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Overview of Pay-Adjustment Factors for Asphalt Concrete Mixtures

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In the fall of 1979, the Oregon State Highway Division and Oregon State University, with participation from the University of Washington, initiated a research project to study the impact of variations in material properties on asphalt pavement life. The study is aimed at developing a rational approach to assessing the effects of variations from specification limits so that a firm basis can be established for the development of pay factors. To collect information on the status of quality-control procedures and the use of pay-adjustment factors, a questionnaire was distributed to all state agencies, the District of Columbia, and the Federal Highway Administration. Each agency was asked to respond to questions on their current method for acceptance or rejection of asphalt concrete paving materials and related pay-adjustment factors. The results of the questionnaire are summarized. Analysis of the results indicates the following: (a) Most state agencies will accept one or more property characteristics of asphalt concrete that are outside specification tolerances, (b) most state agencies apply a pay-adjustment factor to accepted materials that are outside specification tolerances, (c) only 26 percent of the state agencies consider their pay factors to be proportional to reduced pavement serviceability, (d) approximately half of the agencies consider pay-factor plans to be effective in encouraging compliance with specifications, and (e) there is a wide disparity in the pay-adjustment factors used by the different agencies.

In the fall of 1979, the Oregon State Highway Division and Oregon State University initiated a research project to study the impact of variations in material properties on asphalt pavement life. The University of Washington is cooperating in the study with Oregon State University. The questionnaire was prompted by an increase in the occurrence of pavement problems during recent years and in the proportion of pavements constructed with a significant amount of material outside of specification limits (1). The effect of construction noncompliance on pavement serviceability has been questioned by highway agencies and has resulted in frequent controversy with contractors on the assessment of pay adjustments. The general result is reduced pay to the contractor for material that is determined to be outside the specification tolerances. The current study is aimed at developing a rational approach to assessing the effects of variations from specification limits so that a firm basis can be established for the development of pay factors.

The American Association of State Highway Officials (AASHO) Road Test (1958-1960) emphasized to the highway industry the significance of the relation of the variability of material test properties to highway specifications (2). As a result, many agencies have been developing and experimenting with various combinations of statistically based specifications to provide a more accurate evaluation of the end products and to allow acceptance of noncompliance work in conjunction with a reduced payment for that work. In 1976, 33 states were using or had tried some form of statistically oriented end-result specification (3).

In an effort to collect current information on the status of quality-control procedures and the use of pay-adjustment factors, a questionnaire was developed and distributed to all state agencies, the District of Columbia, and the Federal Highway Administration (FHWA) in November 1979. Questionnaires were returned by all except four states (a 92 percent response rate). Each agency was asked to respond to seven questions concerning their current method for acceptance or rejection of asphalt concrete paving materials. The items of emphasis on the questionnaire included

1. Acceptance of noncompliance construction and materials with or without pay adjustments,
2. Identification of properties tested for acceptance and the method of test used,
3. Pay-adjustment factors used in relation to each tested property,
4. Rationale used in establishing pay-adjustment factors,
5. Relation of pay-adjustment factors to pavement serviceability or other criteria,
6. Effectiveness of pay-adjustment factors in encouraging compliance with specifications, and
7. Summary opinions regarding the use of pay adjustments.

Although the required information could be placed on the questionnaire, the states were encouraged to include copies of supplemental information that would assist in the overall evaluation. Most states did provide supplemental materials.

Although emphasis in this paper is placed on the results of current state practice, a rational approach is presented and discussed that shows significant promise in developing pay factors. The rational development of pay factors is based on selected material properties that can be developed in the laboratory. Preliminary test results and corresponding pay factors are shown for one recent paving project constructed in the state of Oregon.

QUESTIONNAIRE RESULTS

Seven primary questions were contained in the questionnaire. The responses received for each of these questions are discussed below.

Acceptance of Below-Specification Work and Materials

Question 1 was, Do you accept asphalt concrete pavement construction and materials that do not satisfy specification requirements? The responses to this question are summarized below:

Response	Agencies No.	Percent
Will not accept	4	9
Accept without pay adjustment	4	9
Accept with pay adjustment	30	64
Combination acceptance	9	18
Total	47	

Of the 47 agencies that responded, only 4 indicated that they do not accept construction work or materials that are below specification. All of the remaining agencies (91 percent) accept some aspects of the work or materials when they are below specifications. "Combination acceptance" indicates acceptance of some deficient materials with pay adjustment and some without.

