QUALITY CONTROL ANALYSIS
PART V

Review of Data Generated by Statistical Specifications on Asphaltic Concrete

Final Report

by

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and

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Research Report No. 94
Research Project No. 63-1G
Louisiana HPR 1(12)

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research and Development Section
In Cooperation with
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

December 1975

ACKNOWLEDGEMENTS

The author wishes to acknowledge the cooperation of the various districts for providing project data. Special thanks are due to Messrs. Jada Hirschmann and Ronnie Henderson for preparation of data for computer processing.

IMPLEMENTATION

The asphaltic concrete data reported here represent those generated during the period of implementation of statistical oriented end-result type specifications from 1971 through the early part of 1975. The findings reported here are anticipated to aid in the revising and/or updating of these end-result type specifications as may be deemed necessary. Such evaluation is expected to be continued for an additional period after revisions, if any, are incorporated.

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1. INTRODUCTION

The Louisiana Department of Highways has been actively engaged in the development and application of statistically oriented end-result type specifications since the early 1960's. The initial effort of this quality assurance program was directed towards analysis and evaluation of data for variability determination (1, 2, 3)*. The findings from this initial effort led to the development of special provisions for asphaltic concrete and Portland Cement Concrete. The asphaltic concrete special provisions were simulated in the field before their inclusion as standard specifications in 1971 (4). These specifications are included in Appendix A and are discussed briefly in the next section.

Since the inception of these statistically oriented end result specifications, the Department has contracted projects involving approximately four million tons of hot mix. A portion of the data generated by this quantity of hot mix was collected for analysis and evaluation. This report attempts to discuss some of the findings obtained from the analysis of data representing approximately 1.3 million tons of hot mix.

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* Underlined numbers in parentheses refer to list of references.

2. MAJOR FEATURES OF STATISTICAL SPECIFICATIONS FOR ASPHALTIC CONCRETE

One of the important features of the new system of specifications (Appendix A) is the clear definition of the responsibilities of the Department and the Contractor. These responsibilities are listed in Table 2.1. What was previously considered or assumed in the conventional specifications as the responsibility of the Department or the Agency has been clearly delegated to the Contractor. Likewise, the acceptance phase of the responsibility rests on the Agency.

Another important feature of these specifications is the definition of various criteria for control and acceptance of the product. Table 2.2 is a summary of the sampling plan for control and acceptance of asphaltic concrete. The advantage of this feature is that it provides adequate information for making equitable decisions between the Contractor and the Department.

TABLE 2.1

DELEGATION OF RESPONSIBILITY FOR CONTROL & ACCEPTANCE OF ASPHALTIC CONCRETE

CONTROL SAMPLING & TESTING FOR:	DELEGATED TO:
MIX DESIGN	CONTRACTOR
JOB-MIX FORMULA	CONTRACTOR
JOB-MIX APPROVAL	DEPARTMENT
HAVE CERTIFIED TECHNICIAN	CONTRACTOR & DEPT.
PLANT OPERATION	CONTRACTOR
CONTROL CHARTS	CONTRACTOR
ACCEPTANCE SAMPLING & TESTING FOR:	
STABILITY	DEPARTMENT
PAVEMENT SAMPLING	CONTRACTOR
PAVEMENT TESTING	DEPARTMENT
SMOOTHNESS	DEPARTMENT

The third, and probably the most critical, feature of such statistical specifications is the inclusion of provisions for adjustment of contract unit price for a product that fails to meet the stated requirements for 100 percent pay. Schedules 1, 2 and 3 of the specifications in Appendix A list the various adjustments of payment for nonconforming quality characteristics. The advantage of this feature, with respect to the legal ramifications, can not be overemphasized.

All in all, the statistical sampling plan, as used in Louisiana for control and acceptance of asphaltic concrete, has replaced the old acceptance plan, which was predominantly based on the arbitrary principle of substantial conformance and judgment.

TABLE 2.2

SAMPLING PLAN FOR CONTROL & ACCEPTANCE OF ASPHALTIC CONCRETE

REQUIREMENTS FOR	LOT SIZE	SAMPLE SIZE	FREQUENCY	BASIS OF RANDOMNESS
CONTROL :				
BITUMEN CONTENT & GRADATION	DAY'S PRODUCTION	2	ONE IN AM ONE IN PM	TIME
TEMPERATURE	DAY'S PRODUCTION	10	FIVE IN AM FIVE IN PM	NONE
ACCEPTANCE :				
STABILITY	DAY'S PRODUCTION	4*	TWO IN AM TWO IN PM	TIME
ROADWAY COMPACTION	DAY'S PRODUCTION	5	ONE FROM EACH OF FIVE EQUALLY DIVIDED SEGMENTS	PAVEMENT SURFACE AREA
SURFACE TOLERANCE	DAY'S PRODUCTION	1000 FT	FIVE 200 FT SECTIONS	TRANSVERSE DISTANCE

1 FOOT = 0.3048 M

* REDUCTION IN SAMPLE SIZE ALLOWED IF THE PLANT DOES NOT OPERATE THE FULL DAY

3. OBJECTIVES

The primary objective of this study was to review the data generated by projects governed by statistically oriented system of specifications for the control and acceptance of asphaltic concrete and to recommend any revisions that may be deemed necessary. Specifically, the major objectives can be listed according to their order of importance:

1. Determine the effect of the new system on the final adjusted bid price and isolate the acceptance criteria contributing the most to the overall reduction in this bid price.
2. Determine the variability of the product with respect to various quality characteristics and compare this variability of the data with those from which the statistical limits were developed.
3. Compare the performance characteristics of the end product obtained from the conventional specifications with the new system of specifications.
4. Make an overall assessment of these statistically oriented end-result specifications through questionnaire response from construction engineers.
5. Make recommendations on the basis of the above findings.

4. DATA COLLECTION AND ANALYSIS

Data Collection

In order to accomplish the stated objectives, data from 85 projects were collected from all over the State over a period of four years. The selection of these projects was on a random basis. As was mentioned before, these projects represent only a portion of the total contracts let during the four-year period. All projects were identified in coded form beginning with A01 for the first project and ending with A85 for the last one. Four projects were deleted from the analysis because the data represented shoulder mixes or other miscellaneous purpose mixes. The remaining 81 projects cover all types of major mixes, except Type 4, Expanced Clay, as defined in Subsection 502.01 of the Standard Specifications. A breakdown of the tonnage for the various mixes is shown in Table 4.1. The mix codes 1 through 8 represent mix types as defined in the specifications. All mixes, except mix codes 3 and 4, represent sand-gravel-filler mixes. Mix codes 3 and 4 represent shell-sand-filler mixes. The binder in all cases was 60-70 penetration grade asphalt cement.

TABLE 4.1

MIX TYPES & CORRESPONDING TONNAGE

MIX CODE	MIX TYPE	TONNAGE
1	1 WEARING	692148
2	1 BINDER	29270
3	2 WEARING	72502
4	2 BINDER	67654
5	3 WEARING	111237
6	3 BINDER	62422
7	5A BASE	32348
8	5B BASE	286141
TOTAL		1353722

For performance evaluation, objective 3, three pairs of projects were selected, each pair consisting of one project from conventional system and one from the end-result system of specifications. The three end-result projects were independent of the 81 projects discussed above. Each pair of projects had basically similar characteristics with respect to traffic and section type and thickness immediately underneath the asphaltic concrete overlay. Performance criteria were evaluated by means of the Mays Ridemeter, longitudinal rutting in wheel paths, and visual surface evaluation.

Data Analysis

The data collected on the above projects were punched on cards and stored on magnetic tape. This provided easy manipulation of data for subsequent analysis and tabulation. Wherever applicable, standard statistical procedure were used in the analysis. The entire analysis and tabulation was performed using the Statistical Analysis System (SAS) package (5). In the succeeding sections the results of the various analyses are discussed according to the order in which the objectives were listed in the preceding section. The crux of the evaluation, however, is contained in the next section.

5. ASSESSMENT OF PENALTIES*

Effect of End-Result Specifications on Final Payment

Table 5.1 is a summary of data showing final adjusted payment for each project. The table shows, for each project, the total tons, the number of lots tested, the corresponding number of lots penalized, the tons penalized at 50 percent, 80 percent and 95 percent pay as defined in the Standard Specifications. The last column represents the average percent payment for each project. Thus, for Project A14, 20 lots were involved representing a total of 12,086 tons. Of the 20 lots, four lots were penalized for deficiency in the quality characteristics. The tonnage involved was 1172 at 80 percent pay and 1295 tons at 95 percent pay. The overall payment the Contractor received was 97.52 percent of his bid price, or a loss of 2.48 oercent.

The data presented in this table were extracted from Appendix Table B1. This table represents the detailed output of all projects lots that had penalties. The table also provides information concerning the acceptance criteria that governed the final pay adjustment. Once again, for Project A14 two of the four lots were penalized at 80 percent, and two at 95 percent pay. Table 5.1 shows only the total tonnage for each adjustment.

It should be mentioned that of the total lots penalized, 24 lots, although deficient in either stability or compaction, were paid 100 percent because they represented the first two days of operation. The standard specifications make allowances for such adjustment period.

Table 5.2 is a frequency distribution of the final pay shown in Table 5.1. Forty-five percent of projects had 100 percent pay. The large reduction in pay, indicated by some of the projects, may be due to the small quantity of hot mix involved on these projects. Furthermore, it should be noted that regardless of the volume of hot mix involved, all it takes is one maverick lot to shift the final pay per project out of the 100 percent interval into the lower one. It

*Throughout the report, the terms penalty, penalized, etc. are used without any legal implication to denote reduction in pay for deficient or non conforming product.

TABLE 5.1

AVERAGE PERCENT PAY FOR PROJECTS WITH END-RESULT SPECIFICATIONS

PROJ	TONS	NLOT	LOTP	TP50	TP80	TP95	PPPP
A01	3505	7	0	0	0	0	100.00
A02	9680	15	1	0	0	525	99.73
A03	8008	11	0	0	0	0	100.00
A04	8302	8	0	0	0	0	100.00
A05	13268	23	0	0	0	0	100.00
A06	20430	30	2	0	0	1711	99.58
A07	25864	31	2	0	2173	0	98.32
A08	7204	19	2	223	0	384	98.19
A09	14520	45	0	0	0	0	100.00
A10	53802	94	0	0	0	0	100.00
A11	13057	21	0	0	0	0	100.00
A12	1402	5	0	0	0	0	100.00
A13	1423	4	0	0	0	0	100.00
A14	12086	20	4	0	1172	1295	97.52
A15	2934	7	0	0	0	0	100.00
A16	1575	4	0	0	0	0	100.00
A17	7014	15	0	0	0	0	100.00
A18	6637	14	0	0	0	0	100.00
A19	15667	23	2	0	0	1232	99.61
A20	4272	6	3	0	851	1414	94.36
A21	10917	23	12	1163	572	4505	91.56
A22	8170	25	4	0	1506	405	96.07
A23	5101	11	1	0	0	574	99.44
A24	35198	31	0	0	0	0	100.00
A25	2213	5	0	0	0	0	100.00
A26	9563	12	0	0	0	0	100.00
A27	1539	4	0	0	0	0	100.00
A28	8487	12	0	0	0	0	100.00
A29	3649	10	4	0	418	1242	96.01
A30	47097	29	3	0	0	3709	99.61
A31	32707	38	3	0	0	3169	99.52
A32	43572	43	10	0	9251	1935	95.53
A34	3283	6	2	0	1002	0	93.90
A35	4865	8	5	407	1367	1232	88.93
A36	3894	6	0	0	0	0	100.00
A37	878	4	0	0	0	0	100.00
A38	4341	6	3	0	840	1440	94.47
A39	11802	14	0	0	0	0	100.00
A40	9021	18	0	0	0	0	100.00
A41	1605	3	0	0	0	0	100.00
A42	59076	63	10	0	512	5924	99.33
A43	4925	7	2	0	0	602	99.39
A45	6662	16	2	0	710	0	97.87
A46	22328	28	3	0	0	2666	99.40
A47	2498	3	0	0	0	0	100.00
A48	2401	4	0	0	0	0	100.00
A49	19840	36	8	0	524	3968	98.47
A50	20807	43	0	0	0	0	100.00
A51	6988	15	6	0	482	2192	97.05
A52	26796	35	2	0	1375	1317	98.73
A54	48172	41	13	0	4557	9502	97.12
A55	6057	9	0	0	0	0	100.00
A57	5156	9	6	0	448	3204	95.16
A58	17425	26	7	0	0	2940	99.16
A59	7122	18	1	0	585	0	98.36

NOTE: NLOT = NO. OF LOTS
LOTP = LOTS PENALIZED
TP50 = TONS PENALIZED AT 50% PAY
TP80 = TONS PENALIZED AT 80% PAY
TP95 = TONS PENALIZED AT 95% PAY
PPPP = PERCENT PAY PER PROJECT
1 TON = 0.91 METRIC TON

TABLE 5.1 (CONTINUED)

AVERAGE PERCENT PAY FOR PROJECTS WITH END-RESULT SPECIFICATIONS

PROJ	TONS	NLOT	LOTP	TP50	TP80	TP95	PPPP
A60	20267	31	2	0	0	245	99.94
A61	21471	44	10	0	345	2480	99.10
A62	23894	49	10	0	2023	4034	97.46
A63	144631	89	0	0	0	0	100.00
A64	113172	91	7	0	2787	2341	99.40
A65	9174	20	0	0	0	0	100.00
A66	16867	25	0	0	0	0	100.00
A67	18739	33	2	0	0	575	99.85
A68	34794	35	0	0	0	0	100.00
A69	32168	39	0	0	0	0	100.00
A70	14187	16	1	0	0	885	99.69
A71	18056	25	4	955	1255	680	95.78
A72	8743	17	12	1025	2807	1872	86.65
A73	25206	32	2	0	1077	367	99.07
A74	11497	17	1	0	120	0	99.79
A75	10174	17	1	0	721	0	98.58
A76	6607	11	7	1135	2011	1516	84.18
A77	6876	15	1	0	189	0	99.45
A78	11311	9	1	0	0	768	99.66
A79	11865	15	0	0	0	0	100.00
A80	6904	10	0	0	0	0	100.00
A81	9782	9	0	0	0	0	100.00
A82	8684	7	1	0	920	0	97.88
A83	15838	15	0	0	0	0	100.00
A84	8149	7	0	0	0	0	100.00
A85	7841	10	5	0	3622	0	90.76
TOTAL	1353722	1751	190	4908	46222	72850	

TABLE 5.2

FREQUENCY TABLE FOR FINAL PAY

PPPP	FREQUENCY	PERCENT
90	4	4.938
91	1	1.235
93	1	1.235
94	2	2.469
95	3	3.704
96	2	2.469
97	6	7.407
98	6	7.407
99	19	23.457
100	37	45.679
TOTALS	81	100.000

NOTE: PPPP = 90 MEANS PERCENT PAY PER PROJECT IS 0-90.99,
PPPP = 91 MEANS PERCENT PAY PER PROJECT IS 91-91.99,
ETC.

was also revealing that most of the contractors engaged in large volume hot mix operation had little difficulty meeting the stated requirements.

In order to determine the distribution of penalties with respect to the acceptance characteristics, Table 5.3 was prepared. This summary was prepared from Appendix Tables B2, B3, and B4, which represent a comprehensive breakdown of penalties according to each of the acceptance criteria. Table 5.3 summarizes the contribution of each of the quality characteristics to the final adjustment on the basis of total tonnage and tonnage penalized. It is readily obvious that most of the penalties occurred at 95 percent pay and that roadway compaction is the major source of deficiency contributing to the reduction in pay. The low percentage of deficiency due to Marshall Stability could be related to the guideline values provided in the specifications for design of various mixes. These guidelines presuppose the risk involved if the mixes are not designed and maintained at the indicated stability values (see Table 1 in Appendix A). What happens if the process is not maintained at the specified level is discussed towards the end of this section.

TABLE 5.3

DISTRIBUTION OF PENALTIES ACCORDING TO ACCEPTANCE CRITERIA

BASED ON	PENALTY @	DISTRIBUTION, % ACCEPTANCE CRITERIA STAB	COMP	SURF TOL	TOTAL
TOTAL TONS (1353722)	50	0	.12	.24	.36
	80	.25	1.86	1.31	3.42
	95	.38	3.72	1.28	5.38
	TOTAL	.63	5.70	2.83	9.16
TONS PENALIZED (123930)	50	0	1.27	2.69	3.96
	80	2.77	20.25	14.26	37.28
	95	4.18	40.58	14.00	58.76
	TOTAL	6.95	62.10	30.95	100.00

Table 5.4 shows a similar distribution of penalties according to mix type and acceptance criteria. Thus, 6.2 percent of mix 5 was deficient in stability. Similarly, 9.9 percent of mix 3 had surface smoothness deficiency. Tables 5.3 and 5.4 completely define the distribution of penalties with respect to all possible categories and represent the crux of the entire evaluation.

