PAY ADJUSTMENT SYSTEM
FOR
AC PAVEMENTS

(A 5-Year Evaluation)

OREGON HP&R STUDY #5286

by

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16. Abstract

This study first presents the historical background and an overview of the technical basis for Oregon's current method of statistical quality control. It then evaluates the benefits that the State of Oregon receives by paying out bonuses to contractors on asphalt concrete paving jobs and makes recommendations for improving quality control methods. This problem was approached with the realization that an accurate accounting of costs and benefits was not possible. However, by combining two approaches: statistical analysis of test data; and a questionnaire to field personnel, it became clear from both viewpoints that there are both tangible and intangible benefits that outweigh the costs.

The questionnaire revealed that project managers who work regularly with contractors under this system generally believe that it improves the atmosphere of cooperation between the state and contractors and also is effective in improving pavement quality. The statistical analysis demonstrates that relative compaction has increased by at least 1.1% since the system was initiated. This improvement in compaction alone is estimated to increase pavement fatigue life by an average of approximately 16% while the average bonus is only 1.7% of the original bid price.

An analysis is also made of recent paving projects showing signs of early distress. This information and suggestions from field personnel are combined to form recommendations for improving the pay adjustment system.

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DISCLAIMER

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Oregon Department of Transportation or the Federal Highway Administration. The report does not constitute a standard, specification, or regulation.

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1.0 INTRODUCTION

The topic of quality is a timely concern with managers in both private industry and government agencies seeking the way to "Total Quality Management" as our country seeks a return to its identity as a world leader in quality manufacturing. In the field of highway construction, the topic of quality assurance is following a parallel course, as the need to improve construction quality is gaining universal recognition. While the quest for quality is not new, it has taken on a different dimension in recent years as statistical specifications and pay incentives have come into use in the highway construction industry. An essential part of quality assurance is to measure the specific progress that has been made and the reasons for that progress. This paper reports Oregon's experience with statistically based pay adjustments for quality control, evaluates how the statistical system has affected quality, and recommends future changes.

As of July, 1991 the State of Oregon has paid out approximately $2.5 million worth of bonus payments and has imposed $0.5 million worth of pay reductions (penalties) on asphalt paving contracts, since the first statistical specification was implemented in 1985. The net bonus amount ($2.0 million) represents approximately 1.7% of the total outlay for asphalt concrete mix under statistical specifications during that period. Because of concern over whether this money is being wisely spent, this study was undertaken to evaluate, as much as possible, if these payments are providing corresponding value to the State. Since there are certain inherent obstacles to performing a realistically objective economic analysis of costs versus benefits, it was determined in advance that much of the analysis would have to be subjective and qualitative in nature.

Although no cost/benefit ratio was determined, the statistical analysis portion of the study clearly leads to the conclusion that pavements are being significantly better compacted now than before the current pay adjustment system was implemented. Current theory suggests that the level of improvement achieved produces approximately a 16% increase in fatigue life. The improvement cannot be attributed entirely to the statistical specification and incentive payments, as it may be partially caused by simultaneous changes in other parts of the specifications such as the requirment for using pneumatic rollers for breakdown and compaction.

The questionnaire results generally confirmed this first analysis and reveal the general belief among most parties involved that the new specification, containing a clearly spelled out method for determining pay adjustments, has resulted in improved cooperation between the State and contractors and is helping to produce a better product.

1.1 Objectives of Study

Analyze construction test data to determine if there has been either an improvement in adherence to specifications or a reduction in the variability of the product produced since 1985 when the bonus payments started.

Survey the opinions of ODOT project managers to determine whether they think the pay adjustment system has improved cooperation with the contractors, and obtain suggestions for improving it. Tabulate and report the results.

Identify any "bonus projects" that may be showing signs of early distress. Determine if this distress may be due to factors that are influenced by the pay adjustment system. Use this information to recommend improvements to the pay adjustment system.

2.0 BACKGROUND

2.1 Normal Variability

Oregon's statistical specifications have a similar heritage to those developed in other states. The AASHTO road test (completed in 1959) played an important early role in pointing out the need for a specification that takes into consideration the normal variability of materials production processes (NCHRP Synthesis 65, 1979). Before the concept of normal variability was widely understood the "recipe method" was used for most highway materials and it was believed that quality could only be assured by requiring exact adherence to the specifications. This concept was taken to its ultimate extreme when a congressional committee ("Blatnik Committee") was appointed to investigate several highway failures. As a result of the 1962 report from this committee, the U.S. Congress threatened to pass laws making it "... a federal offence to knowingly incorporate nonspecification material into federally funded highway projects." (NCHRP Synthesis 38, 1976). Further investigation of the records of the AASHTO road test, however, revealed that even under the highly controlled conditions artificially imposed on the construction of the test roads, a large percentage of the material and finished product still did not meet specifications. It then became clear that under the more loosely controlled conditions of ordinary highway construction, it was unreasonable to expect that all material should comply 100% with specifications. Non-perfect compliance was due to a combination of imperfect testing methods, sampling that was not perfectly representative of the mass of material, and the normal variability found within materials that are found to perform adequately. The idea of a statistical End Result Specification (ERS) linked with appropriate pay adjustment factors was based on these concepts.

2.2 Statistical Specifications

The statistical procedure called the "non-central t distribution" that is now commonly used in statistical specifications for highway construction was published in 1957 by the Department of Defense as Military Standard 414 (MIL-STD-414, 1957). In 1964 Mississippi was the first state to implement a statistical procedure (although not based on Military Standard 414) and the concept gradually took hold during the 60's and 70's. In 1971 it was reported that approximately 25 highway agencies had at least experimented with a specification that recognized the realistic variability of test results (HRB Special Report 118, 1971). By 1976 another study (NCHRP Synthesis 38, 1976) found that 33 states had some form of a statistical specification. Most of the states with statistical specifications have, from the beginning, used methods based on Military Standard 414. This standard has become widely recognized as the accepted approach to statistically determine the "**buyer's risk**", and the "**seller's risk**", and their relationship to sample size when computing pay adjustments for paving construction. The mathematical name for this method is the "non-central t distribution". Its practical application was popularized in 1982 when two HP&R studies sponsored by the New Jersey Department of Transportation clarified the issues and statistical techniques, and produced a computer program to perform the calculations (Weed 1982; Barros 1982). This computer program was then modified by Bruce Wasill of the Western Federal Lands Highway Division (WFLHD) of the Federal Highway Administration to produce the tables currently used by Oregon (see Appendix A_1)*.

2.3 End Result Specifications

In the field of highway engineering, the terms "statistical specification" and "End Result Specification" (ERS) are often used interchangeably. Although these terms are not synonymous, the two concepts are usually used together in highway construction. Statistics is actually the tool used to determine the level of adherence to specifications. Close adherence to specifications is the desired end result and is assumed to be related to pavement performance. NCHRP Synthesis 38 defined the meaning of ERS as follows:

> Essentially this means that instead of inspecting the process that produces a certain material or item of construction the agency monitors the contractor's control of the process and accepts or rejects the end product.

This is essentially the concept that how the contractor produces the product is not so important as the final product quality or its performance in service. The responsibility for product quality is placed on the contractor. Generally an incentive is produced by specifications that provide a pay adjustment factor allowing contractors to either receive bonus payment or to accept reduced pay depending on the level of quality produced. The ongoing difficulty of applying this concept properly to asphalt paving materials is that no single test has yet been found that can reliably predict pavement life from materials properties at the time of construction. For this reason, the measures of "quality" such as asphalt content, gradation control, compaction, smoothness, or thickness control, are actually only surrogates for the concept of quality or performance. Such properties and measures of construction quality all interact in a complex manner that cannot in all cases be related to pavement performance.

By the above definition of ERS, Oregon does not truly have an end result specification for asphalt concrete because the State has direct control over several areas of the production process itself. Examples of this include the specification requiring the use of a pneumatic roller, for breakdown and compaction, and the use of mix designs by the State. Implementation of a true ERS would require either a test that is a good predictor of long-term pavement performance, or a long term maintenance agreement with contractors to guarantee certain standards for pavement performance. Oregon is currently conducting research that is aimed at developing an improved field test to predict pavement performance

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* The Oregon table for Quality Level (Table 106-1; Special Provisions) is essentially the same as AASHTO Table 4A in Section R9-90

(Terril, unpublished). If successful, this test could allow greater contractor control of the end product.

2.4 Oregon's Specification

Oregon's first effort to implement a statistical specification for asphalt concrete pavements came shortly after an Oregon sponsored HP&R study (Puangchit and Hicks, 1982). This study evaluated how variations in materials properties affected fatigue life as determined by laboratory fatigue testing of 4" X 2-1/2" briquettes in the diametral mode. The results of this study gave general guidance to the State regarding the level of importance of the various test parameters on the fatigue life of asphalt pavement. Although the study did not specifically recommend weighting factors for each parameter, it did clarify the order of importance for the parameters. For example, the finding that low void content (high density) had the greatest impact on fatigue life, influenced the decision to weight compaction at 40%, which is a higher weighting than all other factors. One major difference between the 1982 study and the specification, as implemented, is that Puangchit and Hicks recommended a maximum bonus of 10%. In practice, however, FHWA policy limits federal participation to no more than a 5% bonus on federally funded projects. Oregon therefore implemented a maximum bonus of 5% as represented by a pay factor of 1.05 as shown in Appendix A_1.

Although Oregon's weighting factors were influenced by the 1982 study, the statistical procedure itself can be traced more directly to that used by the WFLHD. The statistical tables that appear in Section 106 of Oregon's Special Provisions (see appendix A_1) are exact copies of those originally developed by the WFLHD office. These tables were derived from the computer program for the "non-central t distribution" (NONCENTT) by Barros, 1982. Other aspects of Oregon's procedure differ from that used by WFLHD office of FHWA. For example, WFLHD does not use weighting factors to compute a composite pay factor as does Oregon. Instead, the WFLHD procedure calculates a separate pay factor for each test result and bases the bonus on the lowest of these individual pay factors.

The statistical tables currently in use in Oregon (See Appendix A_1) have remained unchanged since the original specification was written in 1985. These tables produce a maximum bonus of 5% (pay factor of 1.05) and a maximum pay reduction of 25% (pay factor of 0.75). Under the theory that produced the tables, full payment (pay factor of 1.0) is allowed for an Acceptance Quality Level (AQL) of 5% defective in the entire population. In practice, the tables were produced with a rounding rule favoring the contractor, and no effort was made to limit the owners (Government's) risk in the bonus portion of the table (PF $>$ 1.0). Also favoring the contractor is the fact that each column in Quality Level table (Appendix A_1) is based on the smallest value of sample size (n) in the range. As a result of these practices, an average expected pay factor greater than 1.0 results. The Pay Factor table (Appendix A_1)

was based on providing a constant level of risk to the contractor of 5%). The owner's risk* is variable between 48% for 3 sublots to less than 1% for 22 or more sublots.

It is important that these basic trade-offs be understood when considering how to modify the statistical specification and bonus payments in the future. It is worthwhile to note that the WFLHD has modified their tables (see Appendix A_2) to create a better balance between the risk to the owner (Government) and the contractor. This has been done by modifying the bonus portion of the pay factor table (pay factor > 1.0) to reduce the risk to the owner and to generate an average expected Pay Factor of 1.0 for production of 5% AQL (Acceptance Qualtity Level) material. The results of this modification can be evaluated by comparing the tables in Appendix A_1 to those in Appendix A_2. When comparing, note that the newer Pay Factor table (106-3; Appendix A_2) displays percent <u>defective</u>, whereas the old Pay Factor table (106-2; Appendix A_1) displays percent <u>within</u> specifications (100 - percent defective). Another change in the new table is to the use of two columns, one for "major" and one for "minor" criticality levels. The "minor" criticality level corresponds with the older table. All of these changes were made by WFLHD in order to conform more closely with the recommended practices in the AASHTO Materials Manual. Section R 9-90 of the AASHTO manual presents the recommended practices for developing acceptance sampling plans for highway construction. These practices should be adhered to as much as possible in the future and it is therefore recommended that Oregon should at least change its tables to agree more closely with these practices. Serious consideration should be given to adopting the WFLHD tables much as they are. The new WFLHD tables are as close to an established standard as any that are now in use, as they are used by all Federal Lands Highway Division offices in the country. The principle changes from the older tables are:

1) The bonus side of the Pay Factor table has been modified to produce an expected average pay factor of 1.0 for an AQL of 5%. This is in accordance with the recommended practices established by AASHTO.

2) This has been done by increasing the risk to the contractor. For example, while the contractor's risk** was previously 5% at a pay factor of 1.01 across all sample size ranges, the contractor now accepts 40% risk at $n = 5$. This tapers to a 5% risk at $n > 14$. It then remains at 5% for all values of $n > 14$.

