 40 | 45 | 4.0 | 11.3 | 113 |
| 0440 | 6.0 | 10 | 60 | 67 | 6.0 | 11.2 | 112 |
| 0474 | 4.0 | 10 | 40 | 44 | 4.0 | 11.0 | 110 |
| 024Y | 2.0 | 10 | 20 | 19 | 2.0 | 9.5 | 95 |
| 1352 | 6.0 | 10 | 60 | 37 | 6.0 | 6.2 | 62 |
| 033Y | 4.0 | 10 | 40 | 24 | 4.0 | 6.0 | 60 |
| 266Y | 2.0 | 10 | 20 | 10 | 2.0 | 5.0 | 50 |
| J237 | 2.0 | 10 | 20 | 4 | 2.0 | 2.0 | 20 |
| 034Y | 4.0 | 10 | 40 | 8 | 4.0 | 2.0 | 20 |
| 035Y | 4.0 | 10 | 40 | 8 | 4.0 | 2.0 | 20 |
| Total (Weighted Average) | 55.0 | 10 | 550 | 599 | 55.0 | 10.9 | 109 |
| Total* | 36.0 | 10 | 360 | 375 | 36.0 | 10.4 | 104 |

* With 2 highs & 3 lows omitted

## Standards Analysis

Project Type: Construction, No Modifiers

Activity: 42 Structure/Box Culvert Inspection
Unit of Measure: 100 Square Yards

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 033Y | 3.2 | 60 | 192 | 650 | 3.2 | 203.1 | 339 |
| 0285 | 3.6 | 60 | 216 | 612 | 3.6 | 170.0 | 283 |
| 0440 | 11.0 | 60 | 660 | 1,533 | 11.0 | 139.4 | 232 |
| 0474 | 5.4 | 60 | 324 | 509 | 5.4 | 94.3 | 157 |
| 035Y | 3.1 | 60 | 186 | 222 | 3.1 | 71.6 | 119 |
| 063W | 2.5 | 60 | 150 | 179 | 2.5 | 71.6 | 119 |
| 061W | 4.6 | 60 | 276 | 283 | 4.6 | 61.5 | 103 |
| 034Y | 3.1 | 60 | 186 | 168 | 3.1 | 54.2 | 90 |
| J237 | 3.8 | 60 | 228 | 192 | 3.8 | 50.5 | 84 |
| 259Y | 4.4 | 60 | 264 | 221 | 4.4 | 50.2 | 84 |
| 1352 | 7.3 | 60 | 438 | 349 | 7.3 | 47.8 | 80 |
| 163W | 18.0 | 60 | 1,080 | 765 | 18.0 | 42.5 | 71 |
| 2365 | 10.0 | 60 | 600 | 353 | 10.0 | 35.3 | 59 |
| 024Y | 1.6 | 60 | 96 | 45 | 1.6 | 28.1 | 47 |
| 266Y | 1.9 | 60 | 114 | 36 | 1.9 | 18.9 | 32 |
| 265Y | 1.9 | 60 | 114 | 25 | 1.9 | 13.2 | 22 |
| 620X | 2.0 | 60 | 120 | 8 | 2.0 | 4.0 | 7 |
| Total | 87.4 | 60 | 5,244 | 6,150 | 87.4 | 70.4 | 117 |
| (Weighted Average) | | | | | | | |
| Total* | 76.7 | 60 | 4,602 | 4,855 | 76.7 | 63.3 | 105 |

* With 2 highs & 2 lows omitted

## Standards Analysis

Project Type: Construction, No Modifiers

Activity: 43 PCC Plant Inspection -- Structures
Unit of Measure: 100 Square Yards

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 024Y | 1.6 | 8 | 13 | 153 | 1.6 | 95.6 | 1,195 |
| 259Y | 4.4 | 8 | 35 | 206 | 4.4 | 46.8 | 585 |
| J237 | 3.8 | 8 | 30 | 158 | 3.8 | 41.6 | 520 |
| 2365 | 10.0 | 8 | 80 | 217 | 10.0 | 21.7 | 271 |
| 266Y | 1.9 | 8 | 15 | 36 | 1.9 | 18.9 | 237 |
| 620X | 2.0 | 8 | 16 | 26 | 2.0 | 13.0 | 163 |
| 163W | 18.0 | 8 | 144 | 198 | 18.0 | 11.0 | 138 |
| 0440 | 11.0 | 8 | 88 | 100 | 11.0 | 9.1 | 114 |
| 0474 | 5.4 | 8 | 43 | 42 | 5.4 | 7.8 | 97 |
| 034Y | 3.1 | 8 | 25 | 22 | 3.1 | 7.1 | 89 |
| 033Y | 3.2 | 8 | 26 | 22 | 3.2 | 6.9 | 86 |
| 265Y | 1.9 | 8 | 15 | 11 | 1.9 | 5.8 | 72 |
| 0285 | 3.6 | 8 | 29 | 20 | 3.6 | 5.6 | 69 |
| 1352 | 7.3 | 8 | 58 | 31 | 7.3 | 4.2 | 53 |
| 061W | 4.6 | 8 | 37 | 8 | 4.6 | 1.7 | 22 |
| 063W | 2.5 | 8 | 20 | 2 | 2.5 | 0.8 | 10 |
| 035Y | 3.1 | 8 | 25 | 2 | 3.1 | 0.6 | 8 |
| Total (Weighted Average) | 87.4 | 8 | 699 | 1,254 | 87.4 | 14.3 | 179 |
| Total* | 67.4 | 8 | 539 | 725 | 67.4 | 10.8 | 134 |

* With 3 highs and 3 lows omitted

Activity: 44 Structure/Box Culvert -- Office
Unit of Measure: 100 Square Yards

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 0474 | 5.4 | 5 | 27 | 69 | 5.4 | 12.8 | 256 |
| 033Y | 3.2 | 5 | 16 | 30 | 3.2 | 9.4 | 188 |
| 2365 | 10.0 | 5 | 50 | 53 | 10.0 | 5.3 | 106 |
| 061W | 4.6 | 5 | 23 | 7 | 4.6 | 1.5 | 30 |
| 0440 | 11.0 | 5 | 55 | 15 | 11.0 | 1.4 | 27 |
| Total (Weighted Average) | 34.2 | 5 | 171 | 174 | 34.2 | 5.1 | 102 |