TABLE 5.4

PERCENT DISTRIBUTION OF PENALTIES FOR ACCEPTANCE CRITERIA

MIX	MARSHALL STABILITY	ROADWAY COMPACTION	SURFACE TOLERANCE	TOTAL
1	0.1	5.6	3.6	9.3
2	0	11.7	---	11.7
3	0	3.9	9.9	13.8
4	0	3.9	---	3.9
5	6.2	8.5	5.4	20.1
6	0	20.4	---	20.4
7	2.3	7.6	---	9.9
8	0	1.3	---	1.3

Review of data in Table B1 indicated that: of the total number of lots penalized, none of the lots had penalties due to deficiency in all three acceptance requirements; and only six lots had penalties due to deficiency on two criteria. For three of these lots, the penalty had occurred at different levels and consequently, the Contractor was paid the lower of the two levels.

The above discussion can be summed up in the following statements.

1. On the basis of total tonnage, an average reduction in pay of approximately 1.5 percent of the contract price can be expected. Furthermore, less than 50 percent of the projects may have 100 percent payment (Tables 5.1 and 5.2).

2. Less than one percent of the total mix was penalized at the 50 percent or remove penalty. 3.4 percent of the mix was involved at the 80 percent penalty scale and 5.4 percent at the 95 percent scale (Table 5.3).

3. Sixty-two percent of the mix penalized was due to deficiency in roadway compaction, and two thirds of this deficiency occurred at 95 percent pay (Table 5.3).

4. More than 50 percent of the surface tolerance deficiency had occurred on shell mixes (Table 5.4).

5. Ninety-seven percent of the penalty was due to single item deficiency. There were no lots with deficiencies in all three acceptance characteristics.

Relationships Between Specifications and Statistical Parameters

In order to minimize his penalty risks due to deficiency on any of the acceptance criteria, the Contractor should maintain his process at the specified mean level and concurrently attempt to reduce his variability. The present specifications clearly define the level of stability values at which he should maintain his process and further clarify the risk involved for failure to maintain the process level at the specified values. (See Subsection 501.02 (c), paragraph 4 in Appendix.) What happens if this is not adhered to is illustrated theoretically in Figure 5.1.

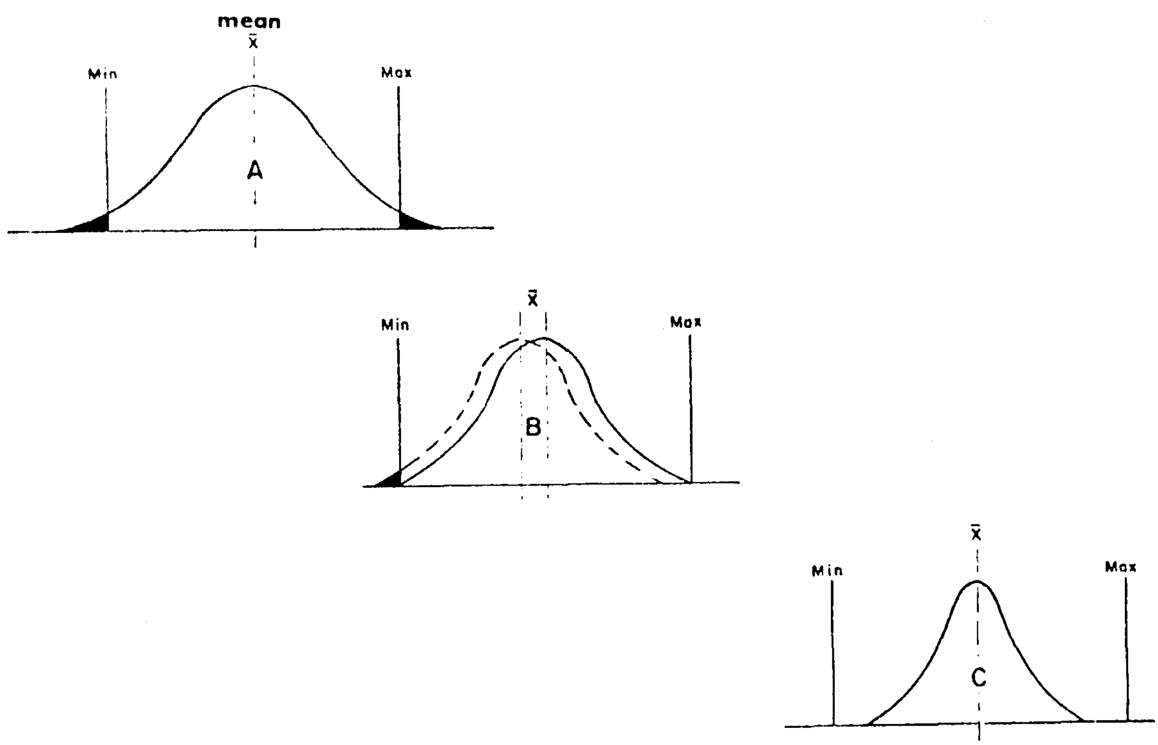

Figure 5.1: Some Distributional Aspects of Specifications

Curve A symbolizes a relationship between specification tolerance limits and statistical parameters (mean and standard deviation) using an idealized normal distribution curve. This stuation is untenable, and the contractor has to reduce the magnitude of variation or sacrifice a percentage of his product, as shown by the shaded portion of the curve.

Curve B shows a situation where the curve just clears the inside limits. Although this might seem perfect at first, there is no allowance for operating tolerance. The dotted curve shows how the measurements would fall outside the limits with only a slight shift in the mean.

The most comfortable situtation is illustrated in Curve C, where some leeway for sampling, testing, or material variation is allowed. Under this condition adequate conformance with specification tolerance can be expected.

The preceding idealized illustration can be applied to explain the occurrence of some of the penalities that were discussed in the preceding section for stability and roadway compaction. Table 5.5 shows the mean and standard deviation for projects that had penalties due to stability deficiencies (Table B1). The data in the table clearly indicate the reason for such penalties. In all cases, the Contractor failed to maintain his process at the specified level for the respective mixes. In fact, his process level was too close to the minimum requirement. This, coupled with the large process standard deviations, increased the probability of defective lots. Overall, the process control on these projects was poorly maintained, as is evident from the standard deviations. These values are for averages (n=4) and not individuals. In order to minimize the penalty risk, the Contractor must necessarily maintain his level at the values specified in Table I of Appendix A and also his variability at or around 125 lbs. (5564 N).

TABLE 5.5

STATISTICS FOR PROJECTS PENALIZED FOR STABILITY DEFICIENCY

PROJECT ID	MIX	SUBGROUP N=4	MEAN, LB	STD DEV, LB	
A07	5	6	1662	175	
A29	7	1	1176		
A54	5	14	1742	78	
A58	5	18	1850	149	
A61	5	4	1751	308	
A61	5	6*	1720	285	* N=3
A82	1	6	1380	214	

1 LB = 4.448 N

Similar reasoning can be applied to the compaction penalty of Table B2. The corresponding statistical paremeters for the penalized lots are indicated in Table 5.6. The Contractor must maintain this phase of the process at at least a 97 percent level with variability at or around 0.7 percent. Any increase in process variability must be balanced by shifting the mean to a higher level. Lack of adequate control on these two parameters will increase the risk of rejection, as is evident from the data in Table 5.6. In almost all instances, the project mean was too close to the minimum tolerance for 100 percent pay. Likewise, the variability was also considerably large. The combination of these levels ultimately resulted in 5.7 percent of the mix failing to meet the requirement for 100 percent pay. (Table 5.3)

TABLE 5.6

STATISTICS FOR PROJECTS PENALIZED FOR COMPACTION DEFICIENCY

PROJECT ID	MIX	SUBGROUP N=5	MEAN, %	STD DEV, %
A02	4	9	92.8	1.88
A06	1	30	96.3	.82
A14	7	20	95.4	.84
A19	3	22	93.6	1.38
A21	3	11	92.6	2.12
A21	4	12	92.4	1.23
A29	5	3	93.6	.78
A30	8	29	96.0	.86
A31	1	38	96.3	.78
A32	1	41	95.6	1.22
A34	1	6	94.2	1.27
A42	1	63	95.8	.97
A43	1	6	95.6	.74
A46	1	27	96.4	.87
A49	1	35	96.0	1.36
A51	1	8	94.5	.95
A51	2	7	94.4	.32
A52	2	12	95.7	1.10
A54	5	16	95.1	.72
A54	6	24	95.2	.71
A58	5	26	96.3	.98
A59	1	18	95.8	.97
A60	2	13	96.3	.62
A61	5	31	96.2	1.15
A62	5	14	96.4	.91
A62	6	24	96.9	.91
A64	1	19	95.8	.61
A67	1	22	96.1	.65
A70	1	15	95.9	.65
A71	1	25	96.0	1.64
A72	1	17	95.7	.92
A73	1	31	96.5	1.10
A74	5	15	96.4	.94
A75	5	17	96.8	.87
A78	1	9	96.1	.80
A85	1	10	95.5	.46

Effect of the New System on the Contract Bid Price

Before implementation of the new system of specifications, it was anticipated that the Contractor's bid price would be buffered by an amount proportional to the risk of rejection of his product and the cost of monitoring the production phase of the contract. In order to determine if these added factors have had any effect on the overall bid price of asphaltic concrete, quarterly bid price data were plotted from 1970 through the first quarter of 1975. Figure 5.2 is a plot of such data. The various symbols represent the types of mixes.

The graph does not indicate any sudden upshot in bid price during the initial period of implementation. In order to confirm this trend, data on other items were plotted for the same time span. These items were picked randomly from data files. Figure 5.3 is a plot for coarse aggregate and Figure 5.4, for reinforcing steel. Both plots indicate a trend similar to Figure 5.2. One possible reason for almost horizontal trend in bid prices from 1971 to 1974 is the wage-price control legislation. The sudden upshot after 1974 could be associated to the lifting of the wage-price control. The fact that the Contractor has to employ the services of private testing laboratories for the design and control of mixes can not be overlooked. Such costs amount to approximately \$150 to \$200 per day. This, according to Contractors, is negligible compared to their daily returns. On the other hand, there is a built in cost for product that may be subject to unforeseen penalty. However, this varies from Contractor to Contractor and is dependent upon his past project's economic returns. Therefore, any discernible trend indicated in the plots should be viewed in light of the factors generally associated with the normal inflationary trend in wage-price system rather than the factors mentioned above.