The key concept illustrated is that 82 percent of the agencies use some form of pay-adjustment factors when accepting one or more of the evaluated criteria. However, only four states indicated a possible acceptance of below-specification work or materials on every evaluated property considered in the questionnaire. All other agencies identified certain criteria that would not be accepted if below specification limits. A detailed discussion of these criteria is included in the analysis of questions 2 and 3 of the questionnaire. The 18 percent labeled "combination acceptance" indicates agencies that accept below-specification work and materials by using a combination of pay adjustment and no pay adjustment, depending on the criteria being considered.

Properties Evaluated to Determine Pavement Acceptability

Question 2 was, What properties do you evaluate to establish the acceptability of an asphaltic pavement? The questionnaire listed eight properties commonly evaluated during or after completion of construction. These properties were thickness, smoothness, compaction, asphalt content, asphalt properties, aggregate quality, mix moisture content, and mix gradation. Each agency was asked to identify which properties are evaluated and controlled by their specifications and to indicate the method of testing used. The table below summarizes data received concerning which properties are evaluated:

Property	Agencies That Test Property No.	Percent
Thickness	31	66
Smoothness	37	79
Compaction	43	91
Asphalt content	43	91
Asphalt properties	44	94
Aggregate quality	39	83
Mix moisture content	21	45
Mix gradation	45	96

The data for the method of testing are discussed in conjunction with question 3, which deals with the use of pay factors. All property criteria except mix moisture content are evaluated by at least two-thirds of the agencies.

Pay-Adjustment Factors for Properties Evaluated

Question 3 was, What are your pay-adjustment factors for each of the properties identified in question 2? The data summaries that relate to pay-adjustment factors and methods of testing are given in the tables that follow. Each table deals with a different property, and each is discussed individually.

A review of the questionnaire results indicates that the basis for applying pay factors can be broken down into the following five categories:

1. Statistical--The concepts of random sampling are used in collecting test data. The statistical methods used to evaluate the measurements can include the use of simple averaging, a range of measurements, the normal distribution, and the Student's t-distribution.
2. Guide in specification--The agency makes use of a pay-adjustment-factors guide, usually in tabular form, which is part of the specification in which statistical methods are not used.
3. Schedule (not in specification)--The agency has established guidelines for use in applying pay factors, but they are not a part of the specifications. For example, one state has a "price adjustment committee", which determines pay adjustments for each case individually. The state has a guide to pay factors, which may be used at the committee's discretion.
4. None--Since materials below specification are not accepted, no pay factors are involved.
5. Negotiated--The agency accepts below-specification work and materials based on negotiations with the contractor. These negotiations include pay adjustment.

It is important to note that many of the agencies that make use of pay-adjustment factors retain a process of decision making by the agency's project engineer. The pay factors are applied only if the below-specification work or material is accepted.

Thickness

The questionnaire information on thickness evaluation is summarized below:

Item	Agencies That Use Method No.	Percent
Test method		
Cores	23	74
Other depth measurements	8	26
Basis of pay factors		
Statistical	5	16
Guide in specification	7	23
Schedule	2	6
None	14	45
Negotiated	3	10

Thirty-one agencies evaluate the thickness of the finished pavement, and 74 percent of this total use cores in measurement of the final thickness. The remaining agencies use other methods, such as measuring the uncompacted thickness at the paver and applying a predetermined coefficient based on density to determine final thickness. Although it is not indicated, all state agencies probably evaluate this property either by direct or indirect evaluation procedures.

Almost half of the agencies do not accept a pavement thickness below specification tolerances. Most of these agencies specify that an overlay is required to bring the thickness up to specification, the contractor assuming all costs. The remaining agencies accept final thicknesses that are below specification in conjunction with some form of pay adjustment.