Standards Analysis

Project Type: Construction, No Modifiers

Activity: 51 Staking Miscellaneous Items
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 1.0 | 25 | 25 | 366 | 1.0 | 366.0 | 1,464 |
| 2085 | 1.8 | 25 | 36 | 161 | 1.8 | 89.4 | 358 |
| 1251 | 1.4 | 25 | 35 | 105 | 1.4 | 75.0 | 300 |
| 034Y | 1.0 | 25 | 25 | 51 | 1.0 | 51.0 | 204 |
| 163W | 3.9 | 25 | 98 | 167 | 3.9 | 42.8 | 171 |
| 035Y | 1.0 | 25 | 25 | 29 | 1.0 | 29.0 | 116 |
| 0440 | 9.3 | 25 | 233 | 252 | 9.3 | 27.1 | 108 |
| 0474 | 8.7 | 25 | 218 | 209 | 8.7 | 24.0 | 96 |
| 2959 | 6.0 | 25 | 150 | 142 | 6.0 | 23.7 | 95 |
| 2656 | 2.5 | 25 | 63 | 48 | 2.5 | 19.2 | 77 |
| 0442 | 6.0 | 25 | 150 | 110 | 6.0 | 18.3 | 73 |
| 2365 | 2.0 | 25 | 50 | 34 | 2.0 | 17.0 | 68 |
| 1352 | 2.0 | 25 | 50 | 29 | 2.0 | 14.5 | 58 |
| 0410 | 2.8 | 25 | 70 | 35 | 2.8 | 12.5 | 50 |
| 033Y | 2.0 | 25 | 50 | 19 | 2.0 | 9.5 | 38 |
| 2983 | 3.5 | 25 | 88 | 29 | 3.5 | 8.3 | 33 |
| 620X | 2.0 | 25 | 50 | 16 | 2.0 | 8.0 | 32 |
| 2626 | 2.0 | 25 | 50 | 13 | 2.0 | 6.5 | 26 |
| Total (Weighted Average) | 58.9 | 25 | 1,466 | 1,815 | 58.9 | 30.8 | 123 |
| Total* | 45.2 | 25 | 1,132 | 1,106 | 45.2 | 24.5 | 98 |

* With 3 highs & 4 lows omitted

Standards Analysis

Project Type: Construction, No Modifiers

Activity: 52 Inspecting Miscellaneous Items
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J237 | 1.0 | 75 | 75 | 1030 | 1.0 | 1,030.0 | 1,373 |
| 620X | 2.0 | 75 | 150 | 1059 | 2.0 | 529.5 | 706 |
| 2085 | 1.8 | 75 | 108 | 440 | 1.8 | 244.4 | 326 |
| 1251 | 1.4 | 75 | 105 | 154 | 1.4 | 110.0 | 147 |
| 2959 | 6.0 | 75 | 450 | 652 | 6.0 | 108.7 | 145 |
| 0410 | 2.8 | 75 | 210 | 198 | 2.8 | 70.7 | 94 |
| 2656 | 2.5 | 75 | 188 | 174 | 2.5 | 69.6 | 93 |
| 0474 | 8.7 | 75 | 653 | 601 | 8.7 | 69.1 | 92 |
| 0440 | 9.3 | 75 | 698 | 636 | 9.3 | 68.4 | 91 |
| 0442 | 6.0 | 75 | 450 | 376 | 6.0 | 62.7 | 84 |
| 163W | 3.9 | 75 | 293 | 176 | 3.9 | 45.1 | 60 |
| 2983 | 3.5 | 75 | 263 | 113 | 3.5 | 32.3 | 43 |
| 035Y | 1.0 | 75 | 75 | 32 | 1.0 | 32.0 | 43 |
| 033Y | 2.0 | 75 | 150 | 56 | 2.0 | 28.0 | 37 |
| 0285 | 1.0 | 75 | 60 | 26 | 1.0 | 26.0 | 35 |
| 2365 | 2.0 | 75 | 150 | 45 | 2.0 | 22.5 | 30 |
| 2626 | 2.0 | 75 | 150 | 44 | 2.0 | 22.0 | 29 |
| 024Y | 1.0 | 75 | 75 | 8 | 1.0 | 8.0 | 11 |
| 265Y | 2.0 | 75 | 150 | 15 | 2.0 | 7.5 | 10 |
| 1352 | 2.0 | 75 | 150 | 12 | 2.0 | 6.0 | 8 |
| 266Y | 2.0 | 75 | 150 | 8 | 2.0 | 4.0 | 5 |
| 034Y | 1.0 | 75 | 75 | 2 | 1.0 | 2.0 | 3 |
| Total | 64.9 | 75 | 4,828 | 5,857 | 64.9 | 90.2 | 120 |
| (Weighted Average) | | | | | | | |
| Total* | 52.1 | 75 | 3,895 | 3,283 | 52.1 | 63.0 | 84 |

* With 3 highs & 5 lows omitted

## Standards Analysis

Project Type: Construction, No Modifiers

Activity: 53 Office Work -- Miscellaneous Items
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 2085 | 1.8 | 15 | 14 | 100 | 1.8 | 55.6 | 370 |
| 1251 | 1.4 | 15 | 21 | 73 | 1.4 | 52.1 | 348 |
| 2983 | 3.5 | 15 | 53 | 105 | 3.5 | 30.0 | 200 |
| 0474 | 8.7 | 15 | 131 | 135 | 8.7 | 15.5 | 103 |
| 2959 | 6.0 | 15 | 90 | 86 | 6.0 | 14.3 | 96 |
| J237 | 1.0 | 15 | 15 | 9 | 1.0 | 9.0 | 60 |
| 033Y | 2.0 | 15 | 30 | 15 | 2.0 | 7.5 | 50 |
| 2626 | 2.0 | 15 | 30 | 13 | 2.0 | 6.5 | 43 |
| 0410 | 2.8 | 15 | 42 | 18 | 2.8 | 6.4 | 43 |
| 061W | 1.0 | 15 | 15 | 4 | 1.0 | 4.0 | 27 |
| 163W | 3.9 | 15 | 59 | 15 | 3.9 | 3.8 | 26 |
| 2656 | 2.5 | 15 | 38 | 9 | 2.5 | 3.6 | 24 |
| 620X | 2.0 | 15 | 30 | 4 | 2.0 | 2.0 | 13 |
| 0440 | 9.3 | 15 | 140 | 16 | 9.3 | 1.7 | 11 |
| Total | 47.9 | 15 | 708 | 602 | 47.9 | 12.6 | 84 |
| (Weighted Average) | | | | | | | |
| Total* | 26.0 | 15 | 391 | 381 | 26.0 | 14.7 | 98 |