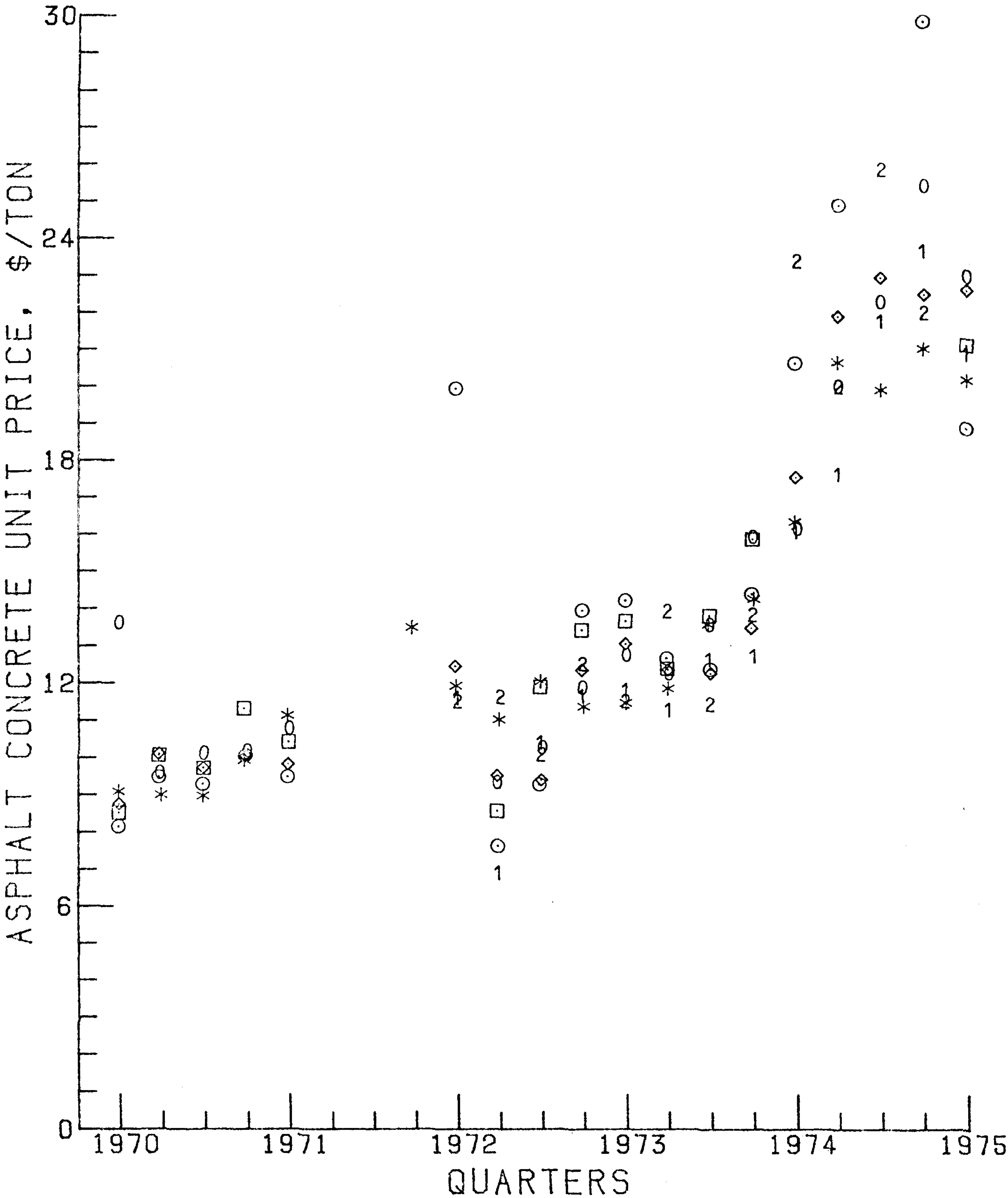

Figure 5.2: Quarterly Bid Price for Asphaltic Concrete

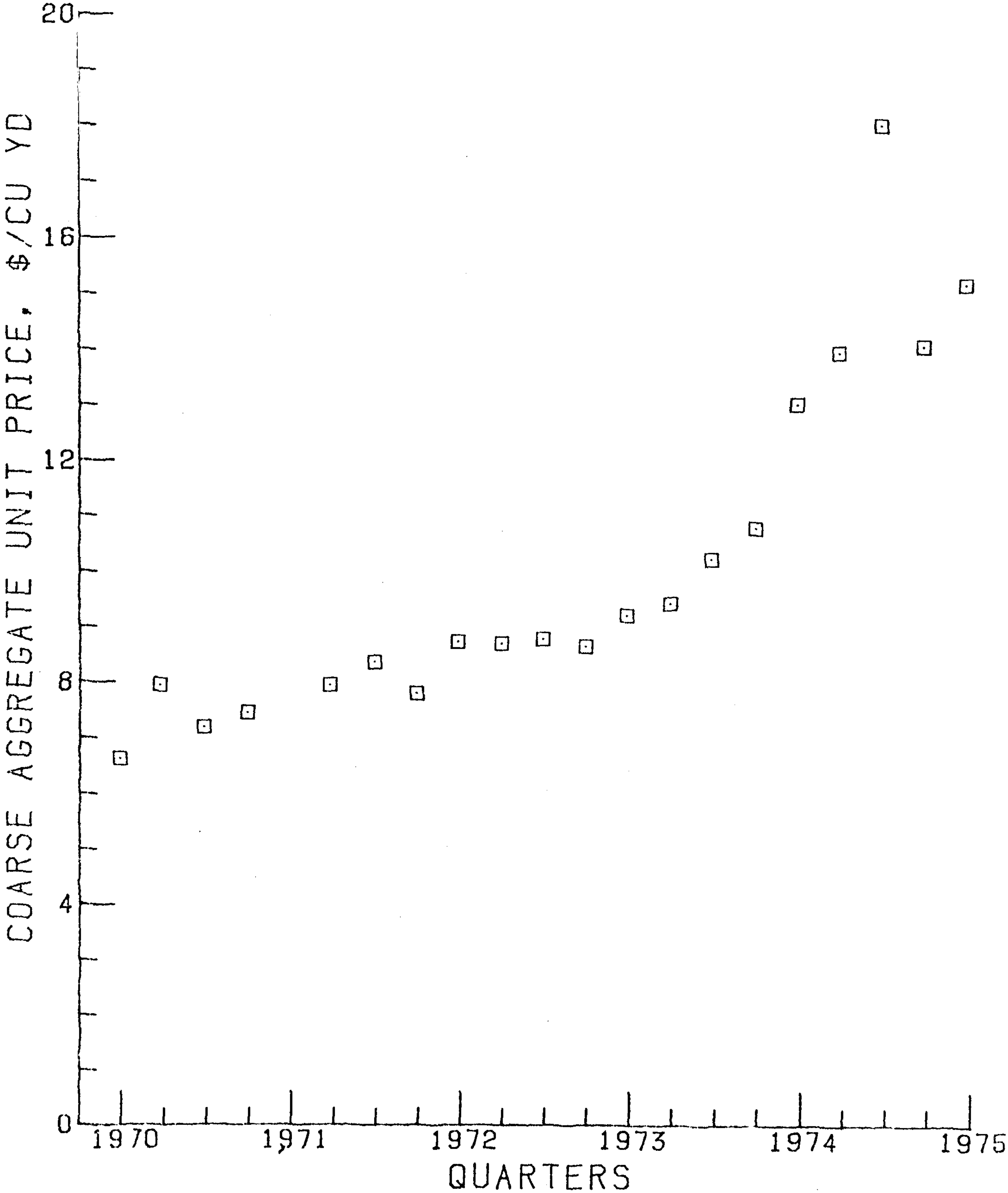

Figure 5.3: Quarterly Bid Price for Coarse Aggregate

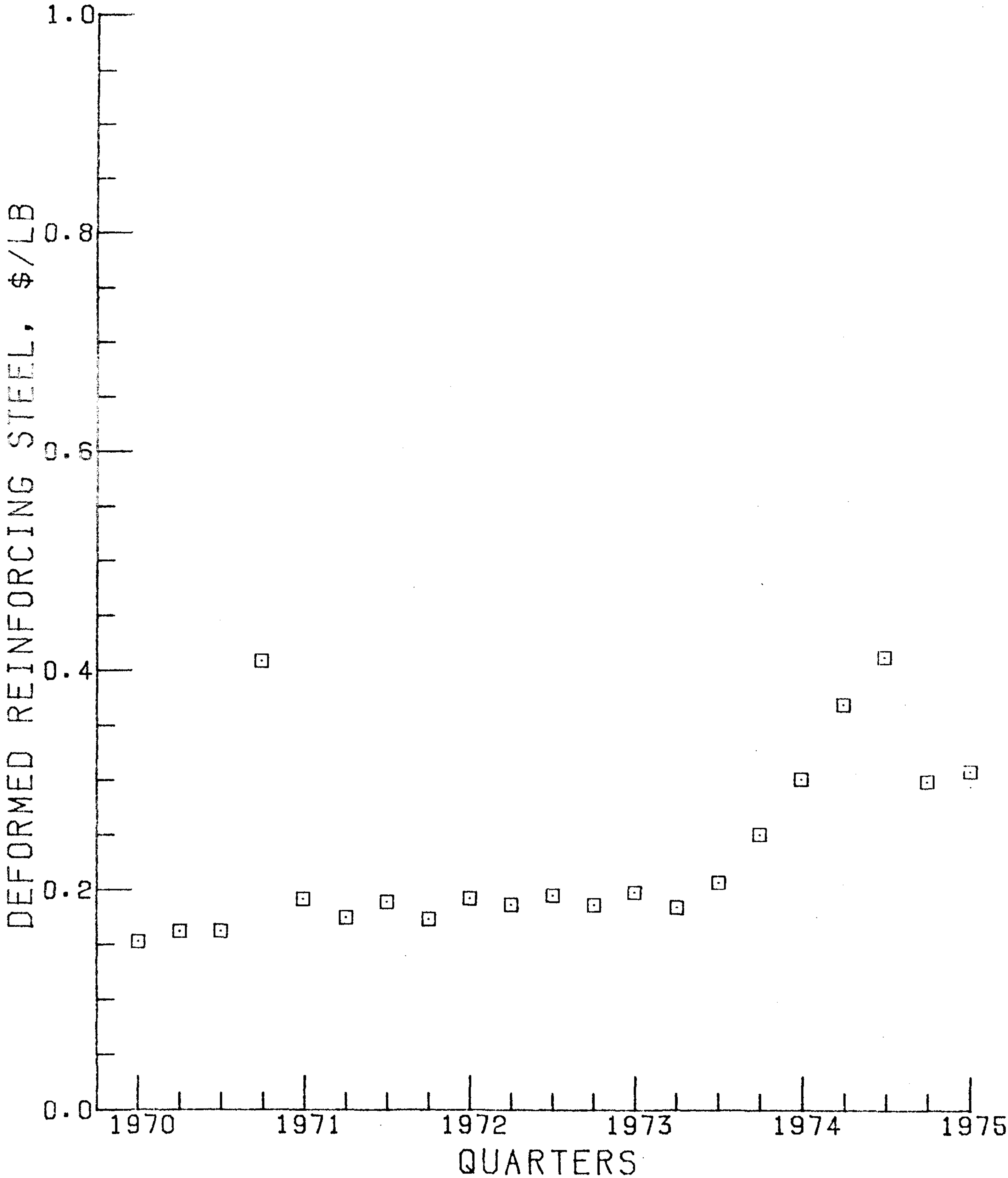

Figure 5.4: Quarterly Bid Price for Reinforcing Steel

6. VARIABILITY OF DATA

Frequency Distribution

This section attempts to discuss the variability of data in various formats. Figure 6.1 through 6.7 represent one such format in graphical form. These figures represent histograms or frequency distribution of data grouped according to their specification tolerance limits. Thus, Figure 6.1 is a histogram for Marshall Stability for mixes 1, 2, and 7. All these mixes have 1200 lb. (5338 N) stability requirement. Mixes 3 and 4 however, were, treated separately because of the type of aggregate (shell) used in these mixes. Likewise, for compaction, data for all mixes except 3 and 4 were grouped together for analysis because of similar requirements.

The histograms indicate the close approximation of data to Gaussian or Normal Distribution. Furthermore, the width of the distribution indicates the relative magnitude of variation within each group of data. Mixes 3 and 4 indicate the largest magnitude of this variation, and mix 7 the least. Similarly, this variability for roadway compaction is also quite pronounced for mixes 3 and 4.

Variability in Stability and Roadway Compaction

The magnitude of variation in stability for each project is presented in Table 6.1. This table presents variability expressed as the range or the difference between maximum and minimum values. The table provides variability information relative to Within Lot or Within Day, Between Lots or Between Days, and between any two individual determinations. The mean and standard deviation values (for n=1) are also provided for each project according to mix types. The distribution of these parameters is shown in Table 6.2. Of interest here are the low and high values for each of the sources of variation. Thus, for mixes 3 and 4, the range of values for Within Lot source varies from a low of 297 lbs. (1321 N) to a high of 1597 lbs. (7104 N). These low and high values for Between Lots source are 214 lbs. (952 N) and 2251 lbs. (10013 N), respectively. Tables 6.3 and 6.4 provide similar information for roadway compaction.

The data in Tables 6.1 and 6.2 indicate the lack in uniformity of the product for all mixes in general and mixes 3 and 4 in particular. In a number of instances, the extent of variation in a given day (Within Lot) was greater than three standard deviations of the process. The significance of this statement has some bearing on the definition of the term Lot. Simply stated, a lot is considered to be a homogeneous segment of construction or production process. The variability of data indicated by Within Lot source is too large to have occurred due to chance and makes the homogeneity of the product questionable.

In order to verify the contention that a longer duration of plant operation provides a more uniform product, Figure 6.8 was prepared from data in Table 6.1. Mixes 3 and 4 were not included in this plot because of the large magnitude of variation reflected by these mixes. The plot assumes the variability generally associated with sampling and testing to remain constant. The data presented in the figure, however, does not verify or refute the association of uniformity with duration of operation.

Comparison of Variability Between Conventional and Statistical Specifications

Before inception of the new system of specifications, it was anticipated that the past product uniformity could be maintained or improved. However, the data does not bear this out with respect to the production process as discussed above. On the other hand, there seems to be an improvement in the overall level of uniformity in the compaction phase of construction. This inference is reinforced by data presented in Table 6.5 and Figure 6.9. The table shows pooled data on statistical parameters according to mix types. The figure shows comparison of variability of data generated by the conventional (old) and end-result (new) system of specifications. The data for conventional specification was extracted from reference 1. Furthermore, the comparison is for mix 1 only because of absence of data on other mixes for conventional specifications.

The data in the figure indicate the lack of quality control of production at the plant. This level is reflected all the way through the acceptance test for Marshall stability. However, it is necessary to evaluate this comparison in light of the source of the two sets of data. The variability of data presented for conventional specifications were generated from historical sources and such sources are normally considered questionable because of certain amount of bias built into it. Nevertheless, the variability indicated by the present data is surprising since, if anything, the level should have improved. The argument stems from the fact that equipment and production technology have improved considerably during the past decade to provide for better control. Furthermore, the problem of excessive variation may be compounded if there is a widespread adoption of the drier-drum concept of mixing operation. This is because the batch proportioning has to be accomplished at the cold feed and control at this stage may not be as easy to maintain as with the conventional bin proportioning.

One of the primary reasons for such lack in quality control could be traced to the contractor's failure to monitor his production process through the use of control charts. This inference is drawn after review of these control charts where definite trends for data moving towards the control limits and beyond were observed, and yet no effort was made to correct this trend. It is firmly believed that the purpose of these control charts is not being viewed in the light it was intended for, namely, as a tool for taking corrective action before the process goes outside the normal range of variation. Likewise, the Department personnel may have been slackening in their level of inspection for this phase, particularly if the new system has been construed to mean freedom from obligation of the legal authority or responsibility to take corrective action whenever results fall outside the specified job mix control limits. However, it could be argued that the Department should be primarily concerned with the quality of the end product, and therefore, such occurrences in quality control inspection may not be caused for alarm, since there was no evidence of inferior end product as a result of nonuniformity in plant production. This may very well be true, since the compaction phase of the acceptance procedure seems to indicate adquate level of uniformity. However, because of lack of comparative data, the level of quality of the riding surface, as is evaluated by present smoothness criteria, is undetermined.

Variability of Data with Time

In order to evaluate the level of control maintained during each time interval, data were grouped according to the year the projects were constructed. This evaluation is based on the assumption that caution and tigher controls generally prevail during the initial period of evaluation of any new system and that one tends to relax his level of control as familiarity is gained with the system. Table 6.6 shows the yearly evaluation of all data generated by these projects during construction. There does not seem to be any well defined trend of nonuniformity in product with the time interval studied. Any discernible trend on individual items should be judged to have occurred due to random causes.

Individual data were checked against their respective tolerances to determine the percentage of the product not meeting the stated requirements. Appendix Table B5 shows these percentages for extraction data. Standard specifications for aggregate gradation were used to determine these percentages. Except for percent crushed material, no more than one percent was outside the master range for gradation. These percentages outside the respective job mixes were, however, in excess of five percent. Appendix Table B6 shows similar types of evaluation for stability and compaction. For these, the limiting values were those indicated for individuals in Table V of Appendix A.

In summary, then, the magnitude of variation indicated by various criteria during the production phase should be associated with the relaxed attitude towards the use of control charts for proper monitoring of production. Likewise the magnitude of variability indicated by the stability data may have occurred as a result of similar lack of control on job-mix formula.

TABLE 6.1

MAX DIFFERENCE WITHIN & BETWEEN LOTS FOR MARSHALL STABILITY

PROJ	MIX	NLOT	WLST	BLST	BSX1X2	NS	MSTAB	STDSTAB
A01	1	7	277	263	411	22	1662	111
A02	3	6	657	288	949	23	1572	241
A02	4	9	707	386	1032	31	1781	234
A03	3	5	482	214	634	18	1622	169
A03	4	7	297	310	497	24	1658	133
A04	3	8	903	474	976	26	1687	271
A05	1	23	948	997	1479	80	1793	335
A06	1	30	778	752	1253	113	1773	266
A07	1	5	765	372	917	17	1281	271
A07	3	21	1468	1401	1562	81	2301	468
A07	5	9	1286	655	1286	29	1704	305
A08	1	15	574	593	1102	40	1603	234
A08	7	4	709	358	868	15	1478	248
A09	1	46	791	1079	1565	137	1891	292
A10	4	94	1552	1409	2278	333	1981	404
A11	3	14	1286	576	1444	48	1782	322
A11	7	7	596	270	663	24	1686	175
A12	1	5	451	421	879	20	1439	220
A13	1	1	181		181	3	1372	94
A13	2	3	661	199	661	9	1616	204
A14	7	20	662	544	870	63	1734	199
A15	1	7	1166	697	1349	24	1782	339
A16	1	4	781	358	828	14	2231	286
A17	1	16	653	439	947	59	1631	213
A18	1	2	859	256	915	8	2260	311
A18	5	8	688	528	982	26	2015	247
A18	6	6	1082	368	1082	24	1759	265
A19	3	23	1570	2251	2864	73	2186	615
A20	1	7	617	454	877	23	1579	199
A21	3	11	589	646	996	32	2396	267
A21	4	12	774	811	1201	37	2306	288
A22	1	11	639	692	789	25	1487	192
A22	5	15	1084	805	1420	50	2590	303
A23	5	6	591	164	591	17	1831	154
A23	6	5	1073	447	1312	18	1783	324
A24	1	34	1159	545	1376	128	1607	221
A25	1	5	357	374	607	16	1534	188
A26	1	14	1011	604	1131	52	1863	260
A27	1	4	411	283	454	13	1894	165
A28	1	12	794	695	1313	39	1797	289
A29	1	2	280	151	374	6	1367	142
A29	5	3	499	606	737	8	2306	278
A29	7	5	335	252	510	12	1244	154
A30	8	29	1191	771	1521	101	1140	233
A31	1	38	437	761	1057	144	1719	220
A32	1	43	664	379	788	152	1758	129
A34	1	6	428	311	632	24	1542	152
A35	5	6	330	461	695	21	1770	193
A35	6	2	231	80	285	8	1772	93
A36	1	6	561	244	600	19	1663	181
A37	1	4	780	406	780	13	1691	254
A38	1	6	713	370	858	24	1755	222
A39	1	14	647	407	1060	48	1572	191
A40	1	18	714	751	1327	48	1736	268
A41	1	3	590	794	1046	11	1789	386

NOTE: WLST = WITHIN LOT FOR STABILITY, LBS
BLST = BETWEEN LOTS FOR STABILITY, LBS
BSX1X2 = BETWEEN STABILITIES X1 & X2
NS = NO. OF STABILITIES
MSTAB = MEAN MARSHALL STABILITY, LBS
STDSTAB= STANDARD DEVIATION FOR STABILITY, LBS

1 LB = 4.449 N

TABLE 6.1 (CONTINUED)

MAX DIFFERENCE WITHIN & BETWEEN LOTS FOR MARSHALL STABILITY

PROJ	MIX	NLOT	WLST	BLST	BSX1X2	NS	MSTAB	STDSTAB
A42	1	65	935	1038	1572	219	1743	271
A43	1	7	1028	413	1083	26	1770	317
A45	1	14	1366	387	1366	49	1576	238
A45	2	2	1366	83	1366	8	1618	463
A46	1	28	812	1024	1417	93	1566	244
A47	7	3	781	123	781	12	1566	245
A48	1	5	557	248	588	18	1481	161
A49	1	36	1110	816	1295	129	1713	277
A50	1	43	564	985	1187	141	1713	201
A51	1	8	386	202	483	31	1411	138
A51	2	7	513	434	687	27	1459	206
A52	1	10	1184	717	1617	33	1785	322
A52	2	13	929	409	1134	47	1821	254
A52	7	12	706	455	861	40	1413	203
A54	5	16	1171	270	1171	62	1749	243
A54	6	25	967	761	1478	96	1666	251
A55	5	4	554	303	841	12	1831	227
A55	6	5	556	368	651	15	1552	207
A57	1	9	742	243	742	35	1663	164
A58	5	26	440	465	1640	84	1845	300
A59	1	18	737	474	1055	56	1588	217
A60	1	11	846	666	1210	37	1729	278
A60	2	20	1169	1015	1497	72	2038	371
A61	1	3	1291	224	1291	10	1472	391
A61	5	31	1167	898	1380	89	1818	319
A61	6	10	1144	678	1326	28	1776	339
A62	5	14	665	579	873	56	1988	206
A62	6	36	1257	698	1257	91	1991	238
A63	8	89	1000	1183	1403	325	1276	241
A64	1	19	796	633	1045	66	1538	199
A64	8	72	708	768	1140	265	1294	159
A65	1	20	726	487	779	57	1762	178
A66	1	25	1396	616	1677	87	1796	305
A67	1	33	789	635	1040	107	1658	216
A68	1	35	635	496	893	129	1689	182
A69	1	39	906	534	1043	128	1546	220
A70	1	16	736	287	1004	61	1561	174
A71	1	25	777	786	1506	86	1663	264
A72	1	17	550	468	963	54	1541	161
A73	1	32	1047	575	1450	122	1536	242
A74	1	4	270	124	283	14	1511	90
A74	5	15	658	458	792	49	1996	196
A75	5	17	1023	653	1250	68	1938	290
A76	3	11	551	488	825	32	1985	198
A77	1	15	284	509	768	55	1400	192
A78	1	9	676	375	710	34	1775	187
A79	1	15	775	674	1071	55	1658	271
A80	1	10	1124	494	1124	36	1480	257
A81	5	9	1053	731	1652	33	2176	363
A82	1	7	1188	582	1154	25	1423	297
A83	1	15	913	612	1177	57	1935	289
A84	1	7	452	429	747	24	1643	214
A85	1	10	605	327	777	37	1349	155

TABLE 6.2

STANDARD STATISTICS FOR MAXIMUM DIFFERENCE TABLE FOR STABILITY

MIX 1,2,7

OBS_TYPE	WLST	BLST	BSX1X2	MSTAB	STDSTAB
N	72.00	71.00	72.00	72.00	72.00
MEAN	745.78	502.39	984.86	1645.81	231.46
STD	281.56	240.12	339.12	188.97	70.60
LOW	181.00	83.00	181.00	1244.00	90.00
HIGH	1396.00	1079.00	1677.00	2260.00	463.00
CV	37.75	47.79	34.43	11.48	30.50