3) The column for $n = 3$ was eliminated, and the minimum sample size was made $n = 5$. This is important because at such a small sample size, although a standard deviation can be calculated, it is a very unreliable estimator of the true standard deviation of the population.

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* The owner's risk is defined as the probability that a bonus will be paid when the actual percent defective is greater than the 5% AQL (Acceptance Quality Level).

** Contractor's risk is defined as the probability that the contractor will not receive a bonus when the actual percent defective is less than the AQL of 5%.

4) WFLHD has adopted the new common method of using % defective instead of % within specification.

5) The use of two criticality levels "minor" and "major" was adopted. Although WFLHD adopted this method, it is not recommended as part of a new table.

2.5 Changes in Oregon's Statistical Specification

The statistical specification used today is directly descended from one first written into Oregon's Special Provisions in 1985. Although pay adjustments were first applied in Oregon in 1983 and 1984 on a few trial projects, these earlier experimental specifications bear little resemblance to those currently used. Prior to 1985, penalties were the only pay adjustment and were not computed from accepted statistical procedures. The major provisions and changes in the specifications starting with 1985 are outlined below. This is only a summary of how the specifications work and is not intended to include all of the details. Also, this outline concentrates on Section 403 of the Special Provisions, although statistical methods were included in Section 402. For complete details see Sections 106.18 through 106.20 and Sections 402, and 403 of the Oregon Special Provisions.

<u>1985 Specification</u>

- Both statistical and non-statistical specifications were allowed under Section 403 of the Special Provisions. The statistical specification generally was applied to projects over 3,000 tons of AC mix, while the non-statistical was applied to projects smaller than 3,000 tons.

- The composite pay factor was based on a table (Table 106-1) which estimated the Quality Level (percent within specification range) for each tested constituent, then another table (Table 106-2) that translated Quality Level to "pay factor" (PF). These tables and sections 106.18 - 106.20 have remained unchanged since 1985 (see Appendix A_1).

- The "composite pay factor" (CPF) was computed from the individual pay factors using the weighting factors given in Table 1 below.

- The entire method was computerized on a Lotus spreadsheet and a copy of the program was provided to any contractor who requested it. This allowed the contractors to evaluate their process control testing.

- Whenever the composite pay factor for a lot fell below 0.75 (25% pay reduction), or below 1.0 if no effort was being made to correct the problem, the construction was to be stopped. When individual pay factors dropped below 0.75, that pay factor was computed as zero.

- Compaction: One of the following three different methods of assuring adequate compaction was used. They are listed in order of how restrictive they are in controlling compaction:

  Moving Average Maximum Density (MAMD) - Density measured as a percent of the moving average of the last 5 maximum density (Rice Gravity) samples. The minimum density for computing bonuses was 91% of MAMD as determined from the average of 5 pairs of nuclear density readings (backscatter mode) for each sublot (500 tons of mix). Pay adjustments were applied to compaction, when applicable, with a 40% relative weight. When not applicable, the compaction pay factor was 1.0.

  Control Strip Method (also called Target Density Method) - When required by the Special Provisions, density is measured as a percentage of the average density of compacted material on a 500-foot control strip as measured by a nuclear gage in backscatter mode. The control strip had to be above the minimum density of 91% of MAMD to be valid. The minimum sublot density was then 98% of the control strip target density. Pay adjustments were applied to compaction with a 40% relative weight.

  Roller Pattern Method - A method was specified requiring a certain number of passes of a roller. No pay adjustments were applied to compaction.

- Unless otherwise specified, all top lift pavements started out using MAMD. If 91% of MAMD could not be achieved then special arrangements were made a few times to change to the Control Strip method. Note that in 1985 there were no written procedures or provisions for changing methods. These changes were negotiated and made effective by change orders.

- Under the 1985 specification, bonuses for compaction (PF > 1.0) were allowed when the contractor was operating under either the MAMD or Control Strip method. In cases where a valid target density could not be achieved, the compaction method was changed to the roller pattern method. The contractor would then sacrifice the possibility of receiving a compaction bonus.

- One key provision that improved cooperation with the contractors was a statement that the State will provide the contractor with test results and pay factor calculations on the morning of the day following the placement of the material.

- The mix tolerances allowed in the job mix formula (JMF) and weighting factors in the 1985 specification were as shown in Table 1.

Table 1: 1985 Specification

Aggregate Passing	Tolerance +/- Leveling Course & Temporary	Tolerance +/- Base & Surface	Pay Factor Weight (%)
1", 3/4", 1/2	As specified	As specified	1/3 each
1/4"	7%	6%	2
#10	5%	4%	4
#40	5%	4%	3
#200	2%	2%	10
Asphalt Cement	0.6%	0.5%	25
Moisture content (max)	0.70%	0.70%	15
Compaction Density (min)	Roller Method	MAMD method: 91% of MAMD Cntl Strip: lower of 91% of MAMD or 98% of target.	40

1986 Specification

- A change was made such that all projects were now under the statistical system.
- Smaller projects (generally less than 5000 tons) went under the 402 specification.
- There was no change in the statistical tables or methods for computing "pay factor".
- Compaction methods were essentially the same as the 1985 specification.
- The method of changing from the MAMD method to the Control Strip method was left essentially the same.
- The specification tolerances and weighting factors were changed to those as shown in Table 2.

Table 2: 1986 Specification

Aggregate Passing	Tolerance +/- Leveling Course & Temporary	Tolerance +/- Base & Surface	Pay Factor Weight (%)
1", 3/4", 1/2	As specified	As specified	**1 each***
1/4"	7%	6%	**3***
#10	5%	4%	**5***
#40	5%	4%	3
#200	2%	2%	10
Asphalt Cement	0.6%	0.5%	**26***
Moisture content (max)	**0.60%***	**0.60%***	**10***
Compaction Density (min)	Roller Method	MAMD method: 91% of MAMD Cntl Strip: lower of 91% of MAMD or 98% of target.	40

*Changed since 1985

1987 Specification

- In 1987, a change was made so that a bonus (PF > 1.0) for compaction was no longer allowed when using the Control Strip method. The same statistical specification was used, however, to determine pay reductions (PF < 1.0) for compaction. A composite pay factor (CPF) of up to 1.03 (3% bonus) could still be applied based on other factors.

- The bonus amount was reduced by 1/2 for temporary surfacing, leveling, and 402 specification projects.

- Most other elements of the pay adjustment provisions and specifications remained the same.

1989 Specification

- The 1989 specification remains in use as of this writing.

- The single greatest change in the 1989 specification is that now the compaction method starts out under the Control Strip method and a bonus is not initially allowed for compaction. If the contractor submits a written request, however, a change can be made to go to the MAMD method to allow the possibility of a compaction pay factor > 1.0.

- Maximum pay factors for compaction were spelled out clearly as shown in Table 3.

Type/Method	Maximum CPF
Normal Pavement:	
Control Strip Method	1.00
MAMD Method	1.05
Thin Pavement	1.00
Open-Graded	1.00
Other Areas	1.00

- A few adjustments were made again in the tolerances and weighting factors as follows:

Table 3: 1989 Specification

Aggregate Passing	Tolerance +/- Leveling Course & Temporary	Tolerance +/- Base & Surface	Pay Factor Weight (%)
1", 3/4", 1/2	As specified	As specified	1 each
1/4"	**6%***	**5%***	**5***
#40	5%	4%	5
#10	5%	4%	3
#200	2%	2%	10
Asphalt Cement	0.5%	0.5%	26
Moisture content (max)	0.60%	0.60%	**8***
Compaction Density (min)	Roller Method	MAMD method: 91% of MAMD Cntl Strip: 98% of target density**	40

*Changed since 1987
**Control Strip method:
Establish a valid target density by obtaining:
91% of MAMD for:
first lift of first course or single lift projects
92% of MAMD for all other pavements

3.0 STATISTICAL ANALYSIS

One of the most critical elements in evaluating the success of any new specification or method is to determine with statistical means how the resulting product changed after the specification was introduced. In this portion of the study, 18 projects were selected from before the pay adjustment system was started ("OLD" projects; - prior to 1985) and 18 were selected from the period after it was operational ("NEW" projects; - 1958 and later). An additional ten "NEW" projects were included in the compaction portion of the analysis to remove bias. Test data from the in-place material were then analyzed to evaluate changes in the following five parameters: percent relative compaction, percent passing the #10 sieve, percent passing the #200 sieve, asphalt content, and moisture content.

3.1 Summary of Results

Since compaction is the parameter that receives the most attention, and because compaction is believed widely to be the parameter most closely related to performance, it also received the most attention in this portion of the study. Compaction and moisture content are the only parameters that showed clear improvement after the statistical specification was introduced. Compaction increased, and moisture content decreased. Although the other 3 parameters; % passing the #200, the % passing the #10, and the asphalt content, all changed significantly as shown on Table 4a, this change does not clearly constitute improvement. Since these latter 3 parameters have both an upper and a lower tolerance limit, "improvement" must be evaluated in terms of adherence to specifications as shown on Tables 5a and 5b. In all three cases, Table 5b shows that the test averages were further away from the center of the tolerance range after the statistical specification was introduced. Table 5a, however, shows that asphalt content improved because of a reduction in the number of times the test results were outside of the specification limits; thus, contradicting the analysis method presented in Table 5b.

The analysis of compaction, however, is unambiguous, as any increase is considered an improvement. As discussed further below, the data shows a nominal increase of 3.5 percentage points in relative compaction. Even when using a highly conservative statistical test with 99% confidence assumed and allowing for changes in measuring technique, there is at least a 1.1 percentage point increase in compaction. This improvement was apparently caused mostly by the change to the pay adjustment system and statistical specification. Other possible contributing factors are discussed in Section 3.3.

Table 4: Summary of Data Analysis

	Table 4a				Table 4b			
	AVERAGE VALUES OF EACH PARAMETER STUDIED (Product Quality)				AVERAGE STANDARD DEVIATIONS OF EACH PARAMETER STUDIED (Product Consistency)			
	Old	New	Nominal Difference	Diff. @ 99% Conf.	Old	New	Nominal Difference	Diff. @ 99% Conf.
Compaction % (Corrected)	88.5	92.0	3.5 2.6**	2.0 1.1**	1.98	1.95	-0.03	*
#200	4.43	5.22	0.79	0.14	0.49	0.469	-0.021	*
#10	29.4	30.9	1.45	0.16	2.086	1.986	-0.100	*
Asphalt %	5.65	5.62	-0.03	*	0.316	0.234	-0.082	-0.01
Moisture %	0.45	0.17	-0.28	-0.16	0.098	0.056	-0.042	-0.017

* There is less than 99% confidence that a difference exists. It also happens in all these cases that there is less than 90% confidence.

** Corrected for an estimated 0.9% difference caused by measuring technique. "NEW" projects used sand for seating nuclear gauges, while "OLD" ones did not. Correction derived from reference #10.

The above data represent 18 paving jobs and 520 data points for the "NEW" and 520 data points (sublots) for the "OLD " projects (except in the case of the "NEW" <u>compaction</u> data where 684 data points are represented).

In addition to analyzing the actual difference in the average values of the parameters themselves, an analysis was also performed to determine if there was an increase in product consistency (a reduction in variability) of the product. This was accomplished by analyzing differences in the standard deviation for both "OLD" and "NEW" jobs. Asphalt content and moisture content are the only parameters that show a significant reduction in variability during the period studied.

Table 5a summarizes the number of sublots in which the various parameters were outside of the specifications limits. The main point revealed by this is that asphalt content seems to be staying within the specifications more frequently with the "NEW" jobs. This further confirms the results of the evaluation of the product variability. More consistent asphalt content is also something that would be expected because of improvements in metering equipment for asphalt. Neither moisture content, nor compaction could be evaluated in terms of "out of specification occurrences" because: in the case of moisture content, the "OLD" jobs did not have a moisture specification; in the case of compaction, the earlier specification was based on "relative maximum density" and not "Rice gravity". Thus, a comparison of out of specification occurrences would not be valid for compaction.

Table 5: Adherence to Specifications

	Table 5a				Table 5b			
	TESTS OUT OF TOLERANCE RANGE OCCURENCES OUT OF 520 TESTS				AVERAGE TEST DIFFERENCE FROM CENTER OF TOLERANCE RANGE			
	High/Low #		Total #		Numerical		Percentage	
	Old	New	Old	New	Old	New	Old	New
Compaction %	*	*/16	*	16	*	*	*	*
#200	2/2	6/1	4	7	-0.12	-.39	-0.03%	-0.08%
#10	23/10	12/21	33	33	0.21	-0.4	.007%	-.083%
Asphalt %	28/41	14/9	69	23	-0.02	0.07	-.003%	.013%
Moisture %	*	0/*	*	0/*	*	*	*	*

* This evaluation cannot be applied

3.2 Methodology and Philosophy

The statistical analysis portion of this study is the one area where it is possible to evaluate objectively and mathematically the effects of the pay adjustment system, and is one of the study's most critical elements. For this reason precautions were taken to assure that the analysis was as free of bias as possible. Also any potential sources of bias that could not be eliminated are listed and their effects evaluated.