* With 2 highs & 5 lows omitted

## Standards Analysis

Project Type: Construction, No Modifiers

Activity: 71 General Office Work
Unit of Measure: % of Inspection Man-Hours

| Project | Units | Standard % | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual % | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 1352 | 646 | 8 | 52 | 181 | 448 | 40.4 | 505 |
| 259Y | 510 | 8 | 41 | 171 | 480 | 35.6 | 445 |
| 265Y | 279 | 8 | 22 | 17 | 51 | 33.3 | 417 |
| 0285 | 305 | 8 | 24 | 219 | 766 | 28.6 | 357 |
| 266Y | 279 | 8 | 22 | 20 | 80 | 25.0 | 313 |
| 0442 | 4,660 | 8 | 373 | 927 | 4,461 | 20.8 | 260 |
| 034Y | 286 | 8 | 23 | 39 | 210 | 18.6 | 232 |
| 035Y | 286 | 8 | 23 | 45 | 280 | 16.1 | 201 |
| 0440 | 6,098 | 8 | 488 | 1,312 | 9,170 | 14.3 | 179 |
| 0474 | 3,978 | 8 | 318 | 538 | 4,464 | 12.1 | 151 |
| 2983 | 3,421 | 8 | 274 | 334 | 2,802 | 11.9 | 149 |
| 2959 | 3,343 | 8 | 267 | 427 | 3,962 | 10.8 | 135 |
| 033Y | 483 | 8 | 39 | 94 | 929 | 10.1 | 126 |
| 1251 | 2,925 | 8 | 234 | 218 | 2,316 | 9.4 | 118 |
| 0410 | 1,691 | 8 | 135 | 182 | 1,997 | 9.1 | 114 |
| 024Y | 184 | 8 | 15 | 18 | 206 | 8.7 | 109 |
| 2365 | 830 | 8 | 66 | 56 | 655 | 8.5 | 107 |
| 061W | 388 | 8 | 31 | 24 | 357 | 6.7 | 84 |
| 2626 | 1,111 | 8 | 89 | 67 | 1,072 | 6.3 | 78 |
| 163W | 4,941 | 8 | 395 | 234 | 3,857 | 6.1 | 76 |
| J237 | 686 | 8 | 55 | 144 | 2,504 | 5.8 | 72 |
| 063W | 245 | 8 | 20 | 10 | 186 | 5.4 | 67 |
| 620X | 286 | 8 | 23 | 49 | 1,093 | 4.5 | 56 |
| 2085 | 1,979 | 8 | 158 | 43 | 3,672 | 1.2 | 15 |
| 2656 | 2,115 | 8 | 169 | 11 | 2,654 | 0.4 | 5 |
| Total (Weighted Average) | 41,955 | 8 | 3,356 | 5,380 | 48,672 | 11.1 | 138 |
| Total* | 35,842 | 8 | 2,868 | 4,718 | 40,521 | 11.6 | 146 |

* With 5 highs & 2 lows omitted

## Standards Analysis

Project Type: Construction, No Modifiers

Activity: 72 Project Management and Coordination
Unit of Measure: % of Man-Hours Activities 01-71

| Project | Units | Standard % | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual % | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 024Y | 267 | 15 | 40 | 233 | 243 | 95.9 | 639 |
| 1352 | 860 | 15 | 129 | 718 | 911 | 78.8 | 525 |
| 259Y | 1,114 | 15 | 167 | 484 | 1,113 | 43.5 | 290 |
| 2365 | 1,086 | 15 | 163 | 394 | 916 | 43.0 | 287 |
| 035Y | 405 | 15 | 61 | 136 | 362 | 37.6 | 250 |
| 034Y | 405 | 15 | 61 | 74 | 308 | 24.0 | 160 |
| 620X | 419 | 15 | 63 | 279 | 1,162 | 24.0 | 160 |
| 0410 | 2,796 | 15 | 419 | 750 | 3,212 | 23.3 | 156 |
| 265Y | 411 | 15 | 62 | 18 | 82 | 22.0 | 146 |
| 0285 | 398 | 15 | 60 | 237 | 1,272 | 18.6 | 124 |
| 2085 | 2,955 | 15 | 443 | 962 | 5,261 | 18.3 | 122 |
| 033Y | 1,079 | 15 | 162 | 227 | 1,258 | 18.0 | 120 |
| 2959 | 5,657 | 15 | 849 | 1101 | 6,287 | 17.5 | 117 |
| J237 | 1,270 | 15 | 191 | 501 | 3,347 | 15.0 | 100 |
| 2656 | 3,655 | 15 | 548 | 610 | 4,407 | 13.8 | 92 |
| 063W | 338 | 15 | 51 | 29 | 235 | 12.3 | 82 |
| 266Y | 411 | 15 | 62 | 17 | 144 | 11.8 | 79 |
| 061W | 522 | 15 | 78 | 55 | 516 | 10.7 | 71 |
| 0440 | 15,176 | 15 | 2,276 | 1,916 | 18,072 | 10.6 | 71 |
| 2983 | 5,895 | 15 | 884 | 697 | 6,629 | 10.5 | 70 |
| 1251 | 3,891 | 15 | 584 | 364 | 3,671 | 9.9 | 66 |
| 2626 | 2,184 | 15 | 328 | 175 | 1,852 | 9.4 | 63 |
| 0442 | 10,669 | 15 | 1600 | 762 | 8,377 | 9.1 | 61 |
| 163W | 9,111 | 15 | 1,367 | 693 | 8,845 | 7.8 | 52 |
| Total | 70,974 | 15 | 10,648 | 11,432 | 78,482 | 14.6 | 97 |
| (Weighted Average) | | | | | | | |
| Total* | 69,847 | 15 | 10,479 | 10,481 | 77,328 | 13.6 | 90 |