MIX 3,4

OBS_TYPE	WLST	BLST	BSX1X2	MSTAB	STDSTAB
N	12.00	12.00	12.00	12.00	12.00
MEAN	903.00	771.17	1304.83	1938.08	300.83
STD	448.69	612.16	712.07	296.45	136.22
LOW	297.00	214.00	497.00	1572.00	133.00
HIGH	1570.00	2251.00	2864.00	2396.00	615.00
CV	49.69	79.38	54.57	15.30	45.28

MIX 5

OBS_TYPE	WLST	BLST	BSX1X2	MSTAB	STDSTAB
N	14.00	14.00	14.00	14.00	14.00
MEAN	800.64	541.14	1093.57	1968.36	258.86
STD	316.12	206.79	353.11	245.06	58.87
LOW	330.00	164.00	591.00	1704.00	154.00
HIGH	1286.00	858.00	1652.00	2590.00	363.00
CV	39.48	38.21	32.29	12.45	22.74

MIX 6

OBS_TYPE	WLST	BLST	BSX1X2	MSTAB	STDSTAB
N	7.00	7.00	7.00	7.00	7.00
MEAN	901.43	485.71	1055.86	1757.00	245.29
STD	369.78	242.09	431.29	133.12	81.76
LOW	231.00	80.00	285.00	1552.00	93.00
HIGH	1257.00	761.00	1478.00	1991.00	339.00
CV	41.02	49.84	40.85	7.58	33.33

MIX 8

OBS_TYPE	WLST	BLST	BSX1X2	MSTAB	STDSTAB
N	3.00	3.00	3.00	3.00	3.00
MEAN	966.33	907.33	1354.67	1236.67	211.00
STD	243.25	238.74	195.04	84.20	45.21
LOW	708.00	768.00	1140.00	1140.00	159.00
HIGH	1191.00	1183.00	1521.00	1294.00	241.00
CV	25.17	26.31	14.40	6.81	21.43

1 LB = 4.448 N

TABLE 6.3

MAX DIFFERENCE WITHIN & BETWEEN LOTS FOR ROADWAY COMPACTION

PROJ	MIX	NLOT	WLCP	BLCP	BCX1X2	NC	MCOMP	STDCOMP
A01	1	7	3.8	2.6	4.3	23	96.7	1.27
A02	3	6	3.0	2.3	3.8	30	95.6	1.11
A02	4	9	8.1	6.5	9.6	45	92.8	2.65
A03	3	5	3.0	1.3	4.5	25	93.5	1.09
A03	4	7	6.3	2.4	6.3	35	93.4	1.63
A04	3	8	5.5	3.4	6.8	38	94.4	1.71
A05	1	23	4.7	2.0	5.1	115	96.6	1.18
A06	1	30	6.4	3.0	7.6	150	96.3	1.33
A07	1	5	5.6	2.2	6.9	25	97.4	1.58
A07	3	21	5.5	6.5	8.3	60	95.7	2.11
A07	5	9	3.5	2.4	5.9	35	97.0	1.21
A08	1	15	5.2	2.9	6.5	75	95.9	1.36
A08	7	4	2.6	1.1	3.0	20	97.6	0.84
A09	1	46	6.9	3.7	7.8	192	97.1	1.45
A10	4	94	6.1	6.1	8.6	448	96.0	1.42
A11	3	14	4.2	4.5	7.2	65	93.7	1.39
A11	7	7	3.0	2.0	5.0	35	95.1	0.95
A12	1	5	5.0	1.8	6.0	25	97.4	1.51
A13	1	1	2.2		2.2	5	97.2	1.10
A13	2	3	3.4	2.3	5.9	15	94.9	1.44
A14	7	20	3.7	3.3	6.2	100	95.4	1.19
A15	1	7	5.0	2.6	7.0	35	96.4	1.54
A16	1	4	4.0	1.2	4.0	20	95.5	1.23
A17	1	16	3.5	2.5	6.0	80	97.8	1.29
A18	1	2	2.1	0.5	2.6	10	99.7	0.83
A18	5	8	3.6	2.5	6.0	35	96.8	1.26
A18	6	6	7.3	2.1	9.0	30	96.8	1.93
A19	3	23	4.5	5.9	7.7	114	93.6	1.55
A20	1	7	4.1	2.0	5.8	35	95.8	1.35
A21	3	11	5.4	6.9	10.1	55	92.6	2.56
A21	4	12	6.2	3.8	8.0	60	92.4	1.80
A22	1	11	4.6	2.1	5.4	40	96.3	1.36
A22	5	15	6.1	3.0	8.2	70	97.3	1.59
A23	5	6	6.4	0.4	6.4	22	95.9	1.36
A23	6	5	4.7	1.1	4.7	25	96.4	1.31
A24	1	34	5.1	4.9	8.2	170	97.6	1.47
A25	1	5	2.5	3.2	5.1	18	96.8	1.54
A26	1	14	3.9	2.4	4.7	65	96.1	1.10
A27	1	4	3.0	1.4	4.2	20	95.6	1.10
A28	1	12	5.1	2.7	6.7	55	96.4	1.40
A29	1	2	5.9	0.4	5.9	10	95.6	1.68
A29	5	3	3.8	1.5	4.6	15	93.6	1.18
A29	7	5	6.0	2.9	6.8	25	98.1	1.73
A30	8	29	3.8	3.4	5.5	145	96.0	1.28
A31	1	38	6.4	3.3	7.3	190	96.3	1.30
A32	1	43	4.7	4.1	7.1	210	95.6	1.52
A34	1	6	6.9	3.2	8.6	30	94.2	2.27
A35	5	6	4.2	1.8	5.0	30	96.8	1.10
A35	6	2	3.9	0.4	3.9	10	97.5	1.01
A36	1	6	6.3	2.2	7.2	27	96.0	1.60
A37	1	4	4.3	0.8	4.3	20	95.4	1.10
A38	1	6	3.9	1.5	5.5	30	96.0	1.23
A39	1	14	5.1	3.2	6.4	70	96.2	1.26
A40	1	18	4.7	3.1	7.6	90	96.4	1.38
A41	1	3	3.0	0.4	3.1	15	95.6	1.07

WLCP = WITHIN LOT FOR COMPACTION
BLCP = BETWEEN LOTS FOR COMPACTION
BCX1X2 = BETWEEN COMPACTION X1 & X2
NC = NO. OF COMPACTIONS
MCOMP = MEAN ROADWAY COMPACTION, %
STDCOMP= STANDARD DEVIATION FOR COMPACTION, %

TABLE 6.3 (CONTINUED)

MAX DIFFERENCE WITHIN & BETWEEN LOTS FOR ROADWAY COMPACTION

PROJ	MIX	NLOT	WLCP	BLCP	BCX1X2	NC	MCOMP	STDCOMP
A42	1	65	7.6	5.0	10.6	325	95.8	1.54
A43	1	7	4.3	2.2	4.3	34	95.5	1.40
A45	1	14	5.2	2.4	6.9	70	96.4	1.33
A45	2	2	3.9	0.0	3.9	10	96.1	1.18
A46	1	28	6.0	3.4	8.1	135	96.4	1.33
A47	7	3	3.3	1.5	3.8	15	97.1	1.20
A48	1	5	3.4	0.5	3.8	15	96.0	0.93
A49	1	36	6.0	5.7	8.6	175	96.0	1.73
A50	1	43	6.4	2.6	7.6	215	96.3	1.30
A51	1	8	4.2	2.7	5.9	40	94.5	1.37
A51	2	7	4.8	1.0	5.2	35	94.4	0.96
A52	1	10	7.4	1.5	7.4	40	96.0	1.38
A52	2	13	4.3	3.9	7.4	62	95.7	1.56
A52	7	12	6.9	2.5	7.8	60	96.2	1.54
A54	5	16	7.5	2.4	9.3	80	95.1	1.49
A54	6	25	4.6	3.1	5.5	122	95.2	1.19
A55	5	4	3.9	1.0	4.3	20	97.4	1.17
A55	6	5	3.9	1.2	3.9	25	96.8	1.13
A57	1	9	5.2	3.0	6.4	45	96.6	1.42
A58	5	26	5.2	3.4	7.4	130	96.3	1.51
A59	1	18	5.6	4.2	7.2	90	95.8	1.46
A60	1	11	4.6	3.4	5.9	54	96.4	1.38
A60	2	20	4.7	2.9	6.8	68	96.4	1.10
A61	1	3	5.8	0.7	5.9	15	95.4	1.52
A61	5	31	5.0	3.9	8.2	155	96.2	1.61
A61	6	10	4.6	2.2	5.1	50	97.1	1.20
A62	5	14	4.7	3.6	6.0	70	96.5	1.37
A62	6	36	4.6	4.9	7.7	149	97.1	1.42
A63	8	89	4.6	3.5	7.6	445	96.3	1.22
A64	1	19	4.7	2.4	6.4	95	95.8	1.16
A64	8	72	6.3	3.0	6.7	357	95.9	1.16
A65	1	20	4.2	2.1	6.8	96	96.4	1.24
A66	1	25	4.7	4.2	8.5	120	97.0	1.54
A67	1	33	4.6	2.8	5.9	116	96.1	1.12
A68	1	35	5.5	3.4	6.4	175	96.9	1.28
A69	1	39	4.5	2.9	6.9	190	96.5	1.28
A70	1	16	3.8	2.0	6.4	79	95.9	1.09
A71	1	25	5.6	6.4	9.3	125	96.0	1.89
A72	1	17	6.0	3.1	8.0	85	95.7	1.70
A73	1	32	5.4	4.7	9.8	155	96.5	1.80
A74	1	4	4.2	1.4	4.7	20	97.1	1.17
A74	5	15	3.8	3.8	7.2	75	96.4	1.28
A75	5	17	10.2	4.1	11.5	85	96.8	1.55
A76	3	11	3.5	1.3	4.0	55	93.8	0.99
A77	1	15	3.4	2.0	4.7	75	97.7	1.01
A78	1	9	5.0	2.6	5.0	45	96.1	1.20
A79	1	15	4.7	1.7	4.7	75	96.4	1.07
A80	1	10	5.0	2.0	5.8	50	96.5	1.38
A81	5	9	4.3	1.0	5.1	40	96.0	1.11
A82	1	7	3.9	3.8	7.7	35	97.0	1.69
A83	1	15	4.2	2.1	4.6	75	96.5	1.11
A84	1	7	5.5	1.4	6.8	35	96.1	1.16
A85	1	10	4.2	1.4	4.7	50	95.5	1.04

TABLE 6.4

STANDARD STATISTICS FOR MAXIMUM DIFFERENCE TABLE FOR COMPACTION

MIX 1,2,5,6,7,8

OBS_TYPE	WLCP	BLCP	BCX1X2	MCOMP	STDCOMP
N	96.00	95.00	96.00	96.00	96.00
MEAN	4.85	2.52	6.22	96.30	1.33
STD	1.39	1.24	1.73	0.86	0.24
LOW	2.10	0.00	2.20	93.60	0.83
HIGH	10.20	6.40	11.50	99.70	2.27
CV	28.63	49.33	27.87	0.90	18.32

MIX 3,4

OBS_TYPE	WLCP	BLCP	BCX1X2	MCOMP	STDCOMP
N	12.00	12.00	12.00	12.00	12.00
MEAN	5.14	4.24	7.07	93.96	1.67
STD	1.49	2.11	2.09	1.22	0.54
LOW	3.00	1.30	3.80	92.40	0.99
HIGH	8.10	6.90	10.10	96.00	2.65
CV	29.01	49.71	29.56	1.30	32.52

TABLE 6.5

STATISTICAL PARAMETERS ACCORDING TO MIX TYPES

OBS_TYPE	MIX	TONS	STAB	COMP	P1	P3/4	P1/2	N4	N10	N40	N80	N200	ACX	CRSH
	1	982.00	3436.00	4803.00	224.00	690.00	714.00	714.00	714.00	714.00	714.00	714.00	714.00	715.00
MEAN	1	704.84	1675.80	96.33	100.00	99.98	93.88	57.68	42.25	24.49	11.25	6.13	5.01	81.57
STD	1	375.07	271.42	1.52	0.00	0.21	3.43	4.99	4.67	3.51	2.31	1.37	0.35	5.78
LOW	1	15.00	720.00	88.80	100.00	97.00	81.00	44.00	28.00	10.00	3.00	1.00	4.00	60.00
HIGH	1	1855.00	2846.00	101.30	100.00	100.00	99.00	86.00	64.00	46.00	26.00	12.00	7.00	96.00
CV	1	53.21	16.20	1.58	0.00	0.21	3.66	8.65	11.05	14.34	20.54	22.41	6.91	7.08
N	2	45.00	163.00	190.00	38.00	74.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00
MEAN	2	650.44	1835.36	95.65	99.87	98.49	85.96	52.92	40.08	23.47	10.68	5.28	4.23	72.11
STD	2	333.16	379.11	1.46	0.58	1.86	5.59	5.64	4.54	3.40	2.27	1.41	0.46	8.28
LOW	2	155.00	1027.00	90.90	97.00	93.00	73.00	42.00	29.00	15.00	6.00	1.10	3.30	51.00
HIGH	2	1490.00	2733.00	99.60	100.00	100.00	97.00	65.00	51.00	32.00	18.00	10.00	5.50	87.00
CV	2	51.22	20.66	1.53	0.58	1.89	6.51	10.66	11.33	14.47	21.25	26.79	10.86	11.48
N	3	99.00	333.00	442.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	3	732.34	2044.81	93.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STD	3	438.82	498.61	1.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LOW	3	32.00	1074.00	86.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIGH	3	2440.00	3979.00	99.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CV	3	59.92	24.38	2.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	4	121.00	425.00	588.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	4	559.12	1976.41	95.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STD	4	311.98	396.74	2.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LOW	4	40.00	704.00	87.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIGH	4	1174.00	2982.00	100.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CV	4	55.80	20.07	2.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NOTE: P1, P3/4,... ETC = PERCENT PASSING INDICATED SIEVES
STAB = MARSHALL STABILITY, LBS
COMP = ROADWAY COMPACTION, %
ACX = ASPHALT CONTENT, %
CRSH = % CRUSHED
STD = STANDARD DEVIATION
CV = COEFF. OF VARIATION, %
1 LB = 4.448 N
1 TON = 0.91 METRIC TON

TABLE 6.5

STATISTICAL PARAMETERS ACCORDING TO MIX TYPES

OBS_TYPE	MIX	TONS	STAB	COMP	P1	P3/4	P1/2	N4	N10	N40	N80	N200	ACX	CRSH
N	5	175.00	604.00	862.00	53.00	143.00	188.00	188.00	188.00	188.00	188.00	188.00	188.00	187.00
MEAN	5	631.06	1949.57	96.35	100.00	99.86	93.29	58.28	42.63	24.21	11.56	5.92	5.05	82.20
STD	5	375.28	355.55	1.57	0.00	0.58	2.82	4.96	4.72	3.18	3.42	1.56	0.39	5.11
LOW	5	45.00	806.00	87.20	100.00	96.00	86.00	44.00	30.00	16.00	4.00	2.00	4.00	63.00
HIGH	5	1782.00	3332.00	101.00	100.00	100.00	99.00	70.00	55.00	33.00	21.00	11.00	6.20	97.00
CV	5	59.47	18.23	1.63	0.00	0.58	3.02	8.51	11.08	13.14	29.56	26.36	7.63	6.22
N	6	68.00	280.00	411.00	102.00	109.00	128.00	128.00	128.00	128.00	128.00	128.00	128.00	128.00
MEAN	6	718.44	1794.78	96.47	100.00	99.10	87.07	50.82	38.10	22.48	9.48	5.32	4.38	76.11
STD	6	461.35	294.96	1.59	0.00	1.64	3.98	5.33	4.74	3.56	1.67	1.33	0.45	8.29
LOW	6	32.00	1022.00	92.40	100.00	92.00	76.00	39.00	29.00	15.00	6.00	2.00	3.40	53.00
HIGH	6	1780.00	2690.00	101.70	100.00	100.00	97.00	68.00	49.00	32.00	15.00	10.00	6.00	92.00
CV	6	64.22	16.43	1.64	0.00	1.66	4.57	10.49	12.44	15.82	17.60	25.00	10.27	10.89
N	7	51.00	166.00	255.00	18.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	0.00
MEAN	7	634.27	1578.90	96.09	100.00	91.90	76.40	44.45	33.60	21.05	9.60	4.25	4.45	0.00
STD	7	293.46	257.38	1.62	0.00	2.97	4.49	4.44	3.63	2.98	3.49	1.48	0.25	0.00
LOW	7	140.00	983.00	91.60	100.00	85.00	66.00	36.00	23.00	13.00	4.00	1.00	4.10	0.00
HIGH	7	1155.00	2227.00	101.70	100.00	96.00	84.00	53.00	40.00	25.00	16.00	7.00	4.80	0.00
CV	7	46.27	16.30	1.68	0.00	3.23	5.88	9.99	10.81	14.17	36.31	34.88	5.62	0.00
N	8	190.00	691.00	947.00	306.00	293.00	293.00	305.00	292.00	305.00	292.00	305.00	306.00	0.00
MEAN	8	1506.01	1262.92	96.08	99.38	94.10	85.15	52.02	43.52	26.06	11.07	7.61	4.30	0.00
STD	8	563.71	217.79	1.22	1.78	3.45	4.41	3.44	3.24	2.17	1.59	1.27	0.22	0.00
LOW	8	145.00	308.00	92.40	87.00	83.00	72.00	43.00	31.00	20.00	7.00	4.00	3.00	0.00
HIG	8	2908.00	2005.00	100.40	100.00	100.00	96.00	62.00	53.00	32.00	16.00	11.00	5.10	0.00
CV	8	37.43	17.25	1.27	1.79	3.66	5.17	6.61	7.46	8.34	14.39	16.69	5.04	0.00