Smoothness

The table below summarizes the questionnaire data regarding smoothness:

Item	Agencies That Use Method No.	Percent
Test method		
Straightedge	26	70
Profilograph	4	11
Roadmeter	3	8
Not identified	4	11
Basis of pay factors		
Statistical	6	16
Guide in specifications	6	16
Schedule	4	11
None	18	49
Negotiated	3	8

Thirty-seven of the agencies evaluate the smoothness of the finished pavement surface. Of these, 70 percent use a straightedge as the basis of their measurements, 11 percent did not identify a method of testing, and the remaining 19 percent use either the profilograph or roadmeters such as the Portland Cement Association (PCA) Roadmeter.

As in the case of the thickness evaluations, approximately half of the agencies accept pavements that do not meet the smoothness specification tolerances. Most of these apply a pay-adjustment factor to account for the increased maintenance requirements. The other half of the agencies do not accept pavement surfaces outside the tolerance limits, but most of them allow a contractor to bring the surface up to specification with placement of an overlay at the contractor's expense.

Compaction

The results of the questionnaire data on compaction are given below:

Item	Agencies That Use Method No.	Percent
Test method		
Nuclear gage	26	60
Cores	3	7
Procedure specification	4	9
Other AASHTO	8	19
Not identified	2	5
Basis of pay factors		
Statistical	11	26
Guide in specification	11	26
Schedule	3	7
None	16	37
Negotiated	2	5

Of the 43 agencies that evaluate compaction, 60 percent use nuclear gage methods and 7 percent use pavement cores. The 9 percent that use their own procedural specification gave detailed procedures of the test requirements without reference to any of the standard test methods.

Almost two-thirds of the agencies accept pavement sections that have not been compacted to specification requirements. Note that both statistically and nonstatistically based pay-adjustment factors are used equally. Although 37 percent of the agencies indicated they would not accept pavement that was improperly compacted, the available information was insufficient to identify the procedures used to remedy the deficiency.

Asphalt Content

The testing methods used and the basis for the pay-adjustment factors that are applied when below-specification material is accepted are summarized below:

Item	Agencies That Use Method No.	Percent
Test method		
Extraction	32	74
Tank sticking	3	8
Procedure specification	7	16
Not identified	1	2
Basis of pay factors		
Statistical	17	40
Guide in specification	6	14
Schedule	3	6
None	15	35
Negotiated	2	5

Forty-three of the agencies evaluate asphalt content, and 74 percent of these use extraction methods. The remaining agencies use other methods, such as tank sticking.

Approximately one-third of the agencies do not accept material outside the tolerance limits of the specifications. Most of those agencies check the asphalt content on a regular basis during construction so that adjustments can be readily made without great losses of time or materials. Therefore, pay adjustments are often not needed. The majority of the agencies accept materials that have asphalt contents outside specification tolerances. The most commonly used basis for pay-adjustment factors among these agencies is statistical in nature.

Asphalt Properties

Forty-four agencies, or 94 percent of those that responded to the questionnaire, provide for the evaluation of the asphalt properties in their specifications. A summary of the test methods and pay-adjustment factors used by these agencies is given below:

Item	Agencies That Use Method No.	Percent
Test method		
Producer test	10	23
Agency test	31	70
Not identified	3	7
Basis of pay factors		
Statistical	8	18
Guide in specification	13	30
Schedule	3	7
None	16	36
Negotiated	4	9

The majority (70 percent) use a combination of various American Association of State Highway and Transportation Officials (AASHTO) test methods to evaluate the individual characteristics of the asphalt.

Slightly more than one-third of the agencies do not accept asphalt that has properties outside the specification tolerances. These agencies evaluate the properties before the asphalt is used in mixes; thus, unacceptable asphalt can be rejected with little loss in time or money. The remaining two-thirds of the agencies accept asphalt that has properties that do not meet specification tolerances. The majority of these have a pay-factor guide in their specifications, but only 18 percent base their pay factors on statistical concepts.