3.2.1 Project Selection

While results for all parameters were considered important, the analysis of compaction was considered the most critical. The projects selected for analysis were therefore chosen based largely on criteria established for the compaction analysis. The selection criterion and the logic for each is listed below:

Criterion: Only "B" mix projects (lots) were selected.

Reason: "B" mix is the most commonly used dense gradation for Oregon paving projects. A dense gradation had to be used because only dense gradations have a compaction specification.

Criterion: A representative proportion of "MAMD" projects and "Target Density" projects was selected.

Reason: "MAMD" projects would naturally be expected to get better compaction than "Target Density" projects because the "MAMD" specification is more restrictive. This was in fact the case. In the compaction analysis, 10 of the 28 projects used (or 35%) were "Target Density" projects because approximately 35% of the projects for which density data are available for the period studied were under the "Target Density" specification. Projects compacted under the "Roller Method" could not be included because density data is not available.

Criterion: Where possible, projects having greater than 20 sublots were chosen.

Reason: This assured that the average relative density for the project (lot) was representative and not influenced significantly by random sampling error within the lot. In several cases, projects (lots) this large could not be found under the "Target Density" specification.

Criterion: Projects selected before the pay adjustment system started were all recent enough to have data from nuclear guage density readings. Only projects where nuclear density readings were taken in the "backscatter" mode were selected.

Reason: The density data had to be derived using essentially the same method for each of the two periods studied, in order for the comparison to be valid.

3.2.2 Statistical Methods

In analyzing changes and trends it is not enough to simply look at the differences between two averages. For example, from Table 4a, the average compaction of "OLD" projects (88.5%) compared to the average compaction of "NEW" projects (92%) indicates a nominal difference of 3.5 percentage points. Due to the randomness of the data, however, and the error that may be introduced by chance selection of non-representative projects, this may not represent the actual difference. To properly account for this, a statistical test called the t test was performed. Various forms of this statistical test are used depending on what is already known about the variability of the data, and whether the two sets of data being compared contain the same number of data points or not.

If two different means (averages) are being compared, the test always has the same general form. A "null hypothesis" is defined (referred to as H_0), which is what we are attempting to disprove (reject). Then the two means of each set of data are calculated and compared. Since there is always some finite probability that the result obtained is due to random selection of non-representative data, a statistical test should be used to determine what this probability is. In statistical terms, the test determines the probability of making an error by rejecting the "null hypothesis" when it should not actually be rejected. This probability is referred to as the probability of a "Type I" error (α, or level of significance). If the probability of a "Type I" error is very small, then it is very likely that what we are attempting to prove is actually true (or in statistical terms, the thing we are attempting to disprove, H_0, is false).

The above is a somewhat simplified explanation of the terms and ideas used in a statistical test. In actual practice, a value for α is usually assumed first and the test is conducted to see if the null hypothesis can be rejected at that level of significance.

In this case, for example, we wish to prove that the "NEW" projects have a greater mean value of compaction than the "OLD" projects. So we state H_0, the null hypothesis, as the thing we wish to disprove. H_0 is therefore:

> The mean compaction of the "NEW" projects is the same as or less than the mean compaction of the "OLD" projects.

or:

$$\mu_{new} - \mu_{old} \leq 0$$

We may wish to state the null hypothesis to evaluate if the difference is greater than a certain amount. In that case H_0 would be: The mean compaction of the "NEW" projects is equal to or less than 2 percentage points greater than that of the "OLD" projects.

or:

$$\mu_{new} - \mu_{old} \leq 2.0$$

Then a level of significance (α) is chosen. In this case, as shown on Table 4a, saying that we have 99% confidence is equivalent to saying that there is a 1% chance that we are wrong (or $\alpha = .01$) if the test shows that a difference exists.

The method chosen to perform the statistical test (Walpole and Meyers, 1978) assumes that the standard deviations of the two populations are unequal ($\sigma_{new} \neq \sigma_{old}$), and that they are not known (except that we can calculate the sample standard deviations). Since the sizes of the two samples chosen to represent these populations are also unequal ($n_{new} \neq n_{old}$), the number of degrees of freedom (ν) must be calculated. The formula for this is on the following page:

$$\nu = \frac{\left(\frac{s_{new}^2}{n_{new}} + \frac{s_{old}^2}{n_{old}}\right)^2}{\frac{\left(\frac{s_{new}^2}{n_{new}}\right)^2}{n_{new}-1} + \frac{\left(\frac{s_{old}^2}{n_{old}}\right)^2}{n_{old}-1}} \tag{1}$$

Where:

s_{new} = is the sample standard deviation of the "NEW" projects

s_{old} = is the sample standard deviation of the "OLD" projects

and:

all other parameters are as defined above

In the analysis of compaction means, for example, $s_{old} = 2.325$ and $s_{new} = 1.160$. Also $n_{new} = 28$ and $n_{old} = 18$ as shown in Table B-2a of Appendix B. Equation 1 then yields $\nu = 22.5$. This value is then used to enter a table for the t distribution for the desired value of α (in this case $\alpha = 0.01$) to obtain the critical region for performing the t test. In this case the critical region for t is anything above 2.5 ($t_{crit} = 2.5$). In other words, if the value of t calculated by the following formula is greater than 2.5, then we can reject the null hypothesis, H_0. The calculated value of t (t') is found from this formula:

$$t' = \frac{(\overline{X}_{new} - \overline{X}_{old}) - d_0}{\sqrt{\frac{s_{new}^2}{n_{new}} + \frac{s_{old}^2}{n_{old}}}} \tag{2}$$

Where:

$$\overline{X}_{new}, \text{ and } \overline{X}_{old}$$

are the mean values respectively (of compaction in this example) for the samples of "NEW" and "OLD" projects used.

and:

d_0 = the difference being tested

and:

all other parameters are as previously defined.

In the example case, when we are testing against the first H_0; ($d_0 \leq 0$); t' is calculated at 5.84. Since $t' > t_{crit}$ ($5.84 > 2.5$) we can reject the null hypothesis by saying that the compaction in the "NEW" projects is greater than the compaction in the "OLD" projects.

Since we were testing at the 0.01 level of significance, there is less than a 1% chance that we have made an error in making this statement. Working this method backwards, it was found that, in fact, there is only about a 0.001% probability of making a Type I error.

Further analysis was performed to calculate the value of d_0 which would allow the test to provide exactly a 0.01 level of significance. To accomplish this, equation 2 was solved for d_0 as follows:

$$d_0 = (\overline{X}_{new} - \overline{X}_{old}) - t' \times \sqrt{\frac{s^2_{new}}{n_{new}} + \frac{s^2_{old}}{n_{old}}} \tag{3}$$

Then the value of t_{crit} for $\alpha = 0.01$ was substituted for t'. The result gave $d_0 = 2.0$ for the test of differences in compaction, as shown in Table B-2a. Thus, it can be said with 99% confidence that the true mean compaction for the "NEW" projects (μ_{new}) is at least 2 percentage points higher than the true mean compaction of the "OLD" projects (μ_{old}). Note, however, that a correction of 0.9 percentage points must be applied to reduce the difference to 1.1 based on differences in measurement technique as discussed in Section 2.4; Sources of Bias.

Table 4a contains a summary of similar analyses for compaction as well as for all other parameters. Complete tables of the input data and analyses are included in Appendix B.

3.2.3 Analysis of Variability

Essentially the same statistical methods were used throughout this analysis to test the differences between the mean values of the parameters themselves and to test for any changes in product variability. It might occur to a reader well versed in statistical methods that product variability is related to standard deviation and that the F test rather than the t test is ordinarily used to test differences in standard deviations. The reason for using the t test for both cases is simply that the standard deviations to be tested were actually "means" of the standard deviations for each project. The F test would not be applicable unless a comparison was being made directly between the standard deviations of two sets of data.

The analysis of variability was conducted by comparing the average value of the standard deviation for the "OLD" projects to that of the "NEW" projects. This was done using essentially the same statistical technique described above to evaluate the means. The only two parameters that show a significant reduction in variability are asphalt content and moisture content. According to Table 4b, the average standard deviation of asphalt content shows a nominal reduction from a value of 0.316 for the "OLD" projects to a value of 0.234 for the "NEW" projects. Nominally the difference is 0.082, but when analyzed statistically, we can say with 99% confidence that there is an actual reduction of at least 0.01. For moisture content, there is an even more significant reduction in variability. The standard deviation of moisture content dropped from a value of 0.098 to 0.056. Nominally the difference is 0.042. In this case we can say with 99% confidence that there is a difference of at least 0.017.

One problem encountered in analyzing the variability in compaction was that values for compaction on "NEW" projects represent a total of 10 different nuclear gage readings and 5 different locations on the pavement. On "OLD" projects, these values represent only 1 reading and 1 location on the pavement. An uncorrected comparison of "Coefficient of Variation" would bias the results to show less variation in the "NEW" projects. This was solved by applying the "central limit theorem" which says that:

$$S_{actual} = S_n \, n^{1/2}$$

Where:

S_n is the standard deviation of a sample consisting of the averages of n values; and S_{actual} is the standard deviation of the entire sample before the n values are averaged.

In the case of our data, the standard deviation of the original population can be estimated from the standard deviation of the available data by multiplying by the square root of 5. This is done because, in the above formula, n = 5 (the number of values that were averaged before taking the standard deviation). This computation is shown in the right column of Table B-3 in Appendix B.

Another aspect of this problem is that each of the 5 different pavement locations on the "NEW" projects represent 2 actual gauge readings. This would slightly bias results in the direction of less variability in the "NEW" projects. The maximum amount of this bias is estimated to be slight. It is therefore not believed to be a significant problem in estimating the variability in the material.

3.3 Discussion of Results

The following discussion evaluates the apparent meaning of the statistical analysis for each of the five parameters studied: Compaction; percent passing #200; percent passing #10; asphalt content; and moisture content. Further discussion of possible biases and sources of error is included in Section 3.3.1. One aspect of this analysis that is apparent in Table 4b is that all parameters show a reduction in the nominal value of variability. Although for three of these parameters, the reduction in variability is not statistically significant, it is worthwhile to note the consistent trend toward lower variability in all parameters.

3.3.1 Compaction

Changes in Mean: The results clearly show that there has been a net average increase in compaction since the bonus pay system was initiated. As discussed above there is a 99% probability that the actual difference is at least 1.1 percentage points. This level of improvement was estimated to increase pavement life on the average by approximately 16 %. This was estimated by applying the following regression equation developed by Puangchit and Hicks (1982):

$$\log NF = 4.5072 - 0.00295(VOIDS)^2$$

Where:

NF = the number of load repetitions to failure, and
VOIDS = the void content, in percent, after compaction

Solving directly for NF and substituting:
VOIDS = 100 - COMPACT ;
this becomes:

$$NF = 10^{4.5072 - 0.0295(100 - COMPACT)^2}$$

This equation was used first to estimate NF for the average compaction of the "OLD" projects (NF_{old}), and then for the average compaction of the "NEW" projects ($NF_{new)}$. NF_{new} was found to be 16% greater than NF_{old}. While this equation has a low coefficient of determination ($R^2 = 0.36$), this calculation gives a strong indication that the historical net average bonus of approximately 1.7% is providing benefits well worth the cost.

Changes in Variability: There is no apparent change in product variability based on the data analyzed.

3.3.2 Percent Passing #200

Changes in mean: There has been an apparent increase of 0.79 percentage points in the fines content. Due to the relatively high standard deviation for this parameter, however, the difference is only 0.14 at the 99% confidence level. Note also that Table 5b indicates that, relative to the average center of the tolerance range, the percent passing the #200 actually decreased. This is because there was an increase in the average value of the mix design or Job Mix Formula (JMF) for the percent passing the #200. The average JMF value for the center of the tolerance range increased from 4.55% for the "OLD" projects to 4.83% for the "NEW" projects.

3.3.2 Percent Passing #200 (Continued)

Changes in Variability: The nominal value for change in variability indicates an improvement of 2.1 percentage points. This difference, however, is not significant at the 99% confidence level, and is only barely significant at the 90% confidence level.