TABLE 6.6

YEARLY ANALYSIS OF VARIABILITY FOR CONTROL & ACCEPTANCE CRITERIA

STANDARD DEVIATIONS FOR MARSHALL STABILITIES

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	286.40	271.35	254.72	261.52	213.53
2	371.13	263.80	462.85		
3		528.06	311.72		
4		391.62	287.54		
5	292.34	402.05	333.36	195.81	
6	278.81	256.92			
7		259.03		245.39	
8		208.14		232.66	

STANDARD DEVIATIONS FOR COMPACTION

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	1.59	1.56	1.41	1.47	1.16
2	1.10	1.53	1.18		
3		1.81	2.03		
4		1.90	1.80		
5	1.54	1.66	1.46	1.28	
6	1.37	1.54			
7		1.62		1.20	
8		1.21		1.28	

STANDARD DEVIATIONS FOR % PASSING 1 INCH SIEVE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	.00	0.00	0	0	
2	.58				
3					
4					
5		0.00		0	
6	.00	0.00			
7		0.00			
8		1.78			

STANDARD DEVIATIONS FOR % PASSING 3/4 INCH SIEVE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	0.00	0.33	0	.15	
2	1.97	1.18			
3					
4					
5	0.61	0.64		.00	
6	0.82	1.94			
7		2.97			
8		3.45			

STANDARD DEVIATIONS FOR % PASSING 1/2 INCH SIEVE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	3.10	2.89	2.61	3.51	
2	3.61	6.18			
3					
4					
5	2.54	2.78		2.45	
6	3.25	4.70			
7		4.49			
8		4.41			

STANDARD DEVIATIONS FOR % PASSING NO 4 SIEVE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	4.24	4.16	4.74	5.06	
2	3.08	5.70			
3					
4					
5	4.71	4.26		3.17	
6	4.24	5.93			
7		4.44			
8		3.44			

TABLE 3.8 (CONTINUED)

YEARLY ANALYSIS OF VARIABILITY FOR CONTROL & ACCEPTANCE CRITERIA

STANDARD DEVIATIONS FOR % PASSING NO 10 SIEVE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	3.50	3.85	6.05	3.98	
2	2.20	5.83			
3					
4					
5	4.30	3.72		2.50	
6	4.11	4.91			
7		3.63			
8		3.24			

STANDARD DEVIATIONS FOR % PASSING NO 40 SIEVE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	2.35	2.56	4.28	3.23	
2	1.66	4.32			
3					
4					
5	3.40	2.75		1.90	
6	3.21	3.61			
7		2.98			
8		2.17			

STANDARD DEVIATIONS FOR % PASSING NO 80 SIEVE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	2.65	1.77	2.17	2.72	
2	1.64	2.78			
3					
4					
5	1.63	2.77		1.29	
6	1.49	1.85			
7		3.49			
8		1.59			

STANDARD DEVIATIONS FOR % PASSING NO 200 SIEVE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	1.17	1.47	1.43	1.19	
2	1.13	1.63			
3					
4					
5	1.02	1.48		0.98	
6	0.85	1.33			
7		1.48			
8		1.27			

STANDARD DEVIATIONS FOR % ASPHALT CEMENT

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	.27	.36	.31	.36	
2	.27	.45			
3					
4					
5	.25	.41		.28	
6	.42	.49			
7		.25			
8		.22			

STANDARD DEVIATIONS FOR % CRUSHED AGGREGATE

MIX	YEAR71	YEAR72	YEAR73	YEAR74	YEAR75
1	5.44	6.31	4.36	5.11	
2	6.66	8.56			
3					
4					
5	4.68	3.90		3.64	
6	9.40	6.60			
7					
8					

```
STATISTICS TABLE AND HISTOGRAM FOR STAB

NO. OF VALUES=              3765  NO. MISSING=
SUM=            6319320           MEAN=                 1678.43
UNCORRECTED SS=10899543750.00     CORRECTED SS=         292955366.89
VARIANCE=       77830.86          STANDARD DEVIATION=278.98
COEF. VARIANCE=16.62              STANDARD ERROR=       20.67
```

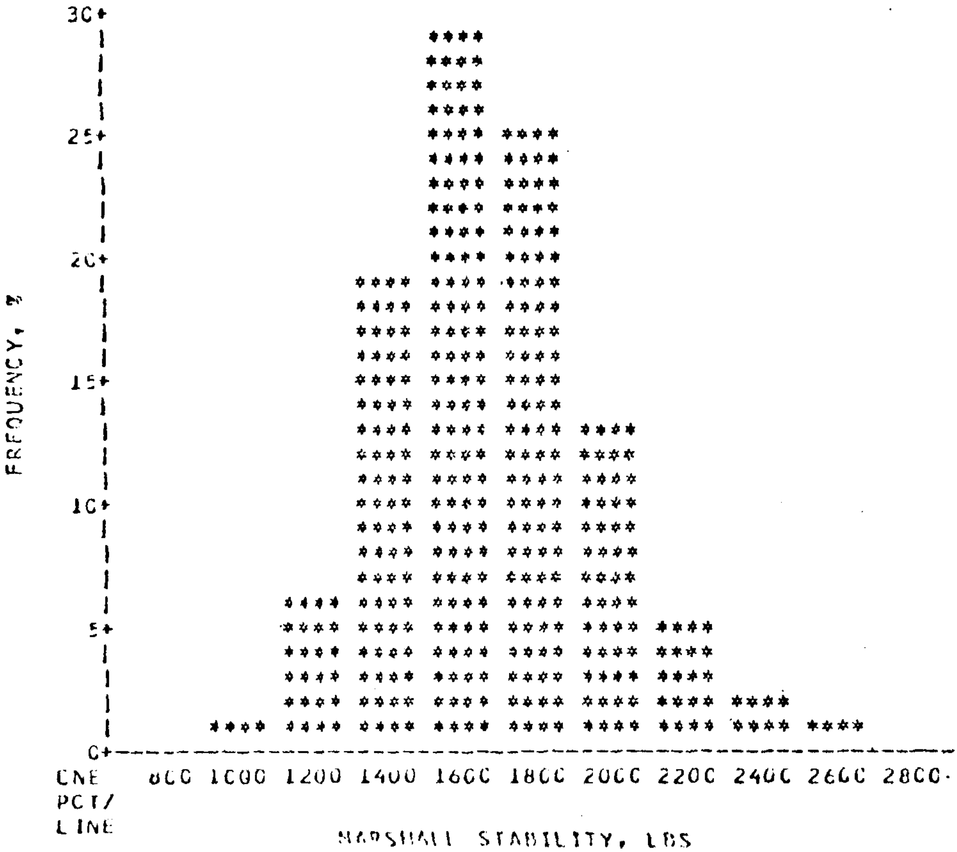

Figure 6.1: Frequency Distribution of Marshall Stability Data for Mixes 1, 2 and 7.

STATISTICS TABLE AND HISTOGRAM FOR STAB

NO. OF VALUES=	758	NO. MISSING=	
SUM=	1520897	MEAN=	2006.46
UNCORRECTED SS=	3201771077.00	CORRECTED SS=	150151440.31
VARIANCE=	198350.64	STANDARD DEVIATION=	445.36
COEFF. VARIANCE=	22.19	STANDARD ERROR=	261.67

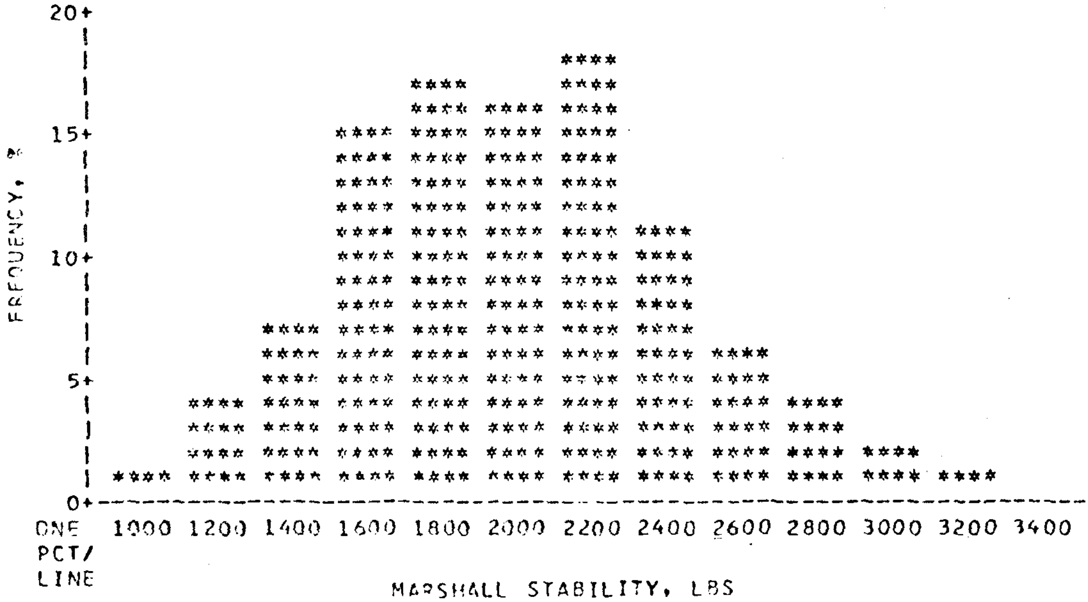

Figure 6.2: Frequency Distribution of Marshall Stability Data for Mixes 3 and 4.

STATISTICS TABLE AND HISTOGRAM FOR STAB

NO. OF VALUES=	604	NO. MISSING=	
SUM=	1177781	MEAN=	1949.96
UNCORRECTED SS=	2372864529.00	CORRECTED SS=	76228628.40
VARIANCE=	126415.63	STANDARD DEVIATION=	355.54
COEF. VARIANCE=	18.23	STANDARD ERROR=	209.29

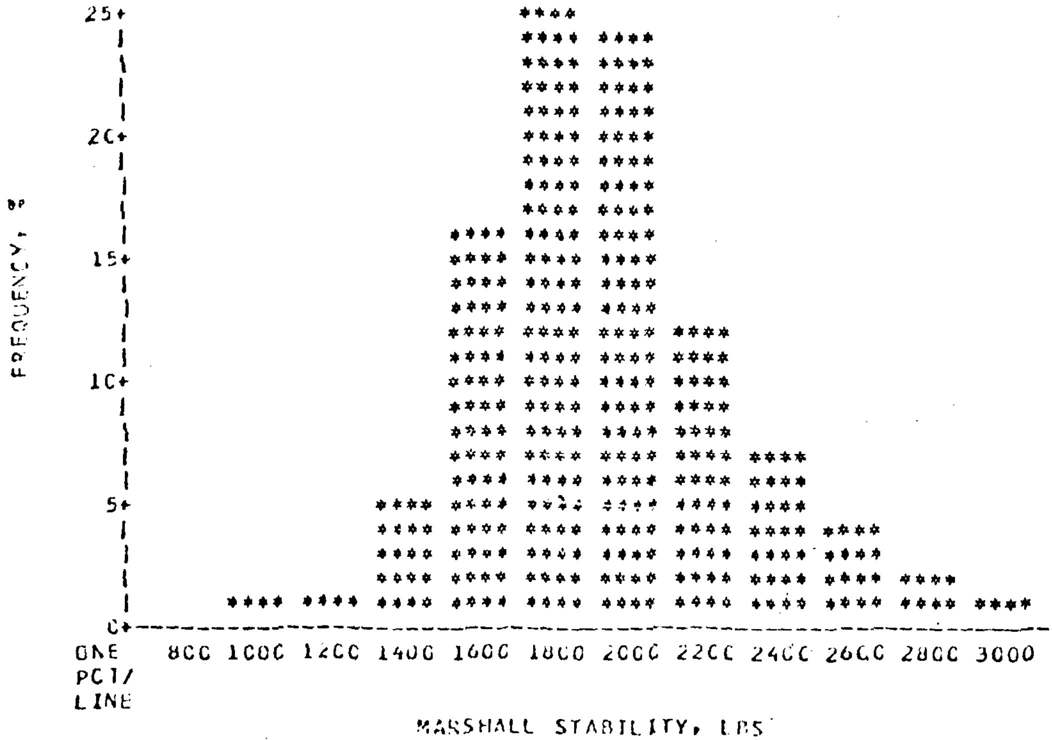

Figure 6.3: Frequency Distribution of Marshall Stability Data for Mix 5.

STATISTICS TABLE AND HISTOGRAM FOR STAB

```
NO. OF VALUES=              280   NO. MISSING=
SUM=              502536          MEAN=              1794.77
UNCORRECTED SS=926216412.00       CORRECTED SS=      24273978.27
VARIANCE=         87003.50        STANDARD DEVIATION=294.96
COEF. VARIANCE=16.43              STANDARD ERROR=    310.72
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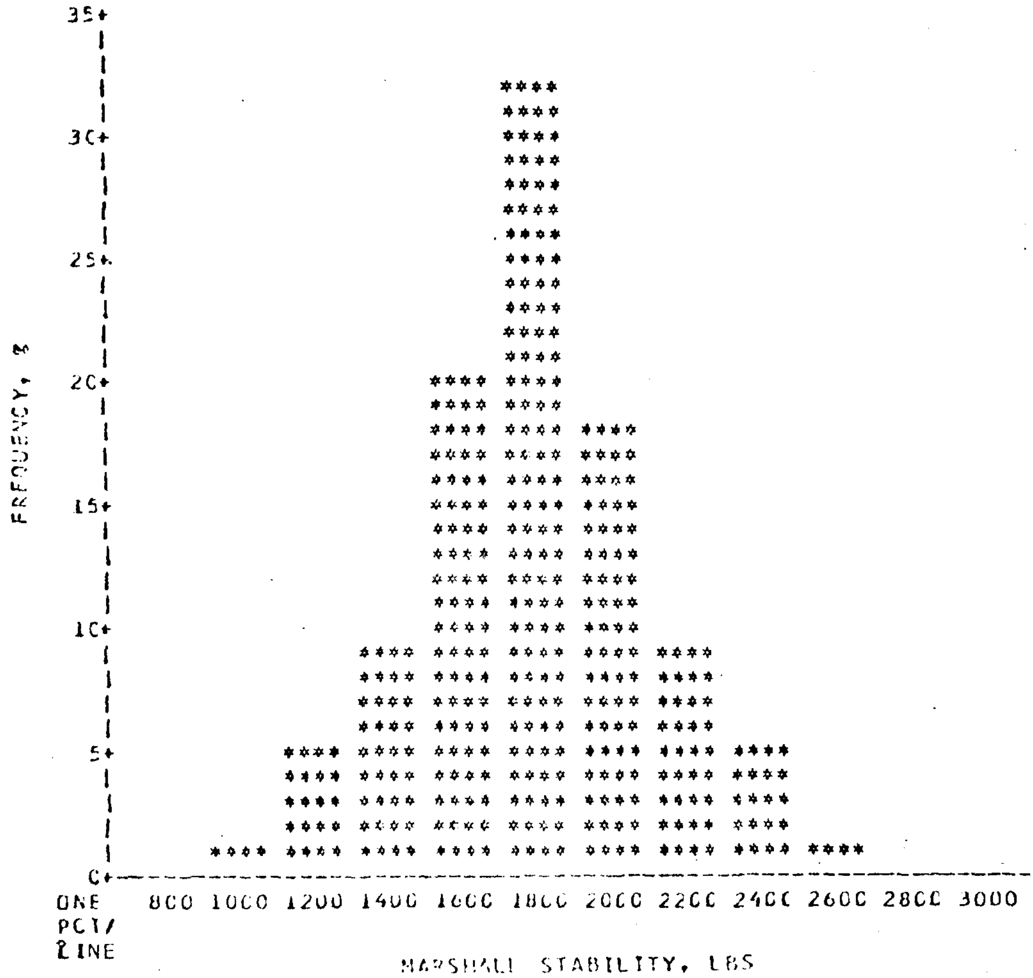

Figure 6.4: Frequency Distribution of Marshall Stability Data for Mix 6.

STATISTICS TABLE AND HISTOGRAM FOR STAB

NO. OF VALUES=	691	NO. MISSING=	
SUM=	872676	MEAN=	1262.91
UNCORRECTED SS=	1134846416.00	CORRECTED SS=	32728614.29
VARIANCE=	47432.77	STANDARD DEVIATION=	217.79
COEF. VARIANCE=	17.24	STANDARD ERROR=	68.64

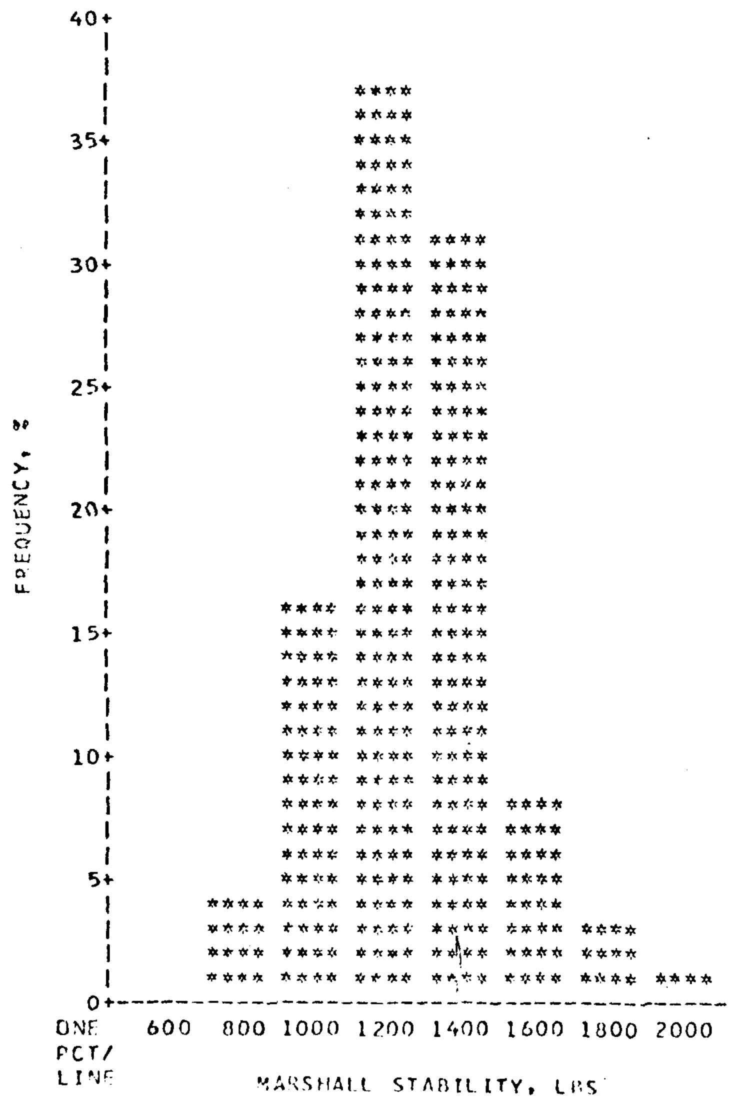

Figure 6.5: Frequency Dstribution of Marshall Stability Data for Mix 8.