Aggregate Quality

Thirty-nine of the agencies that responded provide for evaluation of aggregate quality in their specifications. Several agencies indicated that they do

not evaluate the aggregate quality as part of the contractor's specifications because the aggregate source is supplied by the state. The test methods and the basis of the pay factors currently used are summarized below:

Item	Agencies That Use Method No.	Percent
Test method		
Approved source	9	23
AASHTO	28	72
Not identified	2	5
Basis of pay factors		
Statistical	3	8
Guide in specification	2	5
Schedule	4	10
None	27	69
Negotiated	3	8

Of those agencies that evaluate aggregate quality, 72 percent make use of AASHTO test procedures.

More than two-thirds of the agencies do not accept aggregate below specification quality. Since most testing is completed prior to delivery of material to the construction site, there is seldom a need to accept inferior aggregate. For the few situations in which below-specification aggregate is accepted, there is no dominant method of developing pay-adjustment factors.

Mix Moisture Content

Less than half (21) of the agencies evaluate the mix moisture content as part of their specifications. The test methods and the basis for pay factors used by these agencies are summarized below:

Item	Agencies That Use Method No.	Percent
Test method		
Modified AASHTO	7	33
Standard moisture test	11	52
Not identified	3	15
Basis of pay factors		
Statistical	1	5
Guide in specification	1	5
Schedule	1	5
None	15	71
Negotiated	3	14

Very little information relating to test methods was given in the responses on mix moisture content. Most of the agencies simply indicated the use of standard moisture tests.

Of the agencies that use mix moisture content as a specification criterion, 71 percent do not accept material outside the tolerance limits of the specifications. This is a property that can be controlled during the construction process, often with little loss in time or materials, so that no pay adjustments are necessary. For the few situations in which below-specification materials are accepted, there is no dominant method of developing pay-adjustment factors.

Mix Gradation

All but 2 of the 47 agencies that responded evaluate mix gradation as part of their acceptance criteria. A summary of the questionnaire results concerning the test methods and basis for pay factors used in evaluating mix gradation is given below:

Item	Agencies That Use Method No.	Percent
Test method		
AASHTO	35	78
Own test	7	15
Not identified	3	7
Basis of pay factors		
Statistical	18	40
Guide in specification	8	18
Schedule	2	4
None	14	31
Negotiated	3	7

Most of the agencies use an extraction test followed by a sieve analysis.

Slightly more than two-thirds of the agencies accept mixes that have gradations that do not satisfy specification tolerances. Of these, the majority base their pay-adjustment factors on statistical concepts. The 31 percent that do not accept below-specification mixes indicated that they control the gradation during material preparation. This allows rejection and modification of mixes on a continuing basis, which results in small losses of time or material. Therefore, no pay factors are necessary.

Method of Establishing Pay-Adjustment Factors

Question 4 was, How were your pay-adjustment factors established? This question was used in an effort to identify the background for justification and development of pay-adjustment factors. The four categories listed were laboratory results, field studies, experience, and other. Each agency indicated which categories they relied on in accepting below-specification work or materials and determining the pay adjustments. The table below summarizes the background characteristics used by the various agencies in their specification development:

Method	Agencies That Use Method No.	Percent
Laboratory results	8	17
Field studies	11	23
Experience	28	60
Other	11	23
Pay factors not used	10	21

Sixty percent of the agencies indicated that experience is predominant in the development of pay factors. The remaining background categories are about equally used by the agencies. Since several agencies have relied on more than one background category, the total percentage is greater than 100 percent of the 47 agencies responding.

It should also be noted that a fifth category is added to the results in the preceding table to account for those agencies that do not use pay factors. The 21 percent given includes the four agencies that do not accept anything below specification and the six agencies that occasionally accept one or more properties below specification on a negotiated basis.

Relation Between Pay Adjustment and Pavement Serviceability

Question 5 was, Is your pay adjustment proportional to the value of the reduction in pavement serviceability resulting from specification noncompliance? This question (as well as questions 6 and 7) required the person who responded to the questionnaire to express an opinion on behalf of his or her agency. It is important to note that, since opin-

ions vary within agencies, the response from an agency may be a function of who answered the questionnaire. Therefore, the corresponding data and figures should not be considered absolute agency policy.