* With 2 highs & 0 lows omitted

Standards Analysis

Project Type: Construction, No Modifiers

Activity: 73 Standby
Unit of Measure: % of Man-Hours Activities 01-71

| Project | Units | Standard % | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual % | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 2085 | 2,955 | 0.1 | 3 | 152 | 5,261 | 2.89 | 2,889 |
| 259Y | 1,114 | 0.1 | 1 | 12 | 1,113 | 1.08 | 1,078 |
| 2656 | 3,655 | 0.1 | 4 | 23 | 4,407 | 0.52 | 522 |
| 0410 | 2,796 | 0.1 | 3 | 13 | 3,212 | 0.40 | 405 |
| 2959 | 5,657 | 0.1 | 6 | 8 | 6,287 | 0.13 | 127 |
| 2983 | 5,895 | 0.1 | 6 | 3 | 6,629 | 0.05 | 45 |
| 0440 | 15,176 | 0.1 | 15 | 3 | 18,072 | 0.02 | 17 |
| Total | 37,248 | 0.1 | 38 | 214 | 44,981 | 0.48 | 476 |
| (Weighted Average) | | | | | | | |
| Total* | 18,003 | 0.1 | 19 | 47 | 20,535 | 0.23 | 229 |

* With 2 highs & 1 low omitted

## Standards Analysis

Project Type: Construction, No Modifiers

Activity: 74 Travel
Unit of Measure: % of Staking and Inspection Man-Hours

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Plan |
|---|---|---|---|---|---|---|---|
| 265Y | 349 | 15 | 52 | 31 | 65 | 47.7 | 318 |
| 163W | 7,915 | 15 | 1,187 | 2,706 | 8,357 | 32.4 | 216 |
| 0410 | 2,474 | 15 | 371 | 572 | 2,747 | 20.8 | 139 |
| 266Y | 349 | 15 | 52 | 24 | 124 | 19.4 | 129 |
| 0442 | 9,180 | 15 | 1377 | 1373 | 7,286 | 18.8 | 126 |
| 259Y | 961 | 15 | 144 | 150 | 836 | 17.9 | 120 |
| 0474 | 7,378 | 15 | 1,107 | 1,289 | 7,415 | 17.4 | 116 |
| 033Y | 934 | 15 | 140 | 184 | 1,108 | 16.6 | 111 |
| 620X | 356 | 15 | 53 | 181 | 1,109 | 16.3 | 109 |
| 2656 | 3,266 | 15 | 490 | 458 | 4,245 | 10.8 | 72 |
| 0285 | 355 | 15 | 53 | 109 | 1,038 | 10.5 | 70 |
| 2983 | 5,247 | 15 | 787 | 514 | 5,902 | 8.7 | 58 |
| 0440 | 13,143 | 15 | 1,971 | 1,343 | 15,744 | 8.5 | 57 |
| 024Y | 229 | 15 | 34 | 14 | 225 | 6.2 | 41 |
| 2626 | 1,883 | 15 | 282 | 11 | 1,718 | 0.6 | 4 |
| 2959 | 5,006 | 15 | 751 | 36 | 5,632 | 0.6 | 4 |
| 061W | 453 | 15 | 68 | 2 | 481 | 0.4 | 3 |
| 2365 | 940 | 15 | 141 | 2 | 795 | 0.3 | 2 |
| 2085 | 2,567 | 10 | 257 | 1442 | 4,933 | 29.2 | 292 |
| 1251 | 3,465 | 10 | 347 | 428 | 3,257 | 13.1 | 131 |
| J237 | 1,092 | 10 | 109 | 284 | 3,178 | 8.9 | 89 |
| 034Y | 351 | 10 | 35 | 4 | 269 | 1.5 | 15 |
| Total | 67,893 | 14.4 | 9,808 | 11,157 | 76,464 | 14.6 | 101 |
| (Weighted Average) | | | | | | | |
| Total-15 | 60,418 | 15 | 9,060 | 8,999 | 64,827 | 13.9 | 93 |
| Total-15 | 43,872 | 15 | 6,579 | 6,211 | 47,779 | 13.0 | 87 |
| * With 2 high and 4 low omitted | | | | | | | |
| Total-10 | 7,475 | 10 | 748 | 2,158 | 11,637 | 18.5 | 185 |
| Total-10 | 4,557 | 10 | 456 | 712 | 6,435 | 11.1 | 111 |
| * With 1 high and 1 low omitted | | | | | | | |

Project Type: Construction, No Modifiers

Activity: 11 Line/Grade Control
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J227 | 12.6 | 12 | 151 | 417 | 12.6 | 33.1 | 276 |
| 3082 | 4.6 | 12 | 55 | 77 | 4.6 | 16.7 | 139 |
| J263 | 9.4 | 12 | 113 | 140 | 9.4 | 14.9 | 124 |
| 3083 | 12.1 | 12 | 145 | 150 | 12.1 | 12.4 | 103 |
| J219 | 7.9 | 12 | 95 | 87 | 7.9 | 11.0 | 92 |
| J258 | 11.4 | 12 | 137 | 120 | 11.4 | 10.5 | 88 |
| 3068 | 14.7 | 12 | 176 | 147 | 14.7 | 10.0 | 83 |
| 3073 | 11.0 | 12 | 132 | 98 | 11.0 | 8.9 | 74 |
| J228 | 11.9 | 12 | 143 | 62 | 11.9 | 5.2 | 43 |
| 1264 | 4.1 | 12 | 49 | 17 | 4.1 | 4.1 | 35 |
| Total (Weighted Average) | 99.7 | 12 | 1,196 | 1,315 | 99.7 | 13.2 | 110 |
| Total* | 71.1 | 12 | 853 | 819 | 71.1 | 11.5 | 96 |