```
STATISTICS TABLE AND HISTOGRAM FOR COMP

NO. OF VALUES=           7468  NO. MISSING=
SUM=           719015.90       MEAN=              96.27
UNCORRECTED SS=69243507.82     CORRECTED SS=      16959.29
VARIANCE=        2.27          STANDARD DEVIATION=1.50
COEF. VARIANCE=1.56            STANDARD ERROR=    0.00030
```

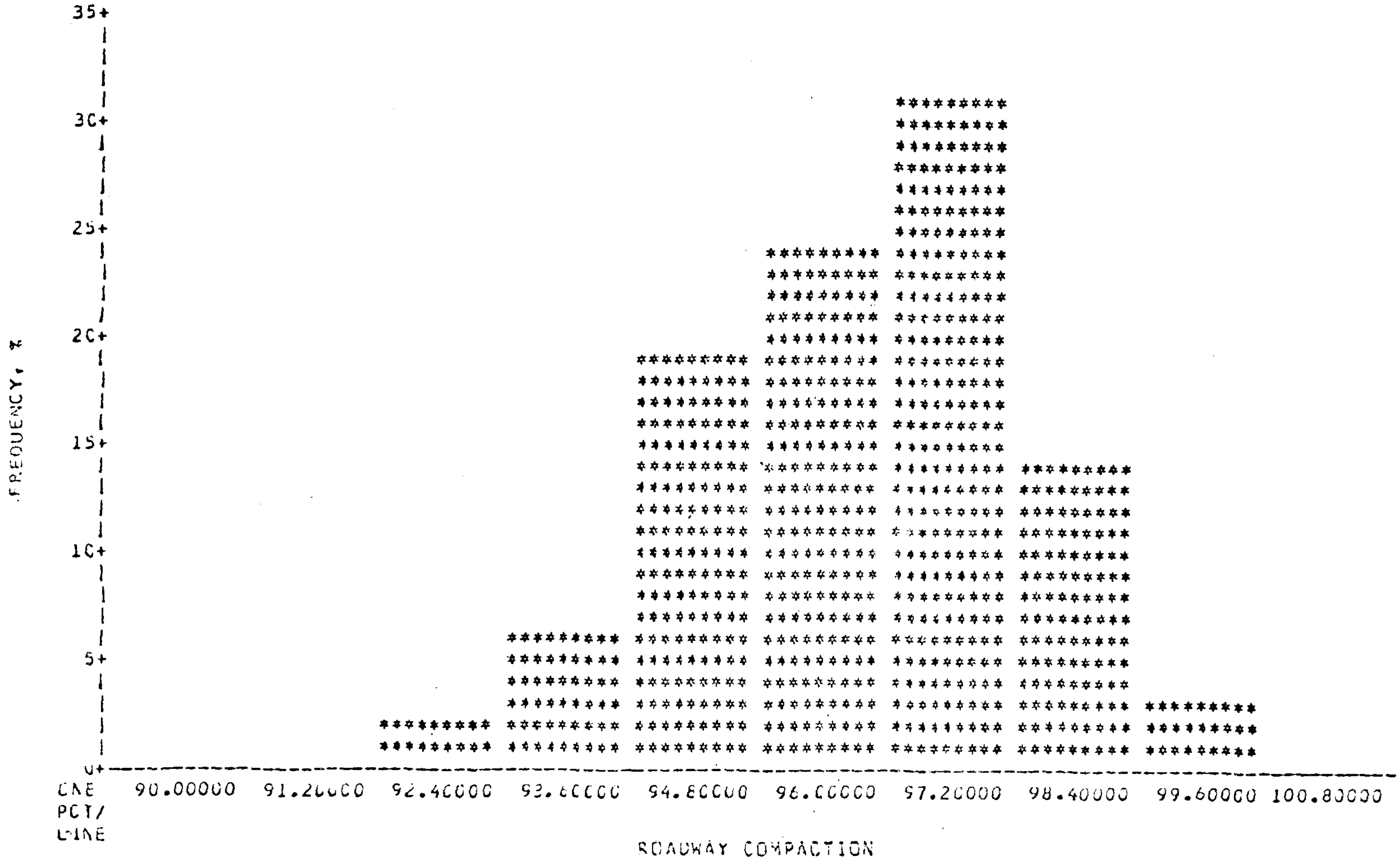

Figure 6.6: Frequency Distribution of Compaction Data for Mixes 1, 2, 5, 6, 7 and 8

STATISTICS TABLE AND HISTOGRAM FOR COMP