The following table summarizes the responses regarding the relation of pay factors and pavement serviceability:

	Agencies	
Response	No.	Percent
Yes	12	26
No	23	48
No response	12	26

Twenty-six percent of the agencies indicated that they believed their pay adjustments to be proportional to reduced pavement serviceability. However, several of those agencies also indicated that they used engineering judgment and experience to develop that rationale and that they could not verify it in terms of engineering principles. Forty-eight percent of the agencies claim little relation between their pay factors and pavement serviceability, and the remaining 26 percent did not respond to this question.

The responses to the second part of this question, in which other rationales for establishing pay-adjustment factors were identified, are summarized below:

	Agencies That Use Rationale	
Rationale	No.	Percent
Cost of replacement	4	17
Discourage noncompliance	7	30
Estimate effect on pavement life	3	13
Recommendation of FHWA	5	22
Cost of production	1	4
Cost of quality control	1	4
Pay factors not used	2	10

The 23 agencies that responded "no" on the first question gave six different rationales for determining pay factors. Thirty percent use pay factors in their specifications to discourage noncompliance. Another 22 percent are following recommendations made in standard specifications of FHWA.

Effectiveness of Pay Factors in Encouraging Compliance with Specifications

Question 6 was, Do you feel your pay-adjustment factors are effective in encouraging compliance with specifications? The responses to this question are summarized below:

	Agencies	
Response	No.	Percent
Yes	25	53
No	8	17
Don't know	5	11
No response	9	19

Slightly more than half of the agencies indicated that they felt their pay-adjustment factors to be effective in encouraging compliance with specifications, whereas 17 percent do not feel they are effective.

Agency Opinion on Pay Adjustments and Other Acceptance Methods

Question 7 was, Summarize your opinion regarding the need for pay adjustments or the success of your method for acceptance of paving materials. The opinions given in answer to this question cover the full spectrum, from "don't believe in pay factors" to "end-result specifications are the way to go". The wide range of positive and negative comments and the lack of agreement among agencies illustrate the controversial nature of this topic and the need to develop a rationale that is consistent with engineering principles acceptable to a majority of the agencies and equitable to all parties. Some of the advantages of the pay-adjustment method identified by the responding agencies are that it (a) induces contractors to improve quality control, (b) creates a uniform procedure for accepting work that does not comply with specifications, (c) reduces problems associated with contract administration, (d) reduces litigation, and (e) requires fewer state personnel.

Among the disadvantages of the method are that (a) it needs to be based on sound engineering approaches, (b) contractors resist, (c) contractors may increase bids, (d) it may result in poor-quality work if pay factors are not severe, (e) it cannot measure reduced serviceability, and (f) it can cause administration problems.

EXAMPLES OF CURRENTLY USED PAY FACTORS

In responding to question 3 of the questionnaire, each agency was requested to identify pay-adjustment factors for the eight properties listed (thickness, smoothness, compaction, asphalt content, asphalt quality, mix moisture content, and mix gradation). A majority of the states included either a tabulation of their current pay factors or partial sections from their specifications. Some of the agencies did not submit detailed information. With this in mind, examples and comparisons of pay factors for the two material properties of compaction and asphalt content are presented. These two factors are selected because of their relative importance in the production of quality asphalt concrete and to reduce the number of properties discussed to provide an overview of the kind of data received and summarized. Detailed presentations of pay-factor information will be available in a subsequent project report.

There are several general considerations that affect the application of pay-adjustment factors regardless of the property being evaluated. These considerations include lot size, the identification of contract pay items affected by pay adjustments, and the effects of multiplicative relations of pay adjustments. As important as these considerations are, a detailed treatment is not provided in this paper.

Compaction

Twenty-three state agencies submitted information on their use of pay-adjustment factors for noncompliance with compaction requirements. There is a wide disparity between the agencies: Ten different approaches are used to determine level of compaction. In addition, the agencies that use the same approach have widely varying values for a pay factor applied to a common level of compaction. Table 1 gives the 10 approaches used and the number of agencies that use each approach.

There is little value in comparing the various approaches and their effect on the contract unit price unless the actual, required data necessary for each are obtained on a common sample. Unfortunately, this is beyond the scope of the existing research. However, the tendency for wide divergence within approaches can be demonstrated. It is this divergence that may cause confusion and dissatisfac-

Table 1. Approaches used by state agencies to determine pay adjustment for noncompliance with compaction requirements.