3.3.3 Percent Passing #10

Changes in Mean: There has been an apparent increase of 1.45 percentage points in the fines content. As with the percent passing the #200, due to the relatively high standard deviation for this parameter, the difference is much smaller (0.16%) when viewed at the 99% confidence level. Also as above, relative to the center of the tolerance range, the percent passing the #10 actually decreased. Again this is because the projects studied showed an increase in the average value of the JMF for the percent passing the #10. The average JMF value for the center of the tolerance range increased from 29.19% for the "OLD" projects to 31.3% for the "NEW" projects.

Changes in Variability: The nominal value for change in variability indicates an improvement of 0.6 percentage points. This difference, however, is not significant at the 99% confidence level, and is only barely significant at the 90% confidence level.

3.3.4 Asphalt Content

Changes in Mean: There is no evidence that there has been any change in average asphalt content during the period of study. It is interesting to note, however, as shown on Table 5b that, relative to the center of the tolerance range, the asphalt content actually increased. This is possible because the average JMF value for asphalt decreased from 5.67% for the "OLD" projects to 5.55% for the "NEW" projects. This suggests that contractors may be operating with a little higher asphalt content as an aid in achieving compaction.

Changes in Variability: There is a strong indication that variability in the asphalt content has decreased. The change is just significant at the 99% level of confidence. This difference may be due, in part, to improvements in the equipment used to meter asphalt. It may also be related to the improved training of technicians and improved testing techniques and equipment in the laboratory. Therefore it does not necessarily mean that there is now better control of the final product.

3.3.5 Percent Moisture

Changes in Mean: There has been a very large decrease in the nominal value of the moisture content (a 0.28 percentage point drop from the original 0.45 %; this translates to a 62% reduction). The large difference also holds up to statistical analysis at the 99% confidence level (0.16 percentage points from the original value of 0.45%, translating to a 36% reduction). This is very likely due to the fact that the "OLD" projects allowed higher moisture content than the newer specifications, as well as the change to the statistical pay adjustment system. The change to using microwave ovens in performing the test could also have affected the results.

The effect that the decrease in moisture may have on pavement quality is not entirely clear, however, because the average value of moisture content for the "OLD" projects was still lower than the 0.6% level of the specification for the "NEW" projects. Note that, in the analysis of moisture content, one data point (job E) was eliminated because its value was so radically higher than all others that it was considered an "outlier".

Changes in Variability: The variability of moisture content within each job was also reduced significantly. This is believed to be caused partly by improvements in testing equipment and training. It may also reflect the incentive provided by the pay adjustment system.

3.4 Sources of Bias

The clear difference demonstrated in the analysis suggests strongly that the pay adjustment system has been effective in providing incentive to the contractors to improve compaction. While there is no clear reason to believe the contrary, our conclusions should be tempered somewhat by considering the limitations of the analysis. First, we are comparing measured values from two different periods of time during which a variety of changes other than the pay adjustment system may have occurred to influence the data. Also, biases can enter the data from a variety of sources. These factors may include:

- differences in laboratory techniques, and technician training
- changes in testing equipment
- changes in construction equipment
- bias in choosing projects for analysis
- any changes in the specifications not related to the statistical pay adjustments.

These are discussed below in the same order as above:

Laboratory Techniques and Testing Equipment: Care was taken to assure that the comparison was being made between comparable values. Prior to 1985 the specification for compaction did not use "relative density" as it does now. Therefore the values of "relative density" for the study had to be calculated. This was done by dividing the nuclear density readings by 62.4 (the unit weight of water in lbs/cubic ft.) times an average of "Rice gravity" values obtained from cores taken at the time of construction. The current method differs in that "Rice gravity" (MAMD) values are now obtained from grab samples and are the average of the five most recent results. It is not believed that these differences should bias the results significantly.

There are some differences in techniques used in nuclear gage testing. Prior to 1984 or 1985, sand was not used to seat the nuclear gages. This may bias the results slightly to show higher densities on the "NEW" projects. A previous study (Scholl and Laylor, 1989) suggests that the amount of this bias is in the range of 0.9 percentage points. This bias is considered in the final analysis when estimating the increase in compaction and pavement life. A second factor to consider is that calibration techniques and training have both improved since the "OLD" projects. Now gauges are calibrated in the shop every year with a calibration block. During the "OLD" projects they were calibrated only at the factory. This may not be a major factor, however, because the standardization block was used daily on both "OLD" and "NEW" projects.

There is also worth noting that the Rice gravity testing for the "NEW" projects was performed in the field labs and somewhat less vacuum may have been available than for the "OLD" projects when testing was performed in the central lab in Salem. This may bias the results to make the apparent increase in density greater than it actually is. At most this may account for 0.5 percentage points of the difference, however, this difference is not documented.

In summary, there are some differences in technique and testing that may partially account for the differences in observed in-place density. To further confirm these differences, further study should be conducted using density data from core samples. This would eliminate much of the doubt due to differences in technique, because the procedure and sampling technique for cores has remained essentially the same during the period of study. The data from core density testing are available, though not in a computerized form. This lack of computerization is the principal reason for not including an analysis of core data in this study.

Other changes in testing technique for asphalt content and aggregate gradation may have the effect of reducing the variability of the test results for those parameters. The newer specifications, for example, now require testing of backup samples whenever the result varies by more than 1.5 times the specification limits.

Changes in Construction Equipment: In general, construction and production equipment is gradually improving with time. Also, as noted under "Other Specification Changes", below, certain changes have been mandated. One example of the former is that equipment for metering and monitoring asphalt content has improved in recent years. This could explain at least part of the reduction in variability of asphalt content.

Bias in Choosing Projects: Only "MAMD" projects and "Target Density" projects were chosen for the analysis because data on compaction was not available for "Roller Method" projects. This may bias the results somewhat to favor the "NEW" projects but "Roller Method" projects represent a much smaller amount of material than the others, although the number of projects is roughly comparable.

Other Specification Changes: Certain specification changes, in addition to the change to the pay adjustment system, may have been made at the same time that may also be affecting the results. One known example of this is a change to require the use of pneumatic rollers, which are generally thought to be more effective. However, even if this does explain some of the increase in compaction, it should not negate the value of the pay adjustment system. Instead, it is one more factor that helps to make higher pay factors more easily attainable.

4.0 QUESTIONNAIRE RESULTS

Since some of the questions concerning the value of the pay adjustment system can only be answered subjectively, a questionnaire was developed and sent to field personnel who work regularly on asphalt paving projects. A total of 42 questionnaires were sent to OSHD project managers, region materials inspectors, and region assurance specialists. The majority (32) being sent to the project managers. The questionnaires had three main objectives:

1) To determine to what extent State personnel are satisfied with the pay adjustment system. Is it creating improved cooperation with the contractors? Do they think that it is providing benefits that are worth the costs?

2) To identify any projects constructed within the previous two years that were showing signs of early distress.

3) To obtain suggestions for improving the pay adjustment system.

Appendix D is an example of the questionnaire as sent to the project managers. It contained the basic questions about the pay adjustment system, as well as a simplified condition survey form, and a list of projects for each project manager to report on. The projects and project managers were selected to provide a cross section of 1 to 2 year old projects, with the intent of identifying the extent and type of any early distress that may have occurred. Each of the 5 Region Assurance Specialists were given only the first page of the questionnaire containing the basic questions about the pay adjustment system. Each of the 5 Region Materials Inspectors were given the first page as well as a list of projects in their Region to identify only whether there was early distress or not and whether it was severe or moderate.

The most meaningful results and most thoughtful responses came from the project managers and their construction inspectors. Of the 32 project managers offices, 23 responded. In 5 cases project managers returned more than one response generating a total of 32 responses from the project manager's level of operation. Most often this included the project manager's own response plus one or more responses from inspectors. In at least 3 cases, the project manager did not respond himself, but left the response to one or more of his inspectors.

Of the five questionnaires sent to Region Assurance Specialists, four responses were received, while only one of the Region Materials Inspectors responded. This makes a total of 37 responses.

The responses for the three main questions are tabulated on the following page:

Question No. 1:

In your opinion, does the bonus pay system improve cooperation with the contractors?

	YES	NO	DON'T KNOW
#	28	5	4
%	76%	14%	10%

Question No. 2:

In your opinion, does the State receive benefits in proportion to the net cost of the bonus pay system?

	YES	NO	DON'T KNOW
#	18	7	12
%	49%	19%	32%

Question No. 3:

Do you think the current bonus pay system is effective?

	YES	NO	DON'T KNOW
#	21	7	9
%	57%	19%	24%

The most significant observations that can be made from the responses are listed below:

There was a generally positive response with regard to the pay adjustment system. Although the positive response was not universal, it is worthwhile to note that most of the negative responses came not from the project managers themselves but rather from inspectors who work for project managers. Their negative response may be partly explained by the intensive work and high overtime requirements imposed by the current system. The specifications require the State to provide the contractor with test results for the each day's work on the morning of the next day. Thus, State inspectors and testing technicians need to remain working long after the contractor's crew quits each day.

Most respondents feel that the system encourages cooperation with the contractors by providing incentive to work harder at meeting OSHD specifications.

Many respondents feel there are less arguments with contractors over equipment required to do the job (rollers etc.), and that contractors are more likely to decrease production rates to assure a better product.

Some project managers believe that the best contractors use the bonus to get an edge on their competition by bidding low and expecting to get their profit out of the bonus.

The most significant suggestions for improving the pay adjustment system are listed as follows:

Eliminate bonuses for temporary pavements.

Include a factor representing appearance or smoothness. (This was the most common suggestion; 6 respondents)

Include a factor representing the quality of the aggregate used.

Give a higher weight to the factors for gradation - particularly fines - when determining the bonus.

Inspect every project 2 years after construction to determine if it earned its pay factor.

We pay too high of a bonus on "control strip" projects. These projects are eligible for up to a 3% bonus based on gradation and asphalt content.

Allocate more engineering money to compensate for the increased inspection costs of the statistical method.

Bonuses should not be paid on projects where any material at all is out of specification.

Specifications should contain guidelines for what to do if a valid "test strip" cannot be obtained.

Change weighting factors for "F" mixes (open graded mix) because an "F" mix gets an automatic 1.0 for compaction. This makes it too easy to get a high pay factor when either the gradation or asphalt content is outside specifications.

5.0 EVALUATION OF EARLY DISTRESS

Part of this study is to evaluate projects showing signs of early distress in order to determine if the pay adjustment system needs to be improved and how to improve it. Based on the response of several of the project managers, it was believed possible that the weighting factors for fine material (#200 minus; and #10 minus) may need to be increased. In order to determine if there is evidence of the need for this change, an evaluation was made of the projects identified in the questionnaire as showing some signs of early distress. The questionnaire identified a total of 19 projects that show some signs of early distress (first 1 or two years of pavement life). This list was then narrowed to eight projects which had a problem that might be related to mixture control. The test results that were originally used to compute the pay adjustments, were then reviewed for any cases where one or more of the constituents were consistently outside specifications.

5.1 Projects Analyzed

In this evaluation out of 48 projects represented in the questionnaire responses, only two projects with early distress were found having a significant amount of "out-of-spec" material. These two projects are listed below along with a discussion of how the pay adjustment system may relate to each problem:

Sams Valley to Shady Cove; Contr. # 10517

Distress: Moderate bleeding and ravelling.
Mix Type: "B"
Spec. Problem: Excess of #200 minus material
Pay Factors:
Composite (top): 0.990
Composite (base): 0.909
#200 (top): 0.930
#200 (base): 0.000 (Automatic when < 0.75)

Discussion: This project was specifically identified by the project manager as being an example showing why the weighting factors for the fine material should be increased. The project manager reports that there was severe bleeding on the base course. This was apparently related to the excess amount of #200 minus material which made the mix overly sensitive to slight changes in asphalt content. The top course also bled in some locations and this was apparently due in part to excessive variability in the content of #200 minus material.

While it is not completely clear what role the mix design or other factors besides gradation control may have played in this case, it is clear that improved gradation control in such cases would remove one major variable and would simplify trouble shooting of such problems in the field.

Noti to Venita - East Unit; Contr. # 10339

Distress: Localized bleeding; eastern 8% of project
Mix Type: "C"
Spec. Problem: Low on the #10 minus material and low compaction
Pay Factors (both base and top):
Composite: 0.913
#10: 0.000 (Automatic when < 0.75)
Compaction: 0.870

Discussion: In this case there may be some relationship between the observed bleeding here and the deficiency of #10 minus material. Earlier analysis, however, performed at the time of construction identified the problem as being related mostly to variability in the absorptive properties of the aggregate and its specific gravity.

5.2 Analysis of Early Distress Projects

It was not possible to make definitive conclusions concerning any needed changes on the basis of evaluations performed here. There were no clear cases identified through the questionnaire in which early distress occurred on a project having a 1.0 or greater pay factor, except in cases where there was an explanation for the problem other than adherence to the specifications.