* With 1 high and 2 lows omitted

Activity: 12 Untreated Aggregate Inspection
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J228 | 2.2 | 6 | 13 | 37 | 1.2 | 30.8 | 514 |
| 3083 | 3.5 | 6 | 21 | 18 | 2.0 | 9.0 | 150 |
| 3068 | 4.8 | 6 | 29 | 22 | 2.5 | 8.8 | 147 |
| 3073 | 15.0 | 6 | 90 | 84 | 14.4 | 5.8 | 97 |
| J219 | 14.3 | 6 | 86 | 43 | 12.6 | 3.4 | 57 |
| 3082 | 3.0 | 6 | 18 | 7 | 3.3 | 2.1 | 35 |
| J227 | 3.2 | 6 | 19 | 10 | 6.5 | 1.5 | 26 |
| Total (Weighted Average) | 46.0 | 6 | 276 | 221 | 42.5 | 5.2 | 87 |
| Total* | 37.6 | 6 | 226 | 167 | 31.5 | 5.3 | 88 |

* With 1 high and 2 lows omitted

## Standards Analysis

Project Type: Construction, No Modifiers

Activity: 13 Testing -- Untreated Aggregate
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J205 | 1.0 | 4 | 4 | 14 | 0.2 | 70.0 | 1,750 |
| 1264 | 1.0 | 4 | 4 | 12 | 0.2 | 60.0 | 1,500 |
| 3083 | 3.5 | 4 | 14 | 42 | 2.0 | 21.0 | 525 |
| J228 | 1.9 | 4 | 8 | 16 | 0.8 | 20.0 | 500 |
| 3068 | 4.8 | 4 | 19 | 24 | 2.5 | 9.6 | 240 |
| J219 | 14.3 | 4 | 57 | 66 | 12.6 | 5.2 | 131 |
| 3073 | 15.0 | 4 | 60 | 65 | 14.4 | 4.5 | 113 |
| 3082 | 3.0 | 4 | 12 | 3 | 3.3 | 0.9 | 23 |
| J227 | 3.2 | 4 | 13 | 5 | 6.5 | 0.8 | 19 |
| Total | 47.7 | 4 | 191 | 247 | 42.5 | 5.8 | 145 |
| (Weighted Average) | | | | | | | |
| Total* | 39.5 | 4 | 158 | 213 | 32.3 | 6.6 | 165 |

* With 1 high and 2 lows omitted

Activity: 16 Weigh Aggregate Materials
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J258 | 2.2 | 5 | 11 | 51 | 1.2 | 42.5 | 850 |
| 3073 | 15.0 | 5 | 75 | 129 | 14.4 | 9.0 | 179 |
| J219 | 14.3 | 5 | 72 | 92 | 12.6 | 7.3 | 146 |
| 3068 | 4.8 | 5 | 24 | 17 | 2.5 | 6.8 | 136 |
| 3083 | 3.5 | 5 | 18 | 13 | 2.0 | 6.5 | 130 |
| J227 | 3.2 | 5 | 16 | 20 | 6.5 | 3.1 | 62 |
| 3082 | 3.0 | 5 | 15 | 7 | 3.3 | 2.1 | 42 |
| Total | 46.0 | 5 | 231 | 329 | 42.5 | 7.7 | 155 |
| (Weighted Average) | | | | | | | |
| Total* | 43.8 | 5 | 220 | 278 | 41.3 | 6.7 | 135 |

* With 1 high and 0 lows omitted

Project Type: Construction, No Modifiers

Activity: 17 Office Work -- Aggregate/Paving
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J228 | 69.5 | 1 | 70 | 188 | 69.6 | 2.7 | 270 |
| 3082 | 15.0 | 1 | 15 | 16 | 15.0 | 1.1 | 107 |
| 3068 | 43.0 | 1 | 43 | 46 | 48.5 | 0.9 | 95 |
| 3073 | 48.7 | 1 | 49 | 36 | 50.8 | 0.7 | 71 |
| J258 | 26.6 | 1 | 27 | 12 | 25.5 | 0.5 | 47 |
| J219 | 49.8 | 1 | 50 | 24 | 51.5 | 0.5 | 47 |
| 3083 | 35.0 | 1 | 35 | 12 | 32.0 | 0.4 | 38 |
| 1264 | 20.5 | 1 | 21 | 4 | 17.8 | 0.2 | 22 |
| J227 | 39.2 | 1 | 39 | 6 | 42.7 | 0.1 | 14 |
| Total | 347.3 | 1 | 349 | 344 | 353.4 | 1.0 | 97 |
| (Weighted Average) | | | | | | | |
| Total* | 218.1 | 1 | 219 | 146 | 223.3 | 0.7 | 65 |

* With 1 high and 2 lows omitted

Activity: 21 Asphalt Paving Inspection
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 1264 | 19.5 | 13 | 254 | 267 | 17.6 | 15.2 | 117 |
| 3068 | 38.2 | 13 | 497 | 554 | 46.0 | 12.0 | 93 |
| 3073 | 33.7 | 13 | 438 | 464 | 36.4 | 12.7 | 98 |
| 3082 | 12.0 | 13 | 156 | 221 | 11.7 | 18.9 | 145 |
| 3083 | 31.5 | 13 | 410 | 464 | 30.0 | 15.5 | 119 |
| J205 | 11.4 | 13 | 148 | 416 | 11.7 | 35.6 | 274 |
| J219 | 35.5 | 13 | 462 | 461 | 38.9 | 11.9 | 91 |
| J227 | 36.0 | 13 | 468 | 462 | 36.2 | 12.8 | 98 |
| J228 | 67.6 | 13 | 879 | 637 | 68.8 | 9.3 | 71 |
| J258 | 24.4 | 13 | 317 | 318 | 24.3 | 13.1 | 101 |
| J263 | 25.0 | 13 | 325 | 305 | 25.1 | 12.2 | 93 |
| Total | 334.8 | 13 | 4,354 | 4,569 | 346.7 | 13.2 | 101 |
| (Weighted Average) | | | | | | | |
| Total* | 265.9 | 13 | 3,458 | 3,679 | 279.7 | 13.2 | 101 |