Approach	No. of Agencies
Percentage reduction in contract price computed by formula based on statistics	3
Pay factors for percentage of target density	7
Pay factors for percentage of control strip density	4
Pay factors for percentage of voidless density	1
Pay factors for daily mean air-void content	1
Pay factors based on deviation of air-void content	1
Price adjustment for percentage of deficiency	1
Pay factors based on computed quality level	2
Pay factors based on computed quality index	1
Pay factors for percentage within limits	2

Table 2. Approaches used by state agencies to determine pay adjustment for noncompliance with asphalt content requirements.

Approach	No. of Agencies
Percentage of reduction in contract price computed by formula based on statistics	3
Pay reduction for percentage out of tolerance	3
Pay factors for average deviation from job mix	13
Pay factors for deviation of sample average as percentage	1
Pay reduction for deviation of sample average as percentage	1
Pay factors based on deviation of mean above or below mix tolerances	1
Price adjustment computed by specified procedure based on percentage of asphalt above or below mix design tolerance	1
Pay factors for degree of nonconformance of moving average	1

tion among paving contractors who undertake work in several states.

The use of pay-adjustment factors determined by comparing the in-place density with the target or laboratory density appears to be the most common approach (seven agencies). The in-place density is typically determined with a nuclear gage, and the target or laboratory density is determined from samples prepared by use of the Marshall or Hveem mixture design procedures. The percentage of the target density achieved is then compared with predetermined values in the agency's specifications. This concept is demonstrated below for the state of Mississippi:

Target Density Achieved (%)	Pay Factor (%)
94.9-100	100
94.2-94.8	90
93.5-94.1	70
92.8-93.4	50
<92.8	0

The table below compares three target densities for the seven state agencies that can be compared:

Target Density (%)	Pay Factor (%)	No. of Agencies
100	100	7
95	100	5
	93	1
	90	1
90	90	1
	75	1
	69	1
	50	2
	40	1
	0	1

For 100 percent of target density, all seven agencies provide for full pay (100 percent pay factor), as would be expected. For 95 percent of target density, the amount of pay received by a hypothetical contractor could range from 90 to 100 percent. This variability increases significantly for 90 percent of target density. The percentage pay received by a contractor could range from 0 to 90 percent depending on the state in which the contractor was performing the work.

The information resulting from the analysis of the questionnaire further reveals that, for most of the seven agencies cited, achievement of at least 95 percent of target density qualifies for full payment for the material in a given lot. If the target density is in the 90 percent range, a number of agencies either apply severe (low) pay factors or require the project engineer to make further evaluations as to whether the lot should be accepted at reduced pay or be totally rejected. Most agencies also give contractors an option of accepting the pay adjustment or removing and replacing the material at their own expense in an effort to achieve work that is in compliance.

Asphalt Content

Information on pay-adjustment factors for asphalt content was submitted by 25 agencies. This material characteristic also showed a wide disparity in pay factors among the state agencies. Table 2 gives the eight different approaches used and the number of agencies using each approach. Again, there is little value in comparing the various approaches due to the lack of supportive data. However, as in the case of the compaction criteria, the tendency for significant divergence within approaches can be demonstrated.

The use of pay-adjustment factors determined by computing the average deviation of the asphalt content from the job mix criteria appears to be the most common approach (13 agencies). The target value established for asphalt content is then used for comparison with the actual asphalt content of the lot samples. This concept is demonstrated below for the state of Nebraska:

Avg Deviation	Pay Factor (%)
0.0-0.31	100
0.32-0.37	95
0.38-0.41	90
0.42-0.45	80
0.46-0.49	70

Note that an equal pay adjustment is applied when the deviation is either above or below the job mix target value.