While it generally makes sense to guide future development of specifications by analysis of past projects, this portion of the study has one serious flaw; the "B" mix material now being used has changed since construction of the projects analyzed here. Now it is coarser and less sensitive to gradation and asphalt content than the older "B" mix (prior to 1989 specification). This reduces the frequency of bleeding problems and decreases the importance of controlling the fines content. Some bleeding problems do continue to occur, however, and many of these may be related to gradation or asphalt content control. If this continues to be a problem, then it may be wise to change the Special Provisions to give the project manager more leverage in controlling individual constituents in the mix. It has been suggested that weights given to the pay factors for fines should be increased. This will not, however, provide the flexibility of judgement needed to handle the variety of problems encountered in the field. It may also not provide the leverage that is needed in cases where severe bleeding is directly related to gradation control. Instead of simply increasing the weighting factors for fines, it is suggested that a statement be inserted giving the project manager authority to shut down production whenever the pay factor for any constituent drops below 0.75.

5.3 Correlation of Test Results with Early Distress

The tests used to measure the level of adherence to specifications are assumed to measure properties that are related to pavement performance. This is an assumption, however, that has never been tested or evaluated statistically for pavements in Oregon. It was initially a goal of this study to evaluate one large project showing signs of early distress in an attempt to determine which test results, if any, correlate with the distress. This was not done, however, because of the difficulty of identifying the exact field location of each sublot. Also, it is believed that little would be gained by this unless a large number of projects were studied. Any study intended to make recommendations for specifications to be used statewide should contain a cross section of projects throughout the state. An effort this large was clearly outside the scope of this study; especially given the difficulty of identifying the field locations of sublots.

To enhance the possibility of conducting such a study in the future, it is recommended that all data from the spreadsheets used to calculate pay factors should be archived in electronic form. It is also recommended that a method be developed to identify the field location (preferably by milepost and direction of travel) of each sublot. This information should then be saved electronically along with the test result data. When this is combined with regular condition surveys now being conducted, it could be a powerful tool for evaluating the causes of pavement distress and improving pavement performance.

6.0 CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. The pay adjustment system for asphalt concrete is producing a significant benefit to the State by improving compaction and reducing the variability of the end product. The improvement in compaction alone is estimated to increase fatigue life by an average of approximately 16% while the average bonus paid is only 1.7% of the original bid price.

2. Most project managers and other state personnel who work with asphalt pavements believe that the pay adjustment system is producing improved cooperation with contractors. A majority also believe that the State is getting its money's worth from the system, although certain adjustments as discussed below could improve it.

RECOMMENDATIONS

1. The pay adjustment system should continue in essentially its present form.

2. Serious consideration should be given to changing the tables used to calculate pay adjustments to more closely agree with the recommendations in the AASHTO Materials Manual (Section R 9-90). In particular, calculations for standard deviation, on which pay factors are based, should not be made on fewer that five sublots or data points. Calculation of standard deviation on three sublots, as currently done, is unreliable. Appendix A_2 contains the statistical tables currently in use by the WFLHD from whom Oregon originally obtained its current tables (Appendix A_1). The new WFLHD tables closely follow the AASHTO recommendations.

3. Consider making a change in the Special Provisions that would give the project manager the authority to shut down a paving project whenever any constituent (parameter) being tested as part of the pay adjustment falls below a 0.75 pay factor.

4. A parameter for "ride" or "smoothness" should be considered for inclusion in the pay factors or as part of a separate pay adjustment. This is currently being evaluated in the study "Development of an Improved Ride Specification" now being conducted by Oregon State University for the Oregon Department of Transportation. Results are expected to be available in 1993.

5. All test data from the spreadsheets used to calculate pay factors should be preserved in electronic form. It is also recommended that a method be developed to identify the field location of each sublot (preferably by milepost and direction of travel). This information should then be saved electronically and archived along with the test result data to enhance future efforts to identify problems and improve pavement performance.

REFERENCES

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Appendix A_1

Statistical Tables Used by ODOT
(In use 1985 through 1991)

TABLE 106-1

QUALITY LEVEL ANALYSIS BY THE STANDARD DEVIATION METHOD

P_U or P_L PERCENT WITHIN LIMITS FOR POSITIVE VALUES OF Q_U or Q_L	UPPER QUALITY INDEX Q_U OR LOWER QUALITY INDEX Q_L														
	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=18	n=19 to n=25	n=26 to n=37	n=38 to n=69	n=70 to n=200	n=201 to n=∞
100	1.16	1.50	1.79	2.03	2.23	2.39	2.53	2.65	2.83	3.03	3.20	3.38	3.54	3.70	3.83
99	-	1.47	1.67	1.80	1.89	1.95	2.00	2.04	2.09	2.14	2.18	2.22	2.26	2.29	2.31
98	1.15	1.44	1.60	1.70	1.76	1.81	1.84	1.86	1.91	1.93	1.96	1.99	2.01	2.03	2.05
97	-	1.41	1.54	1.62	1.67	1.70	1.72	1.74	1.77	1.79	1.81	1.83	1.85	1.86	1.87
96	1.14	1.38	1.49	1.55	1.59	1.61	1.63	1.65	1.67	1.68	1.70	1.71	1.73	1.74	1.75
95	-	1.35	1.44	1.49	1.52	1.54	1.55	1.56	1.58	1.59	1.61	1.62	1.63	1.63	1.64
94	1.13	1.32	1.39	1.43	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.55
93	-	1.29	1.35	1.38	1.40	1.41	1.42	1.43	1.44	1.44	1.45	1.46	1.46	1.47	1.47
92	1.12	1.26	1.31	1.33	1.35	1.36	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.40	1.40
91	1.11	1.23	1.27	1.29	1.30	1.30	1.31	1.31	1.32	1.32	1.33	1.33	1.33	1.34	1.34
90	1.10	1.20	1.23	1.24	1.25	1.25	1.26	1.26	1.26	1.27	1.27	1.27	1.28	1.28	1.28
89	1.09	1.17	1.19	1.20	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.23
88	1.07	1.14	1.15	1.16	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.06	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13
86	1.04	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
84	1.01	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99
83	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95
82	0.97	0.96	0.95	0.94	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
81	0.96	0.93	0.91	0.90	0.90	0.89	0.89	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88
80	0.93	0.90	0.88	0.87	0.86	0.86	0.86	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.84
79	0.91	0.87	0.85	0.84	0.83	0.82	0.82	0.82	0.82	0.81	0.81	0.81	0.81	0.81	0.81
78	0.89	0.84	0.82	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.77	0.77	0.77
77	0.87	0.81	0.78	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.74	0.74	0.74	0.74
76	0.84	0.78	0.75	0.74	0.73	0.73	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.71
75	0.82	0.75	0.72	0.71	0.70	0.70	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.67
74	0.79	0.72	0.69	0.68	0.67	0.66	0.66	0.66	0.66	0.65	0.65	0.65	0.65	0.64	0.64
73	0.76	0.69	0.66	0.65	0.64	0.63	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.61	0.61
72	0.74	0.66	0.63	0.62	0.61	0.60	0.60	0.60	0.59	0.59	0.59	0.59	0.59	0.58	0.58
71	0.71	0.63	0.60	0.59	0.58	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.55	0.55
70	0.68	0.60	0.57	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.53	0.53	0.53	0.52
69	0.65	0.57	0.54	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50
68	0.62	0.54	0.51	0.50	0.49	0.49	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.47
67	0.59	0.51	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44
66	0.56	0.48	0.45	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.41	0.41	0.41
65	0.52	0.45	0.43	0.41	0.41	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39
64	0.49	0.42	0.40	0.39	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.36
63	0.46	0.39	0.37	0.36	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.33	0.33	0.33
62	0.43	0.36	0.34	0.33	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31
61	0.39	0.33	0.31	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.29	0.28	0.28
60	0.36	0.30	0.28	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25
59	0.32	0.27	0.25	0.25	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23
58	0.29	0.24	0.23	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.20
57	0.25	0.21	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
56	0.22	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
55	0.18	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
54	0.14	0.12	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
53	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
52	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
51	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NOTE: For negative values of Q_U or Q_L, P_U or P_L is equal to 100 minus the table value for P_U or P_L.
If the value of Q_U or Q_L does not correspond exactly to a figure in the table, use the next higher figure.

Oregon 1985 - 1991

TABLE 106-2-PAY FACTORS

PAY FACTOR	REQUIRED QUALITY LEVEL FOR A GIVEN SAMPLE SIZE (n) AND A GIVEN PAY FACTOR													
	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=18	n=19 to n=25	n=26 to n=37	n=38 to n=69	n=70 to n=200	n=201 to n=∞
1.05	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1.04	90	91	92	93	93	93	94	94	95	95	96	96	97	97	99
1.03	80	85	87	88	89	90	91	91	92	93	93	94	95	96	97
1.02	75	80	83	85	86	87	88	88	89	90	91	92	93	94	95
1.01	71	77	80	82	84	85	85	86	87	88	89	90	91	93	94
1.00	68	74	78	80	81	82	83	84	85	86	87	89	90	91	93
.99	66	72	75	77	79	80	81	82	83	85	86	87	88	90	92
.98	64	70	73	75	77	78	79	80	81	83	84	85	87	88	90
.97	62	68	71	74	75	77	78	78	80	81	83	84	85	87	89
.96	60	66	69	72	73	75	76	77	78	80	81	83	84	86	88
.95	59	64	68	70	72	73	74	75	77	78	80	81	83	85	87
.94	57	63	66	68	70	72	73	74	75	77	78	80	81	83	86
.93	56	61	65	67	69	70	71	72	74	75	77	78	80	82	84
.92	55	60	63	65	67	69	70	71	72	74	75	77	79	81	83
.91	53	58	62	64	66	67	68	69	71	73	74	76	78	80	82
.90	52	57	60	63	64	66	67	68	70	71	73	75	76	79	81
.89	51	55	59	61	63	64	66	67	68	70	72	73	75	77	80
.88	50	54	57	60	62	63	64	65	67	69	70	72	74	76	79
.87	48	53	56	58	60	62	63	64	66	67	69	71	73	75	78
.86	47	51	55	57	59	60	62	63	64	66	68	70	72	74	77
.85	46	50	53	56	58	59	60	61	63	65	67	69	71	73	76
.84	45	49	52	55	56	58	59	60	62	64	65	67	69	72	75
.83	44	48	51	53	55	57	58	59	61	63	64	66	68	71	74
.82	42	46	50	52	54	55	57	58	60	61	63	65	67	70	72
.81	41	45	48	51	53	54	56	57	58	60	62	64	66	69	71
.80	40	44	47	50	52	53	54	55	57	59	61	63	65	67	70
.79	38	43	46	48	50	52	53	54	56	58	60	62	64	66	69
.78	37	41	45	47	49	51	52	53	55	57	59	61	63	65	68
.77	36	40	43	46	48	50	51	52	54	56	57	60	62	64	67
.76	34	39	42	45	47	48	50	51	53	55	56	58	61	63	66
.75	33	38	41	44	46	47	49	50	51	53	55	57	59	62	65
REJECT	QUALITY LEVELS LESS THAN THOSE SPECIFIED FOR A 0.75 PAY FACTOR														

NOTE: If the computed QUALITY LEVEL does not correspond exactly to a figure in the table, use the next lower value.