```
NO. OF VALUES=              1030   NO. MISSING=
SUM=             97554.00          MEAN=                  94.71
UNCORRECTED SS=9244276.36          CORRECTED SS=        4681.29
VARIANCE=            4.54          STANDARD DEVIATION=2.13
COEF. VARIANCE=2.25                STANDARD ERROR=    0.0044168
```

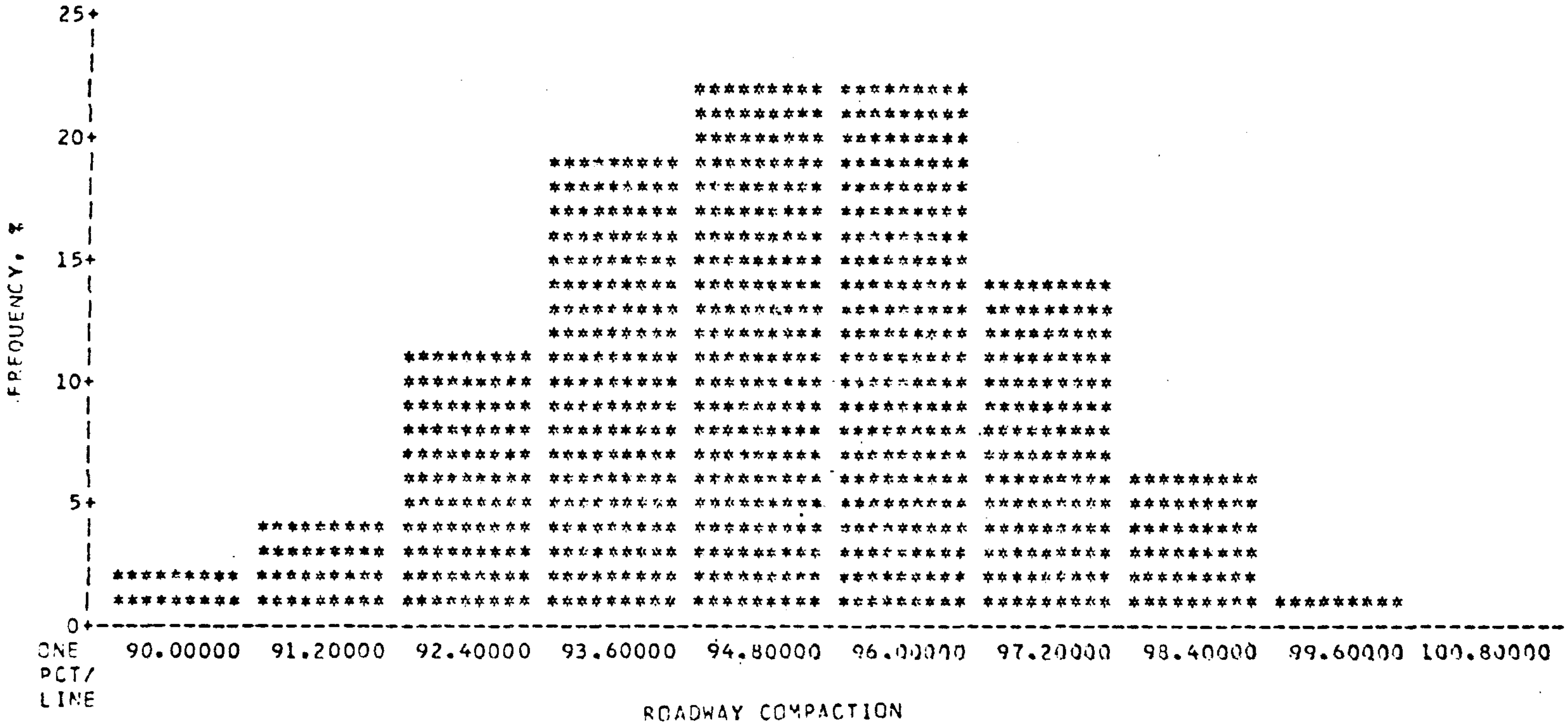

Figure 6.7: Frequency Distribution of Compaction Data for Mixes 3 and 4

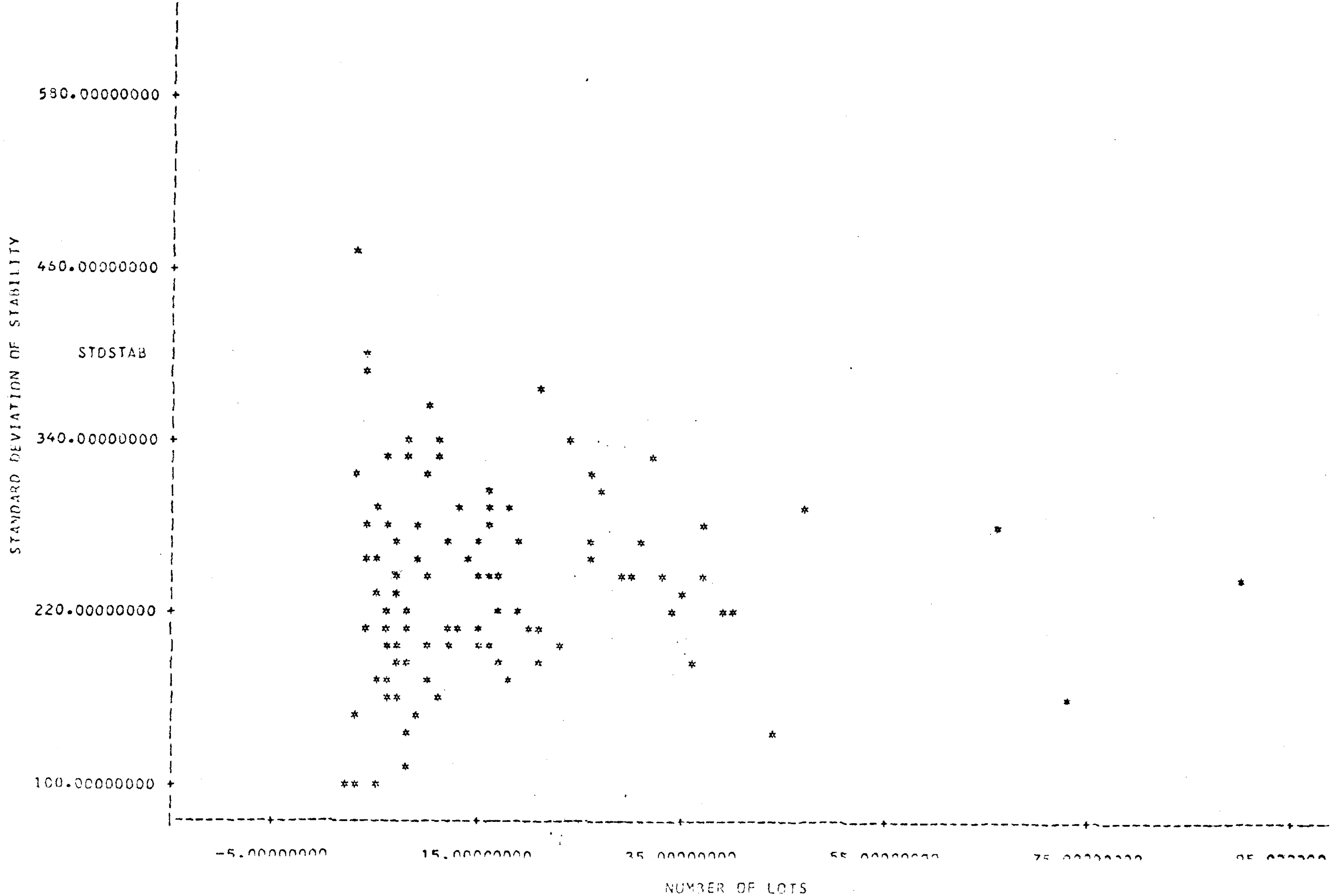

Figure 6.8: Relationship Between Uniformity in Production and Length of Duration of Plant Operation

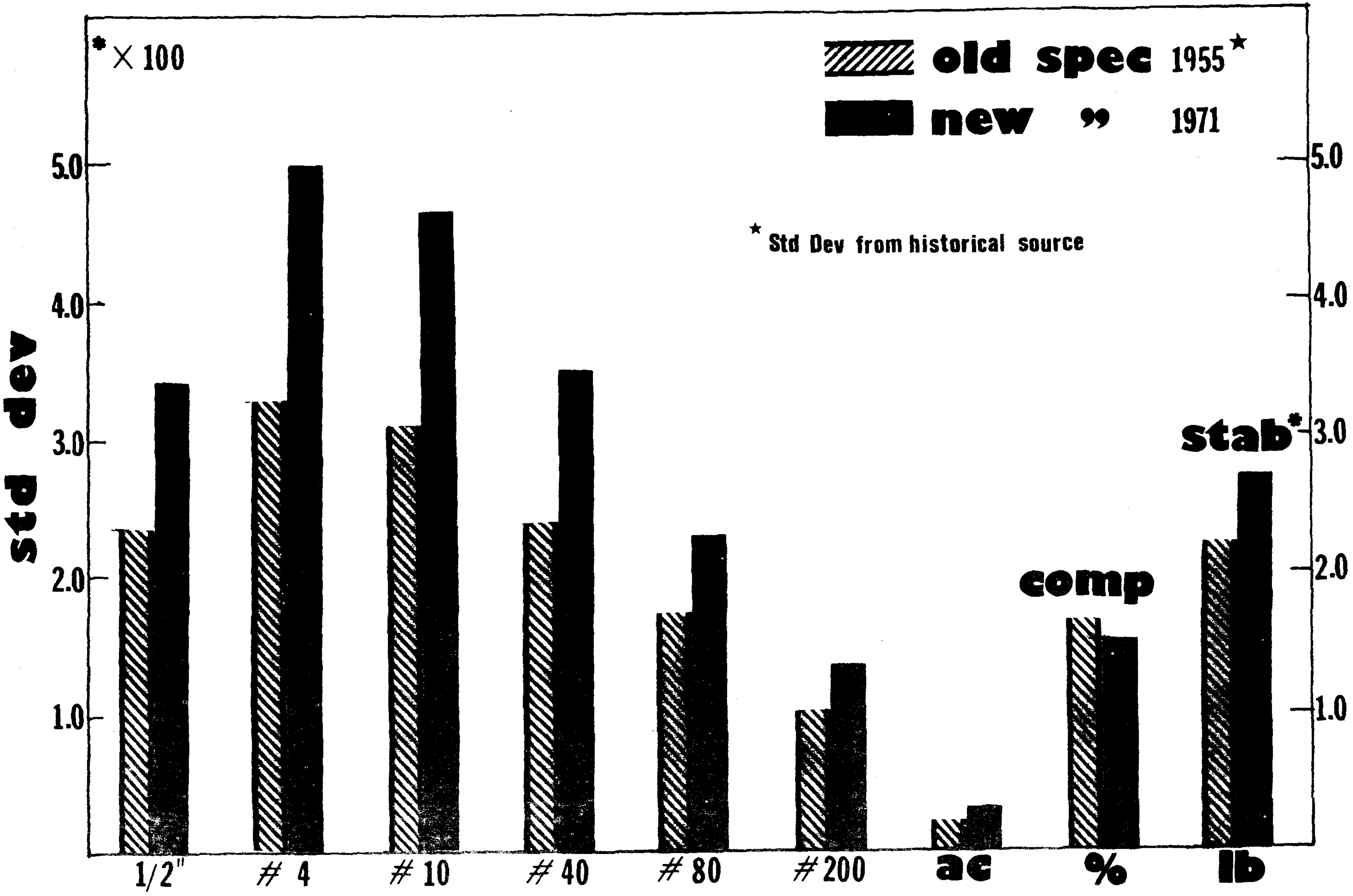

Figure 6.9: Comparison of Variability Generated by Conventional (Old) and End-Result (New) System of Specifications

7. PERFORMANCE EVALUATION OF CONVENTIONAL AND END RESULT SPECIFICATIONS

The end result of any system of specifications should be evaluated in terms of performance of the finished product. An acceptable level of performance had been obtained from the conventional system. The new system should likewise be expected to provide similar quality product. However, such evaluation should only be considered cursory, since the new system of specifications has not replaced any of the former basic equipment, materials, or procedural requirements.

Projects let under both the old and new system of specifications were selected in order to evaluate the overall characteristics of the finished product. Although the plant data were also analyzed for uniformity, major emphasis was placed on performance relating to riding quality and longitudinal rutting, since both characteristics are evaluated during the acceptance phase of the inspection; the former by smoothness criteria and the latter by compaction requirements. The evaluation is confined to a type 1 wearing course mix.

Table 7.1 is a listing of statistical parameters for the three sets of projects. The letter "C" and "E" preceding the numbers in the first column denote "Conventional" and "End-Result", respectively. Each pair is grouped according to the traffic and section characteristics. These projects had approximately six months of traffic on them. The trend in data reinforces some of the trends discussed in the preceding section for production process. The magnitude of variability data for compaction should be judged in the light of the number of projects in this evaluation as compared to the number discussed earlier.

Although the longitudinal rut depths on all projects should be considered negligible in Table 7.2, the end result projects show considerably less rut depths than the corresponding conventional data. However, the riding quality of the end result projects does not seem to reflect the data obtained on these projects during acceptance measurements, since none of these projects had any penalties due to smoothness deficiency. One possible explanation is the sample size for measurement of this criteria. The Mays Ridemeter readings as reported here were obtained on the entire project, whereas the measurements with the rolling straightedge during the construction phase requires five segments, each 200 feet in length, for a day's operation. The point here is that the present sample size for smoothness measurement is too small to provide the true smoothness profile of the finished pavement. This was evidenced in a separate study (6) where the discrepancy in the smoothness data was observed due to sample size. This, coupled with the data presented here, may necessitate some revision in this phase of acceptance sampling.

TABLE 7.1

STATISTICAL PARAMETERS FROM CONVENTIONAL & END RESULT PROJECTS

PROJECT IDENT.	TOTAL TONS	NO. OF STAB.	MEAN STAB, LB	STD DEV STAB, LB	NO. OF RDWYS	MEAN COMP, %	STD DEV COMP, %
C03	24373	130	1403	161	61	97.3	1.45
E07	32798	111	1389	111	162	98.4	1.32
C05	42883	254	1577	210	48	97.5	1.66
E09	29885	185	1678	375	218	96.3	1.99
C02	28985	93	1456	167	125	95.5	1.16
E12	66242	253	1734	268	395	96.5	2.05

TABLE 7.2

COMPARISON OF PERFORMANCE CRITERIA FOR CONVENTIONAL & END RESULT PROJECTS

PROJECT IDENT.	PAVEMENT SECTION	EWL, TOTAL	MAYS, IPM	RUTTING, MM
C03	8.0"PCC	79	72	3.6
E07	7.0"PCC	50	96	2.8
C05	7.0"PCC	279	84	4.6
E09	6.5"PCC	273	74	2.3
C02	8.0"SCG	29	62	3.6
E12	8.0"SCG	40	93	2.8

8. OVERALL ASSESSMENT OF STATISTICAL SPECIFICATIONS

In order to make a more objective assessment of the overall usefulness of these statistical specifications, it was deemed necessary to determine the concensus of those who had gained the expertise through their daily assignment of responsibilities for enforcing these specifications. This gauging was accomplished by distributing questionnaire to construction engineers throughout the State. The results of the findings are presented herein and are of interest in the overall evaluation of the quality assurance program within the State. The response summaries,however, are presented without any critical comment. Sixty, or 79 percent, responded out of the total of 76. The results of the questionnaire follow:

Question 1 How would you compare the present end-result oriented system of specifications with the old conventional system of specifications with respect to:

(A) The effort required in monitoring construction projects?

(B) The effort required at final certification time (2059)?

(C) Overall end product (pavement)?

<u>Response</u>

(A)

More Effort	10%
Same Effort	35%
Less Effort	50%
No Comment	5%

(B)

More Effort	15%
Same Effort	38%
Less Effort	37%
No Comment	10%

(C)

Better Product	22%
Same Product	50%
Inferior Product	25%
No Comment	3%

Question 2	Do you consider these specifications easier to enforce than the old specifications?	
Response	Yes	62%
	No	33%
	No Comment	5%

Question 3	From your review of data for final certification, approximately what percent of the time have contractors received 100 percent pay for the entire project (it should be remembered that all it takes is one failing lot to decrease his chances of getting 100 percent pay for the project)?	
Response ★	(A) 100% of the time	8%
	(B) 95% of the time	60%
	(C) 90% of the time	12%
	(D) 75% of the time	7%
	(E) 50% of the time	0%
	(F) Less than 50% of the time	12%
	No Comment	1%

Question 4	One of the intended features of the new system of specifications is the clear definition of the responsibilities of the Department and the contractor. This feature was lacking in the old specifications. Do you believe this feature has helped in making equitable decisions between the Department and the contractor?	
Response	Yes	80%
	No	17%
	No Comment	3%

Question 5	Do the contractors you have worked with review the control charts for which they are intended, viz. to check whether the process is in control or not?	
Response	Yes	27%
	No	65%
	No Comment	8%

Question 6	Do you review these control charts?	
	Daily	17%
	Occasionally	75%
	Never	7%
	No Comment	1%

★ The response should be interpreted thus:

For B, 60 percent of those reponding indicated that the contractors received 100 percent pay 95 percent of the time, and so on for C,D, etc.

Question 7 — In your opinion do these control charts serve the intended purpose?

Response

Yes	33%
No	64%
No Comment	3%

9. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The preceding sections discussed some of the data generated by asphaltic concrete end-result specifications. These data represented the placement of approximately 1.3 million tons of hot mix over a period of approximately four years. The primary analysis was directed towards the determination of distribution of penalties with respect to various acceptance criteria and types of mixes and the effect such penalties had on the overall final payment to the Contractor. Additionally, variability of the data was compared with the data that was used in the development of these end-result specification tolerance limits. As a final step in the analysis, a cursory evaluation of the old, or conventional system, and the new end-result system of specifications was made in terms of performance of the end product. The conclusions and recommendations that follow are based on the results of the various analyses discussed in this report.

Conclusions

1. Implementation of end-result specifications has resulted in a reduction of pay to the Contractor of approximately 1.5 percent of the contract unit price.

2. The criteria contributing the most to the above reduction was roadway compaction (62%), followed by surface smoothness (31%) and Marshall Stability (7%). Likewise, most of the penalties occurred at the 95 percent pay level, and less than four percent at the 50 percent or remove penalty scale.

3. On of the major reasons for such penalties in compaction and stability is the Contractor's failure to maintain his level of compaction or stability at a specified level with respect to the mean and the standard deviation.

4. Of all the surface course mixes that have a smoothness criteria requirement, shell mixes seem to have a major problem meeting the stated requirements for 100 percent pay.

5. In light of the improved production and equipment technology incorporated into hot mix production during the last decade, there is a decline in uniformity with respect to the production of all asphaltic concrete mixes in general, and shell mixes in particular. The latter mixes indicate a greater degree of

of nonuniformity in the production, compaction and finishing stages of construction. However, the magnitude of variation indicated by the production phase showed no evidence of reduction in the quality of the end product, and therefore, may not be cause for alarm. Likewise, monitoring of production through proper use of control charts is apt to improve the uniformity of the production.

6. A limited evaluation of the performance of new construction let under end result and conventional systems of specifications did not indicate any recognizable differences in the quality of the finished product with respect to rut depths. However, the rougher riding surface indicated by the end-result construction projects necessitates a review of the present sampling and testing procedures for surface tolerance measurements.

7. All in all, the statistically oriented end-result specifications have been satisfactory. The system was not intended as a panacea to the material and construction problems. However, questionnaire response from field personnel has indicated certain advantages to have resulted from implementation of these specifications over the arbitrary conventional specifications.

Recommendations

1. First and foremost, the use of control charts should be made mandatory for maintaining the uniformity of production. The Department should review these charts daily to determine whether the uniformity is disturbed. Any unusual trend in data shifting towards and beyond the control limits must necessarily be viewed as a warning that the process is getting out of control. Every effort should then be made to bring the process back under control.

2. The large magnitude of variation in Marshall Stability, which may have occurred as a result of lack of adequate control on job-mix formula, indicates a need for specifying requirements that would assure better uniformity than presently achieved.

3. The present sample size of 1000 feet for measurement of surface smoothness criteria should be revised to reflect measurements over the entire length of the pavement lot (day's production).

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4. Shah, S. C., Quality Control Analysis, Part IV - Simulation of Asphaltic Concrete Specifications, Louisiana Department of Highways, Research Report No. 36, February 1969.

5. Statistical Analysis System (SAS) - 1972 version, Institute of Statistics, North Carolina State University.

6. Shah, S. C., A Correlation of Various Smoothness Measuring Systems for Asphaltic Concrete Surfaces, Louisiana Department of Highways, Research Report No. 80, June, 1974.

APPENDIX A

STATISTICAL SPECIFICATIONS FOR ASPHALTIC CONCRETE

Section 501

Plant Mix Pavements—General

501.01 DESCRIPTION. These specifications include general requirements that are applicable to all types of bituminous pavements of the plant mix type regardless of the gradation of aggregate, kind and amount of bituminous material or pavement use. Deviations from these general requirements will be indicated in the specific requirements for each type.

This work shall consist of one or more courses of bituminous mixture constructed on the prepared foundation in accordance with these specifications and the specific requirements of the type under contract, and in reasonably close conformity with the lines, grades, thickness, and typical cross sections shown on the plans or established by the engineer. Work will be accepted on a lot basis as described in Subsection 502.04.

501.02 COMPOSITION AND QUALITY CONTROL OF MIXTURES. The bituminous plant mix shall be composed of a mixture of aggregate, filler, if required, and bituminous material with silicone blended together. The several aggregate fractions shall be sized, graded and combined in such proportions that the resulting mixture meets the physical characteristics of these specifications.

(a) **Quality Control of Mixes:** The contractor will assume full responsibility for the quality control of the mixes supplied to the Department. He will assume responsibility for the initial determination and all necessary subsequent adjustments in proportioning of materials used to produce the specified job mix and other physical characteristics. The contractor will have available at all times during the plant operation, the testing equipment necessary to perform the required tests and analyses.

The contractor shall be required to have a Certified Asphaltic Concrete Technician present at all times when the plant is in operation. A Certified Asphaltic Concrete Technician is that person who is capable of designing the asphaltic concrete mixes at the plant. He will also be capable of conducting any test and/or analyses necessary to put the plant into operation and to produce a mixture within the requirements of the specifications. The certification will be awarded by the Department upon satisfactory completion of an examination.

The Department's inspector will also be a Certified Asphaltic Concrete Technician and will not be authorized to assume by act or word the responsibility of testing and analysis of the mix for control purposes, calculations or the setting of dials, gages, scales and meters. Such duties are to be assumed only by the contractor.

In the event the contractor is not in a position to provide a Certified Asphaltic Concrete Technician as specified in the previous paragraphs for quality control of mixes, then the Department shall be so notified in writing prior to operation of the plant. Upon request from the contractor, the Chief Engineer may furnish a Certified Asphaltic Concrete Technician from within the Department's personnel, at a cost of $75.00 per day charge to the contractor. Additionally, the Department may also furnish an asphaltic concrete tester for $50.00 per day upon request. A day will be charged to the contractor whenever the technician reports to the plant to perform his duties in behalf of the contractor regardless of whether the plant runs several hours or not at all. Furnishing of an asphaltic concrete technician by the Department will not relieve the contractor of the responsibility of controlling the mix. The Chief Engineer may also authorize rental of the Department's laboratory testing equipment at a rate of $5.00 per day of possession.

(b) Job Mix Formula: No work shall be started nor any mixture accepted until the contractor has submitted in writing for approval, his job mix formula for the mixture he proposes to furnish. The formula so submitted shall indicate a single definite percentage of aggregate passing each required sieve size, a single percentage of bituminous material to be added to the aggregate, a single temperature at which the mixture is to be produced and the wet and dry mixing time.

(c) Approval of Job Mix Formula: The contractor will be given 2 days operation at the start of the project in order to make any necessary adjustments or corrections

in the proposed job mix formula and establish his construction procedures and sequences. A day's operation will be considered to be any day on which the plant is in operation for a period greater than 2 hours.

The contractor will be given an additional adjustment period whenever a change in mixture type or course is required by the specifications or plans and a change in the proportions of the various components is required to accomplish this. When the contractor elects to substitute a wearing course mixture for binder course, he will not be allowed the adjustment period when he starts the wearing course operations. However, in cases where the mixture being produced is used for patching or other incidental work, an additional adjustment period will be allowed, even though the mix is not changed.

The material produced and placed during this time shall be paid for at 100 percent of the contract unit price, provided it (1) meets the minimum requirements for 80 percent payment given in Schedules 1 and 2; (2) meets minimum requirements for 100 percent payment given in Schedule 3. If it does not meet this requirement it shall be paid for as provided in the schedules. In the event the job mix formula cannot be established during the adjustment period, then all the material produced after the second day shall be paid for in accordance with Subsection 502.12. Following the initial set up of the asphaltic concrete mix according to the contractor's submitted job mix formula, the plant shall operate at least 30 minutes prior to sampling of the mix by the engineer. Four trucks shall be sampled at random for determination of Marshall Test properties as based on one briquette per sample. Only two of these samples shall be analyzed for bitumen content and extracted gradation.

It is recommended that the average of four Marshall Stabilities, for approval of the job mix formula, conform to the desirable values given in Table I. The Contractor may have the option of submitting the job mix formula that does not meet these values, as long as the average of the four stability results meets the minimum requirements given in Table I. However, the contractor should be fully aware that if the design stability values are below the desirable values he is assuming a greater risk that the

Marshall Stabilities for acceptance obtained throughout the project will fall below the required value for 100 percent of the contract unit price.

Table I

Type of Mix	Marshall Stability @ 140°F, lbs. Desirable Values	Minimum Requirements	Flow 1/100"
Type 1, 2 & 4			
AC-1, BC & WC	1650	1200	15 Max.
AC-2, BC & WC	1500	1100	15 Max.
Type 3			
AC-3 Binder	1850	1400	15 Max.
AC-3 Wearing	2150	1700	15 Max.
Type 5(A) Base	1650	1200	15 Max.
Type 5(B) Base	1200	800	15 Max.
Shoulder	1400	1000	8-18

Dry and wet mixing time shall be such as to give a minimum coating of 95 percent of the coarse aggregate particles when tested in accordance with AASHO Designation: T 195. Other pertinent design properties shall be as specified by the Department's Laboratory. The bitumen content and extracted gradation shall be within the tolerances applied to the job mix formula initially submitted by the contractor.

The engineer may permit the contractor to change the job mix formula provided the changed job mix meets all the physical requirements of the specifications. This change shall be made in writing.

(d) Application of Job Mix Formula and Allowable Tolerances for Control of Mixes: Maintenance of adequate control on the quality of bituminous mixes shall be the responsibility of the contractor. In order to check this control, the contractor shall obtain a minimum of two samples of the mixture from each lot. A lot shall be considered as one day's production of a given mixture. He shall obtain these samples using a stratified random sampling plan. One of the samples shall represent the morning control and the other indicative of the afternoon control. The time at which to obtain these two samples shall be set by the contractor using random number tables in accordance with LDH Sampling Manual.

The contractor shall conduct his operations so as to produce a mixture conforming to the approved job mix formula except that variations shall be permitted within specified control limits for individual and average of two samples. Results of each lot shall be charted on the Control Charts for Individuals and Averages. The upper and lower control limits for individuals and averages shall be set at the following values from the specified job mix formula.

Table II

U.S. Sieve	Control Limits Individual	Average of 2 Tests
¾ inch and larger	±9	±6
½ inch	±12	±9
⅜ inch	±10	±7
No. 4	±10	±7
No. 10	±9	±6
No. 40	±7	±5
No. 80	±5	±4
No. 200	±3	±2
% Bitumen	±.6	±.4
Temperature of Mix °F*	±25	±25
Percent Crushed	Minimum Value as Specified in Subsection 903.07, Table VII	

*As based on the approved mixing temperature measured after discharge.

When the tendency of the individual test results on the charts indicate that the mix falls outside of the control limits for individuals, then the contractor shall make adjustments to bring the mix into the job mix formula.