The table below compares three levels of average deviation from the job mix target for the 13 state agencies obtained by using this evaluation method:

Avg Deviation	Pay Factor (%)	No. of Agencies
0.20	105	1
	100	11
	90	1
0.40	100	5
	95	3
	90	2
	80	1
0.55	100	1
	95	1
	80	3
	70	2

For an average deviation of 0.20 (e.g., asphalt

binder content range of 5.8-6.2 percent for a 6 percent target content), 11 agencies provide for full pay (100 percent pay factor), one agency provides a pay factor of 105 percent (which involves a bonus for high uniformity), and one agency provides a pay factor of 90 percent. For an average deviation Of 0.40, the amount of pay received by a contractor could range from 0 to 100 percent, although the majority of the state agencies would provide payments of at least 95 percent. At an average deviation of 0.55, the payment provisions vary from 0 to 100 percent, but the majority of the agencies severely penalize the contractor. One agency gave no pay factor for deviations of 0.40, and five agencies gave no pay factor for deviations as high as 0.55. These agencies could either reject the material at zero pay or accept the noncompliance material at a negotiated pay factor.

RATIONAL PAY-FACTOR DEVELOPMENT

In an attempt to develop more rational pay factors, work is currently under way to evaluate the effects of known mix variations on pavement life. When these effects are known, pay factors can be assigned. The effects of density, gradation (particularly minus 0.074 mm), asphalt content, and aggregate quality are currently being evaluated at Oregon State University.

The procedure being used to develop pay factors is to evaluate the performance of asphalt mixes in fatigue and permanent deformation. The diametral test (4) is used to evaluate these properties. Fatigue (ε_E - N) for permanent deformation (ε_p - N) curves are developed for each mix combination. The fatigue curve shown in Figure 1 indicates the effect of density on fatigue life.

Once developed, pay factors can be determined for any strain level as given in Table 3. The table gives pavement life (repetitions) associated with various mix densities and the pay factors developed with respect to some standard (in this case, 96 percent of maximum density). As indicated, the pay factors developed range from about 5 to 45 percent for poorly compacted specimens (∿90 percent of maximum) to 45-65 percent for specimens compacted to 92 percent of maximum. It should also be noted that specimens compacted to 100 percent would yield fatigue levels about 3.5-4 times greater than the standard condition; however, these mixes may have a greater tendency to bleed or rut. This effect is still being studied.

The important point is that improved mix evaluation methods can lead directly to pay factors if noncompliance in a mix exists. These pay factors should more accurately reflect how a mix will perform in the field than the methods now being used. A detailed presentation of the development of pay factors using this approach will be available in subsequent project reports.

SUMMARY AND CONCLUSIONS

The pay-factor questionnaire prepared and distributed by the Oregon State Highway Division has proved to be extremely useful in evaluating the current status of quality-control procedures and the use of pay-adjustment factors in the construction of asphalt concrete pavement projects. The 92 percent response rate by the state agencies is a key factor

Figure 1. Effect of mix density on fatigue life.

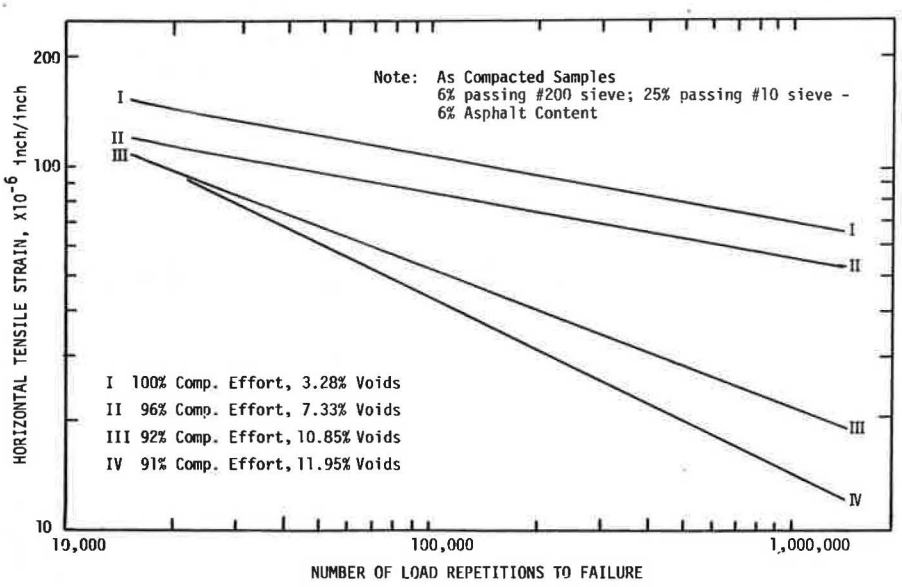

Table 3. Estimated reduction in pavement life and associated pay factors based on fatigue criteria and varying mix densities.