Appendix A_2

Statistical Tables Used by FHWA
Western Federal Lands Highway Division
(In use 1991)

FHWA 1991

Table 106 - 2
Estimated Percent of Work Outside Specification Limits

Estimated Percent Outside Specification Limits	Upper Quality Index Q_U or Lower Quality Index Q_L												
	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=17	n=18 to n=22	n=23 to n=29	n=30 to n=42	n=43 to n=66	n=67 to ∞
0	1.72	1.88	1.99	2.07	2.13	2.20	2.28	2.34	2.39	2.44	2.48	2.51	2.56
1	1.64	1.75	1.82	1.88	1.91	1.96	2.01	2.04	2.07	2.09	2.12	2.14	2.16
2	1.58	1.66	1.72	1.75	1.78	1.81	1.84	1.87	1.89	1.91	1.93	1.94	1.95
3	1.52	1.59	1.63	1.66	1.68	1.71	1.73	1.75	1.76	1.78	1.79	1.80	1.81
4	1.47	1.52	1.56	1.58	1.60	1.62	1.64	1.65	1.66	1.67	1.68	1.69	1.70
5	1.42	1.47	1.49	1.51	1.52	1.54	1.55	1.56	1.57	1.58	1.59	1.59	1.60
6	1.38	1.41	1.43	1.45	1.46	1.47	1.48	1.49	1.50	1.50	1.51	1.51	1.52
7	1.33	1.36	1.38	1.39	1.40	1.41	1.41	1.42	1.43	1.43	1.44	1.44	1.44
8	1.29	1.31	1.33	1.33	1.34	1.35	1.35	1.36	1.36	1.37	1.37	1.37	1.38
9	1.25	1.27	1.28	1.28	1.29	1.29	1.30	1.30	1.30	1.31	1.31	1.31	1.31
10	1.21	1.23	1.23	1.24	1.24	1.24	1.25	1.25	1.25	1.25	1.25	1.26	1.26
11	1.18	1.18	1.19	1.19	1.19	1.19	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12	1.14	1.14	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
13	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.11
14	1.07	1.07	1.07	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
15	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
16	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
17	0.97	0.96	0.95	0.95	0.95	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94
18	0.93	0.92	0.92	0.92	0.91	0.91	0.91	0.91	0.90	0.90	0.90	0.90	0.90
19	0.90	0.89	0.88	0.88	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
20	0.87	0.86	0.85	0.85	0.84	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.83
21	0.84	0.82	0.82	0.81	0.81	0.81	0.80	0.80	0.80	0.80	0.80	0.80	0.79
22	0.81	0.79	0.79	0.78	0.78	0.77	0.77	0.77	0.76	0.76	0.76	0.76	0.76
23	0.77	0.76	0.75	0.75	0.74	0.74	0.74	0.73	0.73	0.73	0.73	0.73	0.73
24	0.74	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.70	0.70	0.70	0.70	0.70
25	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.67	0.67	0.67	0.67	0.66
26	0.68	0.67	0.67	0.65	0.65	0.65	0.64	0.64	0.64	0.64	0.64	0.64	0.63
27	0.65	0.64	0.63	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.61	0.61	0.60
28	0.62	0.61	0.60	0.59	0.59	0.59	0.58	0.58	0.58	0.58	0.58	0.58	0.57
29	0.59	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.54
30	0.56	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.52	0.52	0.52	0.52
31	0.53	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.49	0.49	0.49
32	0.50	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.46	0.46
33	0.47	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.43	0.43	0.43	0.43
34	0.45	0.43	0.43	0.42	0.42	0.42	0.41	0.41	0.41	0.41	0.41	0.41	0.40
35	0.42	0.40	0.40	0.39	0.39	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.38
36	0.39	0.38	0.37	0.37	0.36	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.35
37	0.36	0.35	0.34	0.34	0.34	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.32
38	0.33	0.32	0.32	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30
39	0.30	0.30	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
40	0.28	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
41	0.25	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
42	0.23	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
43	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
44	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
45	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
46	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
47	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
48	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
49	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: If the value of Q_U or Q_L does not correspond to a value in the table, use the next lower value. For negative values of Q_U or Q_L, P_U or P_L is equal to 100 minus the table value for P_U or P_L.

Table 106 – 3 Pay Factors

PAY FACTOR		Maximum Allowable Estimated Percent of Work Outside Specification Limits to Obtain a Given Pay Factor												
Criticality Level														
Major	Minor	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=17	n=18 to n=22	n=23 to n=29	n=30 to n=42	n=43 to n=66	n=67 to ∞
1.05					0	0	0	0	0	0	0	0	0	0
1.04				0	1	3	5	4	4	4	3	3	3	3
1.03			0	2	4	6	8	7	7	6	5	5	4	4
1.02			1	3	6	9	11	10	9	8	7	7	6	6
1.01		0	2	5	8	11	13	12	11	10	9	8	8	7
1.00		22	20	18	17	16	15	14	13	12	11	10	9	8
0.99		24	22	20	19	18	17	16	15	14	13	11	10	9
0.98		26	24	22	21	20	19	18	16	15	14	13	12	10
0.97		28	26	24	23	22	21	19	18	17	16	14	13	12
0.96		30	28	26	25	24	22	21	19	18	17	16	14	13
0.95	1.00	32	29	28	26	25	24	22	21	20	18	17	16	14
0.94	0.99	33	31	29	28	27	25	24	22	21	20	18	17	15
0.93	0.98	35	33	31	29	28	27	25	24	22	21	20	18	16
0.92	0.97	37	34	32	31	30	28	27	25	24	22	21	19	18
0.91	0.96	38	36	34	32	31	30	28	26	25	24	22	21	19
0.90	0.95	39	37	35	34	33	31	29	28	26	25	23	22	20
0.89	0.94	41	38	37	35	34	32	31	29	28	26	25	23	21
0.88	0.93	42	40	38	36	35	34	32	30	29	27	26	24	22
0.87	0.92	43	41	39	38	37	35	33	32	30	29	27	25	23
0.86	0.91	45	42	41	39	38	36	34	33	31	30	28	26	24
0.85	0.90	46	44	42	40	39	38	36	34	33	31	29	28	25
0.84	0.89	47	45	43	42	40	39	37	35	34	32	30	29	27
0.83	0.88	49	46	44	43	42	40	38	36	35	33	31	30	28
0.82	0.87	50	47	46	44	43	41	39	38	36	34	33	31	29
0.81	0.86	51	49	47	45	44	42	41	39	37	36	34	32	30
0.80	0.85	52	50	48	46	45	44	42	40	38	37	35	33	31
0.79	0.84	54	51	49	48	46	45	43	41	39	38	36	34	32
0.78	0.83	55	52	50	49	48	46	44	42	41	39	37	35	33
0.77	0.82	56	54	52	50	49	47	45	43	42	40	38	36	34
0.76	0.81	57	55	53	51	50	48	46	44	43	41	39	37	35
0.75	0.80	58	56	54	52	51	49	47	46	44	42	40	38	36
REJECT	0.79	60	57	55	53	52	51	48	47	45	43	41	40	37
	0.78	61	58	56	55	53	52	50	48	46	44	43	41	38
	0.77	62	59	57	56	54	53	51	49	47	45	44	42	39
	0.76	63	61	58	57	55	54	52	50	48	47	45	43	40
	0.75	64	62	60	58	57	55	53	51	49	48	46	44	41
	REJECT	Values Greater Than Those Shown Above												

Note: To obtain a pay factor when the **estimated percent outside specification limits** from Table 106-2 does not correspond to a value in the table, use the next larger value.

Appendix B

Data from Statistical Analysis of "NEW" and "OLD" Projects

TABLE B-1A

OLD PROJECTS - PERCENT COMPACTION BASED ON RICE GRAVITY

STATISTICS FOR 18 "OLD" PROJECTS BY SUBLOT				
OUT OF SPEC # OCCURRENCES HIGH	LOW	MEAN +/- SPEC CENTER	MEAN	88.678
*	*	*	STD DEV	3.350
			VARIANCE	11.193
			COUNT	520

TABLE B-1B

NEW PROJECTS - PERCENT COMPACTION BASED ON RICE GRAVITY

STATISTICS FOR 28 "NEW" PROJECTS BY SUBLOT				
OUT OF SPEC # OCCURRENCES HIGH	LOW	MEAN +/- SPEC CENTER	MEAN	92.296
*	16.0	*	STD DEV	1.438
			VARIANCE	2.069
			COUNT	684

TABLE B-2A

STATISTICAL TEST OF COMPACTION DIFFERENCES

"t" VALUE (DIFF > ZERO) = 5.83; PROB. TYPE I ERROR = 0.001 %
"t" VALUE (DIFF > 2.0) = 2.50; PROB. TYPE I ERROR = 1.0 %
"t" VALUE (DIFF > 2.7) = 1.32; PROB. TYPE I ERROR = 10.0 %

- THE DIFFERENCE IS HIGHLY SIGNIFICANT -

	STATISTICS OF JOB MEANS (OLD)	NOMINAL DIFFERENCE	STATISTICS OF JOB MEANS (NEW)
MEAN	88.53	3.45	91.98
STD DEV	2.33		1.16
COUNT	18		28

Note that Tables B-1A and B-1B report different values for MEAN and standard deviation (STD DEV) than does Table B-2A. This is because Tables B-1A and B-1B report statistics computed for all sublots combined, while Table B-2A values are computed from the mean for each job or lot. These same two methods of reporting were used in all of the following sets of tables for each parameter studied.

TABLE B-2B

DATA FOR COMPACTION DIFFERENCE TEST (Table B-2A)

JOB	(OLD) MEAN COMPACTION	NUMBER OF SUBLOTS	(NEW) MEAN COMPACTION
A	87.8	35	92.7
B	89.9	35	94.1
C	87.4	34	91.6
D	89.4	20	91.8
E	92.0	19	93.1
F	90.3	40	92.7
G	86.5	37	91.6
H	88.9	22	92.1
I	92.6	60	93.9
J	89.6	20	92.2
K	88.4	21	91.6
L	89.6	20	92.2
M	86.2	19	92.8
N	85.3	21	93.1
O	86.3	24	93.3
P	89.3	23	93.3
Q	83.2	38	92.1
R	90.7	31	92.2
S		18	92.2
T		44	92.0
U		5	91.4
V2		5	90.4
V4		7	90.9
V4T		7	90.3
V8		27	91.1
W		29	90.5
X		11	88.7
Y		11	91.5

TABLE B-3

STATISTICAL COMPARISON OF VARIABILITY COMPACTION

"t" VALUE (DIFF > ZERO) = ** ; PROB. TYPE I ERROR = HIGH

- THE DIFFERENCE IS NOT SIGNIFICANT -

	STD DEV (OLD)	NOMINAL DIFFERENCE	STD DEV (NEW)	STD DEV *SQRT(5)
MEAN	1.986	-0.034		1.9526
STD DEV	0.691			0.8007
COUNT	18.0			28
JOB				
A	1.4860		1.1603	2.5946
B	3.1654		0.9741	2.1781
C	1.5389		0.3137	0.7015
D	1.8173		1.3164	2.9436
E	1.3272		0.5512	1.2324
F	1.2765		1.1369	2.5422
G	1.7434		0.6666	1.4906
H	1.8974		1.2578	2.8125
I	3.2718		1.3841	3.0949
J	3.4315		0.3043	0.6804
K	2.3002		0.4283	0.9577
L	1.0628		0.4360	0.9750
M	2.6348		0.6382	1.4270
N	1.7568		1.0710	2.3949
O	1.9564		0.8451	1.8896
P	1.2798		1.5311	3.4237
Q	1.7511		0.6892	1.5410
R	2.0547		0.5456	1.2201
S			1.1157	2.4948
T			1.3242	2.9610
U			0.6306	1.4100
V2			1.3824	3.0911
V4			0.9907	2.2153
V4T			0.7677	1.7167
V8			0.6558	1.4663
W			0.7056	1.5779
X			1.1972	2.6770
Y			0.4302	0.9620

** Not meaningful because the difference is too small

TABLE B-4a

OLD PROJECTS - PERCENT EXTRACTED MATERIAL PASSING #200

STATISTICS FOR 18 PROJECTS BY SUBLOT			
OUT OF SPEC # OCCURRENCES		MEAN +/- SPEC CENTER	
HIGH	LOW		
2.0	2.0	-0.137	MEAN 4.452 STD DEV 1.030 VARIANCE 1.063 COUNT 520

TABLE B-4b

NEW PROJECTS - PERCENT EXTRACTED MATERIAL PASSING #200

STATISTICS FOR 18 PROJECTS BY SUBLOT			
OUT OF SPEC # OCCURRENCES		MEAN +/- SPEC CENTER	
HIGH	LOW		
6.0	1.0	0.326	MEAN 5.118 STD DEV 0.866 VARIANCE 0.749 COUNT 520

TABLE B-5

STATISTICAL TEST OF DIFFERENCES IN % PASSING #200

"t" VALUE (DIFF > ZERO) = 2.98 ; PROB. TYPE I ERROR = 0.3 %
"t" VALUE (DIFF > 0.140) = 2.45 ; PROB. TYPE I ERROR = 1.0 %
"t" VALUE (DIFF > 0.441) = 1.31 ; PROB. TYPE I ERROR = 10 %

- THERE IS AN INCREASE IN THE % PASSING THE #200 -

	ALL JOBS JOB MEANS (OLD)	NOMINAL DIFFERENCE	ALL JOBS JOB MEANS (NEW)
MEAN	4.435	0.788	5.223
STD DEV	0.900		0.672
COUNT	18.0		18.0
JOB			
A	3.40		4.95
B	3.01		4.89
C	3.38		6.28
D	5.18		5.69
E	5.61		6.41
F	5.28		6.08
G	5.22		4.94
H	4.27		4.87
I	5.01		4.11
J	5.54		6.28
K	2.71		5.40
L	3.16		5.49
M	4.94		5.28
N	4.56		4.95
O	4.04		4.84
P	4.83		4.73
Q	4.89		4.47
R	4.81		4.35