* With 1 high and 2 lows omitted

## Standards Analysis

Project Type: Construction, No Modifiers

Activity: 22 Asphalt Plant Inspection
Unit of Measure: 1,000 Tons

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J227 | 36.0 | 13 | 468 | 565 | 36.2 | 15.6 | 120 |
| J205 | 11.4 | 13 | 148 | 176 | 11.7 | 15.0 | 116 |
| 3083 | 31.5 | 13 | 410 | 369 | 30.0 | 12.3 | 95 |
| 3073 | 33.7 | 13 | 438 | 372 | 36.4 | 10.2 | 79 |
| J228 | 67.6 | 13 | 879 | 618 | 68.8 | 9.0 | 69 |
| J258 | 24.4 | 13 | 317 | 210 | 24.3 | 8.6 | 66 |
| 3082 | 12.0 | 13 | 156 | 100 | 11.7 | 8.5 | 66 |
| 1264 | 19.5 | 13 | 254 | 141 | 17.6 | 8.0 | 62 |
| J263 | 25.0 | 13 | 325 | 169 | 25.1 | 6.7 | 52 |
| 3068 | 38.2 | 13 | 497 | 308 | 46.0 | 6.7 | 52 |
| J219 | 35.5 | 13 | 462 | 259 | 38.9 | 6.7 | 51 |
| Total (Weighted Average) | 334.8 | 13 | 4,354 | 3,287 | 346.7 | 9.5 | 73 |

Activity: 51 Staking Miscellaneous Items
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J228 | 6.0 | 2 | 12 | 68 | 6.0 | 11.3 | 567 |
| 3073 | 5.5 | 2 | 11 | 39 | 5.5 | 7.1 | 355 |
| J263 | 4.7 | 2 | 9 | 16 | 4.7 | 3.4 | 170 |
| J219 | 4.0 | 2 | 8 | 13 | 4.0 | 3.3 | 163 |
| J258 | 11.4 | 2 | 23 | 18 | 11.4 | 1.6 | 79 |
| 3082 | 6.0 | 2 | 12 | 6 | 6.0 | 1.0 | 50 |
| 3068 | 7.3 | 2 | 15 | 1 | 7.3 | 0.1 | 7 |
| Total (Weighted Average) | 44.9 | 2 | 90 | 161 | 44.9 | 3.6 | 179 |
| Total* | 31.6 | 2 | 63 | 92 | 31.6 | 2.9 | 146 |

* With 2 highs and 1 low omitted

Project Type: Construction, No Modifiers

Activity: 52 Inspecting Miscellaneous Items
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 1264 | 8.2 | 10 | 82 | 193 | 8.2 | 23.5 | 235 |
| J219 | 4.0 | 10 | 40 | 70 | 4.0 | 17.5 | 175 |
| J258 | 11.4 | 10 | 114 | 104 | 11.4 | 9.1 | 91 |
| 3083 | 6.0 | 10 | 60 | 50 | 6.0 | 8.3 | 83 |
| 3082 | 4.6 | 10 | 46 | 22 | 4.6 | 4.8 | 48 |
| 3073 | 5.5 | 10 | 55 | 25 | 5.5 | 4.5 | 45 |
| J227 | 6.3 | 10 | 63 | 27 | 6.3 | 4.3 | 43 |
| 3068 | 7.3 | 10 | 73 | 23 | 7.3 | 3.2 | 32 |
| J228 | 6.0 | 10 | 60 | 12 | 6.0 | 2.0 | 20 |
| J263 | 4.7 | 10 | 47 | 7 | 4.7 | 1.5 | 15 |
| Total (Weighted Average) | 64.0 | 10 | 640 | 533 | 64.0 | 8.3 | 83 |
| Total* | 37.8 | 10 | 378 | 298 | 37.8 | 7.9 | 79 |

* With 1 high and 3 lows omitted

Activity: 53 Office Work -- Miscellaneous Items
Unit of Measure: Roadway Miles

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| J219 | 4.0 | 1 | 4 | 47 | 4.0 | 11.8 | 1,175 |
| J228 | 6.0 | 1 | 6 | 21 | 6.0 | 3.5 | 350 |
| J263 | 4.7 | 1 | 5 | 13 | 4.7 | 2.8 | 277 |
| 3083 | 6.0 | 1 | 6 | 6 | 6.0 | 1.0 | 100 |
| J227 | 6.3 | 1 | 6 | 6 | 6.3 | 1.0 | 95 |
| 1264 | 8.2 | 1 | 8 | 4 | 8.2 | 0.5 | 49 |
| Total (Weighted Average) | 35.2 | 1 | 35 | 97 | 35.2 | 2.8 | 276 |
| Total* | 31.2 | 1 | 31 | 50 | 31.2 | 1.6 | 160 |

* With 1 high and 0 lows omitted

Project Type: Construction, No Modifiers

Activity: 71 General Office Work
Unit of Measure: % of Inspection Man-Hours

| Project | Units | Standard % | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual % | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 3082 | 403 | 8 | 32 | 209 | 360 | 58.1 | 726 |
| J263 | 712 | 8 | 57 | 129 | 509 | 25.3 | 317 |
| J258 | 781 | 8 | 62 | 134 | 720 | 18.6 | 233 |
| 3068 | 1,139 | 8 | 91 | 172 | 948 | 18.1 | 227 |
| J228 | 1,847 | 8 | 148 | 205 | 1,283 | 16.0 | 200 |
| J227 | 1,047 | 8 | 84 | 126 | 1,089 | 11.6 | 145 |
| J219 | 1,179 | 8 | 94 | 101 | 991 | 10.2 | 127 |
| 3073 | 1,156 | 8 | 92 | 73 | 1,139 | 6.4 | 80 |
| 1264 | 605 | 8 | 48 | 32 | 638 | 5.0 | 63 |
| 3083 | 933 | 8 | 75 | 39 | 956 | 4.1 | 51 |
| Total (Weighted Average) | 9,802 | 8 | 783 | 1,220 | 8,633 | 14.1 | 177 |
| Total* | 8,687 | 12 | 694 | 882 | 7,764 | 11.4 | 95 |