		Strain Level			
		Heavy-Duty		Primary	
Compaction (%)	Mix Bulk Specific Gravity	50 με (000 000s)	Pay Factor (%)	100 με (000 000s)	Pay Factor (%)
96	2.31	1.62	1.00	0.0406	1.00
100	2.41	6.44	3.98	0.148	3.65
92	2.22	1.04	0.64	0.0182	0.45
91	2.19	0.0788	0.05	0.013	0.32

in the value of this report and is also an indication of the intense interest in this aspect of the construction process.

The data from the questionnaires were summarized, and the analysis of the results indicates the following:

1. Most state agencies (91 percent) will accept one or more properties in the construction and materials of asphalt concrete pavement that are outside of specification tolerances.
2. The specific properties that are accepted outside of specification tolerances by a large majority of agencies, generally with a pay adjustment, are compaction asphalt content, asphalt properties, and mix gradation. Pavement thickness and smoothness are additional properties accepted outside of specification tolerances by approximately half of the agencies.
3. Most of the agencies that accept construction and materials outside of specification tolerances apply a pay adjustment in reducing the compensation to the contractor. It is significant that the current philosophy is to penalize the contractor for properties that are below specification. A few agencies are considering the provision of a bonus for properties that are found to be above specification and provide increased pavement serviceability or life. Illinois appears to be the only state agency that currently provides a bonus for high quality and uniform work.
4. The background most relied on for establishing pay factors is experience.
5. Only 26 percent of the agencies consider their pay factors to be proportional to reduced pavement serviceability. Other widely used rationales for pay factors are to discourage noncompliance by application of the penalty and to comply with the recommendations of FHWA.
6. Approximately half of the agencies consider the use of pay-factor plans to be effective in encouraging compliance with specifications. The remaining agencies either will not use specified pay factors or do not believe the plans currently available are sufficient.
7. There is a wide disparity in the pay-adjustment factors currently used by the different state agencies. Several approaches are used to determine pay factors for each material property evaluated. In addition, agencies that use the same approach have widely varying values for the pay factor applied to a common level of material quality.

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Texturing of Cement Concrete Pavements by Chip Sprinkling the Fresh Concrete

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One of the research projects on slipperiness being conducted by the Centre de Recherches Routières in Belgium concerns the chip sprinkling of cement concrete pavements. Of all the surface treatments for fresh concrete, this technique is the only one that permits the use of polishable aggregates in the bulk of the concrete without prejudicing skid resistance. This is an obvious economic advantage in regions that do not have sufficient reserves of materials with a high resistance to polishing. The large-scale application of the procedure has required the construction of a chip-sprinkling machine, which is now operational for works carried out with both fixed and slip forms. Between 1974 and 1980, a number of large works have been completed in Belgium and France. Guidelines for optimal execution have been published that deal with the laying of the concrete and the chip sprinkling. Existing experimental roads have demonstrated the effectiveness and durability of the technique. The degree of skid resistance is related to the quality of the chipping stones used. The surface rolling noise is less annoying than the noise produced by transverse grooved concrete and is comparable to the rolling noise of other types of skid-resisting pavements that have a random surface texture.

For several years, a major effort has been under way in various countries to improve the skid-resisting properties of pavements. Up to now, research has shown that high skid resistance on wet road surfaces is linked to the following factors (1): (a) a coarse macrotexture, obtained by applying a suitable surface treatment, and (b) a harsh microtexture, obtained by excluding polishable aggregate from the surface of the pavement.

The most widespread surface treatment used today for cement concrete pavements is the deep transverse grooving of the fresh concrete. This treatment has evolved tremendously during the past 15 years or so, both in Europe (2,3) and, more recently, in the United States (4). The application of this technique gives excellent results with regard to skid resistance and ensures effective transverse draining of the road. Nevertheless, the simple and inexpensive technique is sometimes criticized for the in-