TABLE B-6

STATISTICAL COMPARISON OF VARIABILITY IN MATERIAL PASSING #200

"t" VALUE (DIFF < ZERO) = ** ; PROB. TYPE I ERROR = **HIGH**

- THE DIFFERENCE IS NOT SIGNIFICANT -

	STD DEV (OLD)	NOMINAL DIFFERENCE	STD DEV (NEW)
MEAN	0.490	-0.021	0.469
STD DEV	0.221		0.175
COUNT	18		18
JOB			
A	0.4411		0.3835
B	0.3331		0.7387
C	0.4143		0.3014
D	0.4434		0.3229
E	0.4110		0.4689
F	0.5687		0.5269
G	0.5294		0.3544
H	0.5321		0.4750
I	0.7651		0.5469
J	1.2587		0.3076
K	0.5571		0.3154
L	0.5332		0.4638
M	0.3452		0.6428
N	0.3214		0.3911
O	0.4339		0.9823
P	0.3602		0.4788
Q	0.2774		0.2506
R	0.2972		0.4957

** Not meaningful because the difference is too small

TABLE B-7a

OLD PROJECTS - PERCENT EXTRACTED MATERIAL PASSING #10

STATISTICS FOR 18 PROJECTS BY SUBLOT					
OUT OF SPEC # OCCURRENCES		MEAN +/- SPEC CENTER	MEAN	29.605
HIGH	LOW		STD DEV	2.794
23.0	10.0	0.455	VARIANCE	7.823
			COUNT	519

TABLE B-7b

NEW PROJECTS - PERCENT EXTRACTED MATERIAL PASSING #10

STATISTICS FOR 18 PROJECTS BY SUBLOT				
OUT OF SPEC # OCCURRENCES		MEAN +/- SPEC CENTER	MEAN	30.937
HIGH	LOW		STD DEV	2.484
12.0	21.0	-0.321	VARIANCE	6.165
			COUNT	520

TABLE B-8

STATISTICAL TEST OF DIFFERENCES IN % PASSING #10

"t" VALUE (DIFF > ZERO) = 2.75 ; PROB. TYPE I ERROR = 0.5 %
"t" VALUE (DIFF > 0.164) = 2.44 ; PROB. TYPE I ERROR = 1.0 %
"t" VALUE (DIFF > 0.760) = 1.31 ; PROB. TYPE I ERROR = 10 %

- THERE IS AN INCREASE IN % PASSING THE #10 -

	ALL JOBS JOB MEANS (OLD)	NOMINAL DIFFERENCE	ALL JOBS JOB MEANS (NEW)
MEAN	29.416	1.452	30.867
STD DEV	1.688		1.471
COUNT	18.0		18.0
JOB			
A	32.8		30.8
B	32.1		31.3
C	32.0		29.6
D	28.6		30.4
E	28.8		30.4
F	28.0		33.2
G	28.2		30.8
H	27.4		26.7
I	30.8		31.2
J	30.8		32.2
K	29.7		32.9
L	29.0		30.1
M	28.2		31.6
N	26.9		30.6
O	30.5		32.7
P	29.8		30.7
Q	28.5		31.3
R	27.5		29.0

TABLE B-9

STATISTICAL COMPARISON OF VARIABILITY IN MATERIAL PASSING #10

"t" VALUE (DIFF < ZERO) = ** ; PROB. TYPE I ERROR = **HIGH**

- THE DIFFERENCE IS NOT SIGNIFICANT -

	STD DEV (OLD)	NOMINAL DIFFERENCE	STD DEV (NEW)
MEAN	2.086	-0.100	1.986
STD DEV	0.449		0.439
COUNT	18		18
JOB			
A	2.1488		2.2526
B	2.1563		2.3536
C	2.1349		1.8152
D	2.3108		1.6210
E	1.5308		3.1173
F	2.6692		1.9261
G	2.2221		2.5943
H	2.5701		1.9349
I	2.6301		2.1861
J	2.2555		1.8330
K	1.4584		1.5089
L	1.6271		2.0068
M	2.1828		1.2276
N	2.2527		1.7856
O	2.7689		1.9508
P	1.9327		2.3333
Q	1.6018		1.9615
R	1.1025		1.3440

** Not meaningful because the difference is too small

TABLE B-10a

OLD PROJECTS - PERCENT EXTRACTED ASPHALT CEMENT

STATISTICS FOR 18 PROJECTS BY SUBLOT				
OUT OF SPEC # OCCURRENCES HIGH	LOW	MEAN +/- SPEC CENTER		
28.0	41.0	0.004	MEAN	5.661
			STD DEV	0.466
			VARIANCE	0.217
			COUNT	520

TABLE B-10b

NEW PROJECTS - PERCENT EXTRACTED ASPHALT CEMENT

STATISTICS FOR 18 PROJECTS BY SUBLOT				
OUT OF SPEC # OCCURRENCES HIGH	LOW	MEAN +/- SPEC CENTER		
14.0	9.0	0.060	MEAN	5.623
			STD DEV	0.542
			VARIANCE	0.292
			COUNT	520

TABLE B-11

STATISTICAL TEST OF DIFFERENCES IN % EXTRACTED AC

"t" VALUE (DIFF < ZERO) = ** ; PROB. TYPE I ERROR = HIGH

- THE DIFFERENCE IS NOT SIGNIFICANT -

	ALL JOBS JOB MEANS (OLD)	NOMINAL DIFFERENCE	ALL JOBS JOB MEANS (NEW)
MEAN	5.65	-0.0307	5.62
STD DEV	0.35		0.44
COUNT	18.0		18.0
JOB			
A	5.6		5.5
B	5.9		5.3
C	5.4		5.1
D	5.9		5.4
E	5.9		5.3
F	5.7		5.8
G	5.2		5.4
H	6.1		6.6
I	5.8		6.4
J	5.5		6.0
K	6.1		5.4
L	5.4		5.8
M	5.7		5.9
N	4.9		5.6
O	5.5		5.7
P	5.1		6.0
Q	6.2		4.9
R	5.7		5.1

** Not meaningful because the difference is too small.

TABLE B-12

STATISTICAL COMPARISON OF VARIABILITY IN % ASPHALT CEMENT

"t" VALUE (DIFF < ZERO) = -2.79 ; PROB. TYPE I ERROR = 0.5 %
"t" VALUE (DIFF < -.010) = -2.46 ; PROB. TYPE I ERROR = 1.0 %
"t" VALUE (DIFF < -.043) = -1.31 ; PROB. TYPE I ERROR = 10 %

- THE VARIABILITY OF AC CONTENT HAS DECREASED -

	STD DEV (OLD)	NOMINAL DIFFERENCE	STD DEV (NEW)
MEAN	0.316	-0.082	0.234
STD DEV	0.106		0.065
COUNT	18		18
JOB			
A	0.1563		0.2327
B	0.2543		0.1706
C	0.2169		0.2548
D	0.5816		0.1655
E	0.2971		0.2637
F	0.3886		0.4108
G	0.3469		0.3444
H	0.2434		0.2078
I	0.3519		0.2590
J	0.3315		0.2313
K	0.3256		0.2061
L	0.1826		0.1914
M	0.4146		0.1714
N	0.2302		0.2054
O	0.4819		0.2223
P	0.1955		0.3071
Q	0.3628		0.1461
R	0.3257		0.2228

TABLE B-13a

OLD PROJECTS - PERCENT MOISTURE
STATISTICS FOR 18 PROJECTS
BY SUBLOT

OUT OF SPEC # OCCURRENCES HIGH	LOW	MEAN +/- SPEC CENTER		
*	*	*	MEAN	0.432
			STD DEV	0.205
			VARIANCE	0.042
			COUNT	520

TABLE B-13b

NEW PROJECTS - PERCENT MOISTURE
STATISTICS FOR 18 PROJECTS
BY SUBLOT

OUT OF SPEC # OCCURRENCES HIGH	LOW	MEAN +/- SPEC CENTER		
5.0	*	*	MEAN	0.227
			STD DEV	0.498
			VARIANCE	0.249
			COUNT	520

TABLE B-14

STATISTICAL TEST OF DIFFERENCES IN % MOISTURE

"t" VALUE (DIFF < ZERO) = -5.58 ; PROB. TYPE I ERROR < 0.01%
"t" VALUE (DIFF < -0.156)= -2.49 ; PROB. TYPE I ERROR = 1.0 %
"t" VALUE (DIFF < -0.215)= -1.32 ; PROB. TYPE I ERROR = 10 %

- THE REDUCTION IN MOISTURE CONTENT IS HIGHLY SIGNIFICANT -

	ALL JOBS JOB MEANS (OLD)	NOMINAL DIFFERENCE	ALL JOBS JOB MEANS (NEW)
MEAN	0.451	-0.282	0.170
STD DEV	0.194		0.088
COUNT	18		17
JOB			
A	0.569		0.174
B	0.571		0.124
C	0.444		0.218
D	0.920		0.171
E	0.884		~~1.524~~*
F	0.256		0.242
G	0.489		0.143
H	0.300		0.409
I	0.240		0.188
J	0.348		0.048
K	0.563		0.085
L	0.488		0.204
M	0.218		0.045
N	0.282		0.112
O	0.313		0.113
P	0.387		0.166
Q	0.455		0.302
R	0.395		0.141

* Eliminated from analysis because it is an outlier.

TABLE B-15

STATISTICAL COMPARISON OF VARIABILITY IN % MOISTURE

"t" VALUE (DIFF < ZERO) = -4.06 ; PROB. TYPE I ERROR = 0.1 %
"t" VALUE (DIFF < -.017) = -2.46 ; PROB. TYPE I ERROR = 1.0 %
"t" VALUE (DIFF < -.029) = -1.31 ; PROB. TYPE I ERROR = 10 %

- THE VARIABILITY OF MOISTURE CONTENT HAS DECREASED -

	STD DEV (OLD)	NOMINAL DIFFERENCE	STD DEV (NEW)
MEAN	0.098	-0.042	0.056
STD DEV	0.038		0.023
COUNT	18		17
JOB			
A	0.0708		0.0731
B	0.0943		0.0475
C	0.0945		0.0513
D	0.1030		0.1048
E	0.0874		~~2.1808~~*
F	0.0640		0.0801
G	0.1157		0.0495
H	0.1168		0.0668
I	0.0970		0.0798
J	0.1901		0.0201
K	0.1360		0.0330
L	0.1255		0.0574
M	0.0747		0.0206
N	0.0204		0.0339
O	0.0525		0.0393
P	0.1329		0.0634
Q	0.1291		0.0858
R	0.0646		0.0434

* Eliminated from analysis because it is an outlier.

Appendix C

Projects in Statistical Analysis

SUMMARY OF -OLD- PROJECTS
AS STUDIED UNDER STATISTICAL ANALYSIS - CHAPTER 3

Job: "A - OLD" Date: 5/80
Plant: Drum
Section: Bunker Hill - Glen Aiken Cr.
Cont. #: 9056
Mix Type: "B" Rice: 2.42
Lift: Top Depth: 2 in.

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	6	5.9		
LSL	28	2	4.9		92*

Job: "B - OLD" Date:
Plant: Drum
Section: Bunker Hill - Glen Aiken Cr.
Cont. #: 9056
Mix Type: "B" Rice: 2.42
Lift: Base Depth: 2 in.

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	6	6.4		
LSL	28	2	5.4		92*

Job: "C - OLD" Date: 7\81
Plant: Drum
Section: Davis Slough - Bullards Br.
Cont. #: 9301
Mix Type: "B" Rice: 2.45
Lift: Top Depth: 2 in.

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	35	6	5.7		
LSL	27	2	4.7		92*

Job: "D - OLD" Date: 7\82
Plant:
Section: Weston - Weston Mtn.
Cont. #: 9356
Mix Type: "B" Rice: 2.5
Lift: Base Depth: 2 in.

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	34	7	7		
LSL	25	3	6		92*

Job: "E - OLD" Date: 7\82
Plant:
Section: Weston - Weston Mtn.
Cont. #: 9356
Mix Type: "B" Rice: 2.5
Lift: Top Depth: 2 1/2 in.

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	34	7	7		
LSL	25	3	6		92*

Job: "F - OLD" Date: 6\80
Plant:
Section: Dayton Jct.
Cont. #: 9013
Mix Type: "B" Rice: 2.52
Lift: Top Depth:

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	33	7	6.2		
LSL	25	3	5.2		92*

SUMMARY OF -OLD- PROJECTS STUDIED (cont.)