* With 2 highs and 0 lows omitted

Activity: 72 Project Management and Coordination
Unit of Measure: % of Man-hours for Activities 01 -- 71

| Project | Units | Standard % | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual % | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 1264 | 747 | 15 | 112 | 298 | 695 | 42.9 | 286 |
| 3068 | 1,471 | 15 | 221 | 499 | 1,314 | 38.0 | 253 |
| J263 | 922 | 15 | 138 | 264 | 833 | 31.7 | 211 |
| J205 | 574 | 15 | 86 | 157 | 606 | 25.9 | 173 |
| 3082 | 519 | 15 | 78 | 177 | 695 | 25.5 | 170 |
| J227 | 1,340 | 15 | 201 | 325 | 1,644 | 19.8 | 132 |
| J258 | 1,041 | 15 | 156 | 157 | 1,004 | 15.6 | 104 |
| 3083 | 1,206 | 15 | 181 | 130 | 1,169 | 11.1 | 74 |
| 3073 | 1,446 | 15 | 217 | 136 | 1,385 | 9.8 | 65 |
| J228 | 2,226 | 15 | 334 | 139 | 1,827 | 7.6 | 51 |
| J219 | 1,430 | 15 | 215 | 74 | 1,263 | 5.9 | 39 |
| Total (Weighted Average) | 12,922 | 15 | 1,939 | 2,356 | 12,435 | 18.9 | 126 |
| Total* | 9,274 | 15 | 1,391 | 1,485 | 9,163 | 16.2 | 108 |

* With 2 highs and 1 low omitted

Project Type: Construction, No Modifiers

Activity: 73 Standby
Unit of Measure: % of Man-hours for Activities 01 -- 71

| Project | Units | Standard % | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual % | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 3068 | 1,471 | 0.1 | 1 | 76 | 1,314 | 5.8 | 5,784 |
| 3083 | 1,206 | 0.1 | 1 | 50 | 1,169 | 4.3 | 4,277 |
| 3082 | 519 | 0.1 | 1 | 10 | 695 | 1.4 | 1,439 |
| J205 | 574 | 0.1 | 1 | 7 | 606 | 1.2 | 1,155 |
| 3073 | 1,446 | 0.1 | 1 | 15 | 1,385 | 1.1 | 1,083 |
| Total | 5,216 | 0.1 | 5 | 158 | 5,169 | 3.1 | 3,057 |
| (Weighted Average) | | | | | | | |
| Total* | 2,539 | 0.1 | 3 | 32 | 2,686 | 1.2 | 1,191 |

* With 2 highs and 0 lows omitted

Activity: 74 Travel
Unit of Measure: % of Staking and Inspection Man-Hours

| Project | Units | Standard % | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual % | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 3082 | 467 | 15 | 70 | 124 | 470 | 26.4 | 176 |
| J263 | 834 | 15 | 125 | 174 | 691 | 25.2 | 168 |
| 3068 | 1,330 | 15 | 200 | 214 | 1,096 | 19.5 | 130 |
| 1264 | 670 | 15 | 101 | 76 | 655 | 11.6 | 77 |
| 3083 | 1,090 | 15 | 164 | 120 | 1,112 | 10.8 | 72 |
| 3073 | 1,299 | 15 | 195 | 113 | 1,276 | 8.9 | 59 |
| J205 | 526 | 15 | 79 | 44 | 606 | 7.3 | 48 |
| J219 | 1,282 | 15 | 192 | 73 | 1,091 | 6.7 | 45 |
| J228 | 2,002 | 15 | 300 | 26 | 1,413 | 1.8 | 12 |
| Total | 9,500 | 15 | 1,426 | 964 | 8,410 | 11.5 | 76 |
| (Weighted Average) | | | | | | | |
| Total* | 7,498 | 15 | 1,126 | 938 | 6,997 | 13.4 | 89 |

* With 0 highs and 1 low omitted

Activity: 75 Training
Unit of Measure: % of Man-hours for Activities 01 -- 71

| Project | Units | Standard | Planned M-Hrs | Actual M-Hrs | Actual Units | Actual MH/Unit | Actual as % of Std |
|---|---|---|---|---|---|---|---|
| 3068 | 1,314 | 0.10 | 1 | 1 | 1,314 | 0.08 | 76 |

*Appendix E*

# ***Sample Plant Certification Form***

As noted on Page 23, the West Virginia Department of Highways certifies plants for the production of PC and AC concrete. A sample inspection form for certifying a bituminous concrete drum dryer plant is reproduced here as an example.

---

MC-1D (REVISED 7/87)

BITUMINOUS CONCRETE DRUM PLANT INSPECTION REPORT

Plant ______________________________

Make ______________________________

Plant Location:

City ______________

County ______________

State ______________

Company Mailing Address:

City ______________

State ______________

Zip Code ______________

Period of Approval:

Date Inspected ______________

Expires ______________

NOTE: Attach all calibration data to back of plant inspection form (feeders, pumps, scales, thermometers, etc.)

---

1.0 GENERAL INFORMATION

1.1 Inspection conducted by ______________________________

______________________________

1.3 Plant Supervisor ______________________________

1.4 Company certified Bituminous Concrete Technician

Name ______________

Certification No. ______________

## 2.0 TRUCK SCALES

2.1 Plants located in WV: Scales inspected and sealed by the WV Department of Labor on _ ____________ (Date)

2.2 Plant outside of WV: Scales inspected and sealed by ____________________ (Agency) on ______________________ (Date)

2.3 Scales sealed and approved — Yes ___ No ___

2.4 Scale foundation solid and level — Yes ___ No ___

2.5 Do the scales meet the requirements of Section 401.6.8 of the Standard Specifications — Yes ___ No ___

## 3.0 FIELD LABORATORY

3.1 Is the laboratory location satisfactory — Yes ___ No ___

3.2 Are the plant operations visible from the laboratory — Yes ___ No ___

3.3 Working area ________________________________ (Dimensions)

3.4 Is the size of the working area adequate — Yes ___ No ___

3.5 Are the following items adequate:

| | |
|---|---|
| Ventilation | Yes ___ No ___ |
| Heat | Yes ___ No ___ |
| Light | Yes ___ No ___ |
| Water | Yes ___ No ___ |
| Sink and drainage | Yes ___ No ___ |
| Electrical and\or gas outlets | Yes ___ No ___ |
| Work tables | Yes ___ No ___ |
| Shelves | Yes ___ No ___ |
| Supply cabinets | Yes ___ No ___ |

3.6 Does the laboratory comply with Section 401.6.19 of the Standard Specifications — Yes ___ No ___

3.7 List below any items of test equipment required by the specifications, that are missing, broken, or in unsatisfactory condition. Give date of repair or replacement.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

## 4.0 SAFETY

4.1 Is safe access provided to the operating areas of the plant — Yes ___ No ___

4.2 Is a platform or other safe area provided for taking samples from the trucks — Yes ___ No ___

4.3 Are all moving parts (gears, pulleys, etc.) covered or guarded — Yes ___ No ___

4.4 Is the space in and around truck loading area free of asphalt drippings — Yes ___ No ___

4.6 List any additional safety hazards ____________________

____________________

____________________

____________________

## 5.0 AGGREGATE STOCKPILES

5.1 Is stockpile separation area adequate — Yes ___ No ___

5.2 Aggregate segregation: None ( ), Slight ( ), Excessive ( )

5.3 Is the mineral filler kept dry — Yes ___ No ___

5.4 Is the general condition of the aggregate stockpiles satisfactory — Yes ___ No ___

## 6.0 BITUMINOUS MATERIALS STORAGE

| Tank No. | Type of Material | Temp. | How is Tank Heated |
|---|---|---|---|
| ______ | ____________ | ______ | __________________ |
| ______ | ____________ | ______ | __________________ |
| ______ | ____________ | ______ | __________________ |
| ______ | ____________ | ______ | __________________ |

6.1 Is the condition of the storage tanks satisfactory — Yes ___ No ___

6.2 Is the heating system adequate — Yes ___ No ___

6.3 Is an adequate means provided for sampling bituminous material — Yes ___ No ___

6.4 Where are samples taken: Sample valve ( ), Hatch ( ), or Other ( )

6.5 Are open flames used to heat storage tanks — Yes ___ No ___

6.6 Is a return line provided between the asphalt pump and storage tank — Yes ___ No ___

6.7 Does the return line discharge below the surface of stored liquid asphalt — Yes ___ No ___

6.8 Are all lines and fittings heated — Yes ___ No ___

6.9 How are the lines and fittings heated ____________________

6.10 Is an in-line thermometer provided — Yes ___ No ___

6.11 Where is the thermometer located ____________________

6.12 What is the thermometer range ____________________

6.13 Has the thermometer been calibrated — Yes ___ No ___

6.14 The thermometer was calibrated by ____________________

6.15 Date of calibration ____________________

## 7.0 COLD FEED

7.1 Are separate cold bins provided for each size of aggregate and reclaimed material — Yes ___ No ___

7.2 Does each bin have an adjustable feeder gate or variable speed feeder to accurately regulate the aggregate feed rate — Yes ___ No ___

| | | |
|---|---|---|
| 7.3 | Are the feeders calibrated in such a manner that aggregate samples can be obtained for calibration or gradation analysis | Yes ___ No ___ |
| 7.4 | Date of calibration ______________________ | |
| 7.5 | Is there a weight sensing device in the feed belt, or other adequate device, to monitor the quantity of aggregate being delivered to the dryer | Yes ___ No ___ |
| 7.6 | Is the plant equipped with a moisture compensator | Yes ___ No ___ |
| 8.0 | DUST COLLECTORS | |
| 8.1 | Type ______________________ | |
| 8.2 | If the plant is located in WV, does it have a current permit from the WV Air Pollution Control Commission | Yes ___ No ___ |
| 8.3 | Permit Number ______________________ | |
| 8.4 | If the plant is located outside of WV, has it been approved by the state agency responsible for air pollution | Yes ___ No ___ |
| 9.0 | BITUMEN PUMP | |
| 9.1 | Type of pump ______________________ | |
| 9.2 | Pump is heated by ______________________ | |
| 9.3 | Is the pump jacketed or electrically heated | Yes ___ No ___ |
| 9.4 | Are the pump and aggregate feeder interlocked so the start and stop together, and change speed together | Yes ___ No ___ |
| 9.5 | Describe the means by which the pump and aggregate feeder are interlocked<br>______________________<br>______________________<br>______________________ | |
| 9.6 | Pump calibrated by ______________________<br>Date ______________________ | |
| 9.7 | Is the pump calibrated satisfactory | Yes ___ No ___ |
| 9.8 | Is a bypass provided for checking the delivery rate of bitumen material | Yes ___ No ___ |
| 10.0 | MIXER | |
| 10.1 | Is the mixer capable of heating material to the required temperatures | Yes ___ No ___ |
| 10.2 | Is the mixer capable of producing a uniform mix without stripping | Yes ___ No ___ |
| 10.3 | Are there devices at the drum discharge to measure the temperature of the completed mix | Yes ___ No ___ |
| 10.4 | Has the heat measuring device been calibrated | Yes ___ No ___ |
| 10.5 | Calibrated by ______________________<br>Date ______________________ | |

| | | |
|---|---|---|
| 11.0 | STORAGE BINS | |
| 11.1 | Does the plant have a storage bin | Yes ___ No ___ |
| 11.2 | Do the bins cause any segregation | Yes ___ No ___ |
| 11.3 | Is a means provided for loading trucks directly from the plant | Yes ___ No ___ |
| 11.4 | Is the bin used for temporary storage | Yes ___ No ___ |
| 11.5 | If the bin is used for other than temporary storage, has testing been conducted to allow such usage | Yes ___ No ___ |
| 11.6 | Does the bin conform to the requirements of Section 401.6.11 of the Standard Specifications | Yes ___ No ___ |

## SUMMARY

12.0 REMARKS

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

12.1 CORRECTIVE ACTIONS

Below list those items found to be unsatisfactory or not meeting specifications, and the corrective action taken

| Deficiencies | Corrective Action |
|---|---|
| ______________________________ | ______________________________ |
| ______________________________ | ______________________________ |
| ______________________________ | ______________________________ |
| ______________________________ | ______________________________ |
| ______________________________ | ______________________________ |
| ______________________________ | ______________________________ |
| ______________________________ | ______________________________ |
| ______________________________ | ______________________________ |