Job: "G - OLD" Date: 6\82
Plant:
Section: Martin Creek - Anlauf Inter.
Cont. #: 9037
Mix Type: "B" Rice: 2.55
Lift: Top Depth:

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	32	7	5.4		
LSL	24	3	4.4		92*

Job: "H - OLD" Date: 9/80
Plant: Batch
Section: Willamette River - Goshen
Cont. #: 8975
Mix Type: "B" Rice: 2.48
Lift: Base Depth:

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	32	7	6.5		
LSL	24	3	5.5		92*

Job: "I - OLD" Date: 9/80
Plant: Batch
Section: Willamette River - Goshen
Cont. #: 8975
Mix Type: "B" Rice: 2.47
Lift: Top/A Depth:

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	32	7	6.5		
LSL	24	3	5.5		92*

Job: "J - OLD" Date: 9/80
Plant: Batch
Section: Willamette River - Goshen
Cont. #: 8975
Mix Type: "B" Rice: 2.47
Lift: Top/B Depth:

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	32	7	6.5		
LSL	24	3	5.5		92*

Job: "K - OLD" Date: 6/82
Plant: Drum
Section: Elkhead - Rice Hill
Cont. #: 9381
Mix Type: "B" Rice: 2.46
Lift: Base Depth: 2 in.

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	34	6	6.5		
LSL	25	2	5.5		92*

Job: "L - OLD" Date: 6/82
Plant: Drum
Section: Elkhead - Rice Hill
Cont. #: 9381
Mix Type: "B" Rice: 2.48
Lift: Top Depth: 2 in.

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	33	4	5.7		
LSL	25	2	4.7		92*

Job: "M - OLD" Date: 10/82
Plant: Drum
Section: Sunny Valley - Jump off Joe Cr.
Cont. #: 9383
Mix Type: "B" Rice: 2.66
Lift: Base Depth: 2 in.

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	33	7	6.1		
LSL	25	3	5.1		92*

SUMMARY OF -OLD- PROJECTS STUDIED (cont.)

Job: "N - OLD" Date: 10/82
Plant: Drum
Section: Sunny Valley - Jump off Joe Cr.
Cont. #: 9383
Mix Type: "B" Rice: 2.69
Lift: Top Depth: 2 in.

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	33	7	5.6		
LSL	25	3	4.6		92*

Job: "O - OLD" Date: 8/82
Plant: Drum
Section: Burnt Hill - Thomas Crk
Cont. #: 9369
Mix Type: "B" Rice: 2.52
Lift: Base Depth: 1 1/2 in.

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	34	6	6		
LSL	26	2	5		92*

Job: "P - OLD" Date: 8/82
Plant: Drum
Section: Burnt Hill - Thomas Crk
Cont. #: 9369
Mix Type: "B" Rice: 2.52
Lift: Top Depth: 1 1/2 in.

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	34	6	5.5		
LSL	26	2	4.5		92*

Job: "Q - OLD" Date: 10/80
Plant: Drum
Section: S. Unit, Astoria - Camp Rilea
Cont. #: 8949
Mix Type: "B" Rice: 2.59
Lift: Base Depth:

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	31	7	6.5		
LSL	23	3	5.5		92*

Job: "R - OLD" Date: 10/80
Plant: Drum
Section: S. Unit, Astoria - Camp Rilea
Cont. #: 8949
Mix Type: "B" Rice: 2.57
Lift: Top Depth:

SPECIFICATIONS	#10	#200	Asphalt	Moist	Compact
USL	31	7	6		
LSL	23	3	5		92*

*This compaction specification could not be used in the data analysis because it was based on "recompacted density" and not "Rice gravity" as the new spec. is.

SUMMARY OF -NEW- PROJECTS
AS STUDIED UNDER STATISITCAL ANALYSIS - CHAPTER 3

Job: "A - NEW" Date: 8/88
Plant: Drum Compact: MAMD
Section: Irrigon - Umatilla
Cont. #: 10545
Mix Type: "B"
Lift: Top Lot #: 2

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	6.4	5.9	0.6	
LSL	28	2.4	4.9		91

Job: "B - NEW" Date: 11/88
Plant: Batch Compact: MAMD
Section: Leb/Corv Intch-Halsey Intch
Cont. #: 10426
Mix Type: "B"
Lift: Top Lot #: 6

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	7.5	5.8	0.6	
LSL	28	3.5	4.8		91

Job: "C - NEW" Date: 8/87
Plant: Drum Compact: MAMD
Section: Southside Bypass - Washburn Way
Cont. #: 10171
Mix Type: "B"
Lift: Base/Top Lot #: 1

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	34	7.5	5.5	0.6	
LSL	26	3.5	4.5		91

Job: "D - NEW" Date: 5/89
Plant: Compact: MAMD
Section: Murphy Rd - Lava Butte
Cont. #: 10462
Mix Type: "B"
Lift: Base Lot #: 1

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	35	7	5.8	0.6	
LSL	27	3	4.8		91

Job: "E - NEW" Date: 6/89
Plant: Batch Compact: MAMD
Section: Arlington - Tower Rd.
Cont. #: 10687
Mix Type: "B"
Lift: Top Lot #: 1B

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	7	5.4	0.5	
LSL	28	3	4.6		92

Job: "F - NEW" Date: 10/88
Plant: Drum Compact: MAMD
Section: S. Ashland-Calif line
Cont. #: 10439
Mix Type: "B"
Lift: Top/Base Lot #: 3

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	34	7	6.2	0.6	
LSL	26	3	5.2		91

SUMMARY OF -NEW- PROJECTS STUDIED (cont.)

Job: "G - NEW" Date: 10/87
Plant: Drum Compact: MAMD
Section: Halsey - Harrisburg
Cont. #: 10484
Mix Type: "B"
Lift: Top Lot #: 2

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	7	6	0.6	
LSL	28	3	5		91

Job: "H - NEW" Date: 9/86
Plant: Cat Drum Compact: MAMD
Section: Meacham Hilgard
Cont. #: 10192
Mix Type: "B"
Lift: Top Lot #: 5

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	34	7.5	7	0.6	
LSL	26	3.5	6		91

Job: "I - NEW" Date: 6/87
Plant: Batch Compact: MAMD
Section: Liberty Road - Sweet Home
Cont. #: 10400
Mix Type: "B"
Lift: Base/Top Lot #: 2

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	35	6	7	0.6	
LSL	27	2	6		91

Job: "J - NEW" Date: 10/86
Plant: Drum Compact: MAMD
Section: Linn Co Line - Suttle Lake Sec
Cont. #: 10286
Mix Type: "B"
Lift: Base/Top Lot #: 1

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	7.5	6.5	0.6	
LSL	28	3.5	5.5		91

Job: "K - NEW" Date: 9/88
Plant: Continuous Compact: MAMD
Section: Little Nestucca R. - Neskowin
Cont. #: 10300
Mix Type: "B"
Lift: Top Lot #: 1

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	37	7.5	5.8	0.6	
LSL	29	3.5	4.8		91

Job: "L - NEW" Date: 10/87
Plant: Drum Compact: MAMD
Section: Mill Cr Dr - BNRR STR
Cont. #: 10374
Mix Type: "B"
Lift: Lot #: 3

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	34	6.7	6.3	0.6	
LSL	26	2.7	5.3		91

SUMMARY OF -NEW- PROJECTS STUDIED (cont.)

Job: "M - NEW" Date: 6/88
Plant: Batch Compact: MAMD
Section: Leb/Samt Canal-Sodaville Rd
Cont. #: 10569
Mix Type: "B"
Lift: Lot #: 1

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	34	6	6.5	0.6	
LSL	26	2	5.5		91

Job: "N - NEW" Date: 7/88
Plant: Drum Compact: MAMD
Section: Irrigon - Umatilla
Cont. #: 10545
Mix Type: "B"
Lift: Lot #: 1

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	6.4	5.9	0.6	
LSL	28	2.4	4.9		91

Job: "O - NEW" Date: 10/86
Plant: Batch Compact: MAMD
Section: Park Place - Clackamas Comm. Coll
Cont. #: 9928
Mix Type: "B"
Lift: Lot #: 2

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	35	6	6.1	0.7	
LSL	27	2	5.1		91

Job: "P - NEW" Date: 10/85
Plant: Batch Compact: MAMD
Section: Hermiston - Stanfield N.C.L.
Cont. #: 10010
Mix Type: "B"
Lift: Lot #: 1

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	7	6.5	0.7	
LSL	28	3	5.5		91

Job: "Q - NEW" Date: 9/88
Plant: Drum Compact: MAMD
Section: Columbia R BR - Old Ore. Tr
Cont. #: 10387
Mix Type: "B"
Lift: Top Lot #: 3

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	36	7	5.1	0.6	
LSL	28	3	4.1		91

Job: "R - NEW" Date: 6/88
Plant: Drum Compact: MAMD
Section: Farewell Bend - N FK Jacobsen Gul
Cont. #: 10530
Mix Type: "B"
Lift: Lot #: 1

SPECIFICATIONS

	#10	#200	Asphalt	Moist	Compact
USL	35	6	5.5	0.6	
LSL	27	2	4.5		91

SUMMARY OF -NEW- PROJECTS STUDIED (cont.)

Job / details	Notes
Job "S - NEW" Date: 1985 Plant: Compact: Target density Section: Hermiston - Stanfield Cont. #: 10010 Mix Type:"B" Lift: Lot #: 5	Used only in analysis of compaction. "Target" compaction spec. not comparable to MAMD" spec.
Job "T - NEW" Date: 1986 Plant: Compact: Target density Section: N.Grants Pass Intch - Rock Point Cont. #: C10186 Mix Type: "B" Lift: Shoulder Lot #: 2	Used only in analysis of compaction. "Target" compaction spec. not comparable to MAMD" spec.
Job: "U - NEW" Date: 1987 Plant: Compact: Target density Section: West Creek - Clatskanie Cont. #: 10429 Mix Type: "B" Lift: Top Lot #: 1	Used only in analysis of compaction. "Target" compaction spec. not comparable to MAMD" spec.
Job: "V - NEW" Date: 1988 Plant: Compact: Target density Section: Queen Ave - Corvallis/Lebanon Hwy Cont. #: 10489 Mix Type: "B" Lift: Base/Top Lot: 2, 4, 4T, 8	Used only in analysis of compaction. "Target" compaction spec. not comparable to MAMD" spec.
Job: "W - NEW" Date: 1988 Plant: Compact: Target density Section: Glencoe Rd - Helvetia Rd Cont. #: 10524 Mix Type: "B" Lift: Base Lot: 2A	Used only in analysis of compaction. "Target" compaction spec. not comparable to MAMD" spec.
Job "X - NEW" Date: 1989 Plant: Compact: Target density Section: Redmond - Bend (S Unit) Cont. #: 10672 Mix Type: "B" Lift: Base Lot: 3	Used only in analysis of compaction. "Target" compaction spec. not comparable to MAMD" spec.
Job "Y - NEW" Date: 1989 Plant: Compact: Target density Section: NE Hancock St - NE Haig St. Cont. #: 10764 Mix Type: "B" Lift: Top Lot: 1	Used only in analysis of compaction. "Target" compaction spec. not comparable to MAMD" spec.

Appendix D

Questionnaire as Distributed

QUESTIONNAIRE: BONUS PAY SYSTEM STUDY HP&R # 5286

Return by May 31, 1990 to:
Keith Martin, Research Unit Engineer

1. In your opinion, does the bonus pay system improve cooperation from the contractors? Discuss.

2. In your opinion, does the State receive benefits in proportion to the net cost of the bonus pay system? Discuss.

   a. What benefits do you think the State receives? Can you place a dollar value on these benefits?

   b. What costs are there, both hidden and actual. Can you place a Dollar value on these costs.

3. Do you think the current bonus pay system is effective? Why? State any suggestions you may have for improving it.

4. We need to identify any "403 Specification" projects that have shown signs of early distress. The attached page lists a selection of paving projects that your office has constructed. Make one copy of this page for each project on the attached list and answer the following questions. If necessary, please contact the local Section Foreman for the information. Also include an overall estimate of the severity of any distress on the attached list.

a. Project name ____

HWY # ______ BMP ______ EMP ______

b. Were there any problems with distress during the first or second year of pavement life?

	Distress Severity			Age When Observed (months)
	Severe	Moderate	None	
Bleeding	______	______	______	______
Ravelling	______	______	______	______
Joint Problems	______	______	______	______
Rutting	______	______	______	______
Cracking	______	______	______	______
Other__________	______	______	______	______
Overall distress	______	______	______	______

c. Was any early distress noted in "b" above due to these factors?

Inadequate Compaction	Yes_____	No_____	Don't Know_____
Excess Compaction	Yes_____	No_____	Don't Know_____
Poor A/C Content Control	Yes_____	No_____	Don't Know_____
Poor Gradation Control	Yes_____	No_____	Don't Know_____

d. What other factors do you think may contribute to any early distress noted in "b" above?