Individual materials from more than one source shall not be used alternately nor mixed when used in surface courses without the written consent of the engineer. Where additional sources of materials are approved, a job mix formula shall be established and approved before the new material is used. When unsatisfactory results or other conditions make it necessary, the contractor may be required to establish a new job mix formula.

In the event a change in the job mix formula for the mixture being used is necessary, there will be no additional adjustment period and the mix produced during this period shall be paid for in accordance with Subsection 502.12.

501.03 AGGREGATES. Aggregates shall meet the requirements of Subsection 903.07.

501.04 **FILLER.** Filler shall meet the requirements of Subsection 903.07.

501.05 **BITUMINOUS MATERIALS.** The type and grade of bituminous materials will be specified in the plans or special provisions.

A silicone additive shall be dispersed in the asphalt cement by methods and in concentrations that are determined by the engineer. The silicone additive material shall be approved by the Department prior to use.

When Grade AC-3 or Grade AC-5 is specified, the grade may be changed by the engineer whenever applicable from AC-3 to AC-5, or from AC-5 to AC-3, as the case may be, at no change in unit price. When such a change is required, the engineer will give sufficient notice to the contractor to allow the changing of materials in tank. Only AC-3 grade asphalt will be used in Type 3 mixes.

The bituminous material shall meet the applicable requirements of Section 902, Bituminous Materials.

CONSTRUCTION REQUIREMENTS

501.06 **WEATHER LIMITATIONS.** Bituminous plant mix shall not be applied on a wet surface, except that material in transit at the time the plant operation is discontinued may be laid, subject to the end product meeting specifications. Placing of bituminous plant mix shall be discontinued when the descending air temperature in the shade and away from artificial heat falls below 45°F and shall not be resumed until the ascending air temperature in the shade and away from artificial heat reaches 40°F.

If the work consists of placing material in lift thicknesses 3½ inches or greater, then these temperature limitations shall not apply provided all other requirements of the specifications are met.

501.07 **BITUMINOUS MIXING PLANT.** The plant may be of either a batch or a continuous mixing type. All plants used by the contractor for the preparation of the bituminous mixture shall conform to all requirements of these specifications.

(a) Batch Plants:

(1) Uniformity: The plant shall be so designed, coordinated and operated as to produce a mixture within the specified tolerances of the job mix formula.

(2) Equipment for Preparation of Asphalt: Asphalt working tanks shall be capable of heating the material, under effective and positive control at all times, to the temperature requirements set forth in the specifications. The heating system shall provide uniform heating of the entire contents of the tanks. Heating shall be accomplished by steam coils, electricity or other approved means so that no flame shall come in contact with the heating tank. The circulating system for bituminous material shall be of adequate size to insure proper and continuous circulation during the entire operating period. All pipe lines and fittings shall be steam-jacketed or otherwise properly insulated to minimize heat loss. Working tank capacity shall be sufficient for satisfactory plant operation. In addition to working tanks, the contractor shall provide adequate storage of asphalt in order that the asphalt may be tested. The contractor shall also provide a calibration chart and a measuring stick for each tank to measure the amount of asphalt cement actually used when deemed necessary.

(3) Cold Aggregate Feeder: The plant shall be provided with accurate mechanical means for uniformly feeding the aggregate into the drier to secure a uniform production and a uniform temperature. The feeder or feeders shall be capable of delivering the maximum number of aggregate sizes required in their proper proportion. When more than one cold feed is used, each shall be fed as a separate unit, and the individual controls shall be integrated with a total master control. Mixing on the ground, at the plant site, of the various aggregates will not be permitted at any time.

(4) Drier: The plant shall include one or more driers that will continuously agitate the aggregates during the heating and drying process. The equipment shall be capable of heating and drying all aggregates specified in the necessary quantities to supply the mixing unit continuously at its operating capacity and at a specified temperature and moisture content.

(5) Screens: Plant screens capable of screening all aggregates to the sizes required for proportioning, and having normal capacity in excess of the full capacity of the mixer or the drier, shall be provided. The contractor shall expose the screens for inspection at the request of the engineer.

(6) Bins: The bin sizes shall be adequate for continuous operation of the plant at rated capacity. Bins shall be so arranged to insure separate and adequate storage of appropriate fractions of the aggregate. Adequate dry storage shall be provided for the mineral filler and provisions made for proportioning the filler for each batch of mixture. Each hot bin shall be provided with a overflow pipe or chute (except the mineral filler bin) to prevent contamination of materials. Each size of aggregate, as required, shall be stored in separate bins.

(7) Asphalt Control Unit: An approved means of weighing or metering shall be provided to obtain the required percentage of asphalt in the mix within the tolerances specified. Suitable steam-jacketing or other insulation for maintaining the specified temperature of asphalt in pipe lines, weigh buckets, flow lines or other containers shall be provided. Where the quantity of asphalt is controlled by metering, provisions shall be made whereby the amount of asphalt delivered through the meter may be readily checked by weight when deemed necessary.

(8) Thermometric Equipment: An armored thermometer of adequate range shall be fixed in the asphalt feed line at an approved location near the discharge valve at the mixer unit. The plant shall also be equipped with an approved mercury-actuated thermometer, a recording electric pyrometer or other approved thermometric instrument having an accuracy of ±5°F and a sensitivity which will provide an indication of temperature change at the rate of not less than 10°F per minute. It shall be so placed at the discharge chute of the drier to register automatically the temperature of the heated aggregate. The engineer shall have the right to test the efficiency of thermometric instruments for better control of asphalt, aggregate and mix tempera-

tures. The immediate repair or replacement of any defective or unsatisfactory instrument by some approved temperature recording apparatus will be required.

(9) Dust Collector: The plant shall be provided with a dust collection system meeting all federal, state and local requirements. All plants shall have mixer covers and such additional housing as may be necessary to insure the proper collection of dust.

(1) Plant Scales: Scales for any weigh box or hopper shall be the springless dial type and shall be of a standard make and design, accurate to ½ percent of the indicated load.

Dial scales shall be springless and of standard make. They shall be designed, constructed and installed in such a manner as to be reasonably free from vibration. They shall also be of such size that the numerals on the dial can be read at a reasonable distance. All dials shall be so located as to be plainly visible to the operator at all times. The end of the pointer shall be set close to the face of the dial and shall be free from excessive parallax. The accumulative weights shall be marked on scales.

Scales for the weighing of asphalt shall conform to the requirements for aggregate scales. Dial scales for weighing the asphalt shall read to the nearest pound. All scales for weighing the asphalt shall have a capacity which will insure accuracy within the tolerances specified elsewhere herein.

Scales shall be tested as often as deemed necessary to insure their accuracy. All weighing equipment shall be substantially constructed and of a design which will permit easy realignment and adjustment. Weighing equipment that easily gets out of adjustment shall be replaced when so ordered. The Department shall provide and have on hand at least ten 50-pound standard weights for frequent testing of all scales or provide other adequate means.

The test weights shall be kept clean and near the scales. The contractor shall provide for each scale a suitable cradle, or platform, for applying the test load so that the load is uniformly distributed. The contractor shall also provide an approved printer system which will print separately the weights of the aggregate and of the asphalt. The total of the printed weights, delivered to a truck, shall be the verification for issuing haul tickets for each load.

In the event of a breakdown of the printing mechanism, the contractor will be permitted to operate through a maximum period of 48 hours (two consecutive calendar days) from the time of the breakdown. During the breakdown period, the pay quantity will be determined by visual observation of the weighing operation by an authorized representative of the Department.

(11) Weigh Box or Hopper: Equipment shall include a means for accurately weighing each bin size of aggregate in a weigh box or hopper suspended on scales ample in size to hold a full batch without hand raking or running over. The weigh box or hopper shall be supported on a fulcrum; knife edges shall be so constructed that they will not easily be thrown out of alignment. Gates on both bins and hopper shall be so constructed as to prevent leakage when they are closed. Proportioning of aggregates and charging of mixer shall be performed so as to blend the aggregates thoroughly and prevent segregation in the mixer. Automatic plants may proportion and discharge all aggregate sizes simultaneously if provision is made to establish or control individual bin proportions by weight.

(12) Asphalt Measuring Equipment: Asphalt measuring equipment provided on the plant shall be capable of accurately measuring into each batch the required amount of asphalt within the tolerance of ±½ of one percent of the weight of asphalt.

The asphalt bucket shall be a non-tilting type provided with a loose sheet metal cover. The capacity of the asphalt bucket shall be at least 15 percent in excess of the weight of asphalt required for a one-batch mix. The plant shall have a steam or hot oil jacketed, quick closing, non-dripping, charging valve. The length of the discharge opening or spray bar shall not be less than ¾ of the length of the mixer, and it shall discharge directly into the mixer. The discharge system shall be designed and arranged to deliver the asphalt the full

length of the mixer in a thin, uniform sheet or in multiple streams or sprays.

(13) Mixer Unit: The plant shall include a batch mixer of an approved pugmill containing twin shafts and shall be steam or hot oil jacketed. It shall be capable of producing a uniform mix within the specified tolerances.

During mixing at full capacity, the paddle tips of the mixer shall remain exposed at the top of their periphery. In cases where the pugmill is designed to accommodate more mix than this, then the pugmill will be inspected by the engineer to determine its mixing capacity.

Deviation in size of batches will be permitted to provide for mixing batches 20 percent below the full capacity of the mixer, thus established, provided the *quality of the mix is not impaired.*

The clearance of the blades from all fixed and moving parts shall not exceed ¾ inch. The paddles shall be set in such a manner to insure a completely uniform mix. If not enclosed, the mixer box shall be equipped with a dust hood to prevent loss of dust. The mixer shall be so constructed as to prevent leakage of contents until the batch is to be discharged.

(14) Control of Mixing Time: The mixer shall have an approved accurate timing device to prevent the entrance of additional material while the mixing operation is in progress, and the discharge gates shall be locked to insure proper mixing. The device shall also lock the asphalt bucket throughout the dry mixing period. The dry mixing period is the interval of time between the opening of the weigh box gate and the application of asphalt. The wet mixing period is the interval of time between the start of the application of asphalt and the opening of the mixer gate for discharge.

(b) Continuous Mix Plants: It shall be the contractor's responsibility to furnish equipment that will produce a satisfactory paving mix. The plant shall meet the following minimum requirements.

(1) General Requirements: The requirements as set

forth under paragraphs 1 through 6, 8 and 9 for batch plants shall apply for continuous mixing type plants.

(2) Mixer Unit: The plant shall include a continuous mixer of an approved pugmill containing twin shafts capable of producing a uniform mix within the job mix tolerances specified. The paddles shall be of a type adjustable for angular position on the shafts and reversible to retard the flow of the mix. The clearance of the blades from all fixed and moving parts shall not exceed ¾ inch. The mixer shall carry a manufacturer's plate giving the net volumetric contents of the mixer at the several heights inscribed on the permanent gage.

(3) Asphalt Control Unit: Means shall be provided to obtain the required percentage of asphalt in the mix wherein the tolerances specified either by metering or volumetric measurements. Where the quantity of asphalt is controlled by metering, provisions shall be made whereby the amount of asphalt delivered through the meter may be readily checked by weight. Steam-jacketing or other insulation which will maintain the specified temperature of asphalt in pipe lines, meters, spray bars, flow lines or other containers shall be provided. A continuous recording device will be required on the discharge side of the asphalt pump to the pugmill. This device will record the amount of asphalt introduced into the mix.

(4) Gradation Control Unit: The plant shall include a means for accurately proportioning each bin size of aggregate by volumetric measurement. The unit shall include a feeder mounted under the bins with each bin compartment having an accurately controlled individual gate to form an orifice for volumetrically measuring the material drawn from it. The orifice shall be rectangular, with one dimension adjustable by positive mechanical adjustment, and provided with a lock. Indicators shall be provided on each gate to show the gate opening in inches. Mineral filler, if specified, shall be proportioned separately from a hopper equipped with an adjustable feed which may be accurately and conveniently calibrated and which shall be interlocked with the aggregate and asphalt feeds. The feeder equipment for the mineral filler shall meet the approval of the engineer.

(5) Weight Calibration of Aggregate Feed: Samples shall be taken and weighed as a means of calibrating gate openings. Material shall be fed out of a bin through the individual orifice and bypassed to an approved test box. The material from each compartment shall be taken separately. The plant shall be equipped to handle conveniently such test samples weighing not less than 200 pounds. An accurate platform scale shall be provided by the contractor to weigh the test samples.

(6) Synchronization of Aggregate and Asphalt Feed: Satisfactory means shall be provided to assure positive interlocking control between the flow of aggregate from the bins and the flow of asphalt from the meter or other proportioning device. This shall be accomplished by interlocking mechanical means or by any positive method approved by the engineer. The aggregate bins shall be provided with signal devices and controls which will warn of low levels and which will automatically stop the flow of all aggregate and asphalt to the mixer when the aggregate in any one bin is so low that the feeder will not operate at set capacity. The asphalt storage system shall be provided with signal devices and controls which will warn of low levels of asphalt and which will automatically stop the entire plant operation when the asphalt storage level is lowered to the point of exposing the feed end of the asphalt suction line.

If mineral filler is specified, the plant shall include separate equipment to accurately proportion the mineral filler sufficiently in advance of the addition of the bitumen to give a proper dry mix time. This equipment shall be of such design as to give a constant flow of the material and shall include a storage bin of sufficient capacity and an adjustable calibrated gate. The filler feed system shall be interlocked with the aggregate control system and feed the material by mechanical means. A gravity type feed will not be permitted.

(7) Control of Mixing Time: The plant shall be equipped with a positive means to govern the time

of mixing. Mixing time shall not be altered unless so ordered by the engineer.

The determination of mixing time shall be by a weight method under the following formula unless otherwise instructed by the engineer:

$$\text{Mixing Time, sec.} = \frac{\text{Pugmill Dead Capacity, lbs.}}{\text{Pugmill Output, lbs. per sec.}}$$

The weights shall be determined for the job from tests made by the engineer.

(8) Discharge Box: The plant shall be equipped with a discharge box of sufficient size to collect the mix as it comes out of the pugmill to prevent segregation.

(9) Truck-platform scales will be furnished by the contractor for the purpose of determining the pay weights of the mix when using a continuous mixing type plant. The scales furnished by the contractor shall be of sufficient length to weigh the entire unit transporting the mix and shall be the product of a reputable manufacturer and of a simple rugged design with the minimum number of adjustments consistent with the accuracy required, all as approved by the engineer. Suitable provisions shall be taken to protect all moving parts and to level the equipment. The scales shall be accurate to ½ of one percent of the loads applied.

The contractor shall have the scales certified by the State Bureau of Weights and Measures prior to their use and in the event there is cause to believe that the scales are performing incorrectly, he shall furnish additional certification.

The scales shall be equipped with an approved automatic printer system which will print the weight of the unit transporting the mix.

The printed weight of the loaded truck less the printed weight of the truck when empty shall be used as a basis for issuing haul tickets for each load.

(c) Storage Silos and Surge Bins: The contractor may use storage silos or surge bins for storing asphaltic concrete mixtures with the approval of the Department and provided it is not detrimental to the mix.

(1) Heated Storage Silos: The bins shall be such that mix drawn from the bin meets the same requirements

as mix loaded directly into the trucks from the pugmill for delivery to the job.

The system shall be capable of conveying the hot mix from the plant to the silo by means of a drag-slat conveyor system or other approved systems. The conveyor may be enclosed and heated to prevent a drop in the mix temperature; however, hot air shall not be blown on the mix. The conveyor shall be of a continuous type designed to prevent spillage and to remove the mix from the plant as fast as it is produced.

a. Heating: The silo shall be insulated and may be heated electrically, or with hot oil or hot air.

The atmosphere within the silo may be air or inert gas. The storage silo heating system shall be capable of maintaining the mix temperature without localized heating (hot spots). If inert gas is used, the inert gas system must be capable of purging the silo with an oxygen free (insert) atmosphere and then sealing the silo to prevent the loss of the inert gas.

b. Maximum Allowable Storage Time: The maximum allowable storage time of the hot mix in the heated storage silo shall be as follows:

	Storage Time-Hours	
	Fine Mix (3/4" max. agg. size)	Coarse Mix (1 1/2" max. agg. size)
1. Silicone treated asphalt, air in bin	36	18
2. Silicone treated asphalt, inert gas	144	72

After the storage silo is in use for some time, the Department may grant the contractor permission to exceed the above storage times, provided test results and other data indicate that the additional storage time is not detrimental to the mix.

(2) Unheated Surge Bins: The bins shall be such that the mix drawn from the bin meets the same requirements as mix loaded directly into the trucks from the pugmill for delivery to the job.

The system shall be capable of conveying the hot mix from the plant to the bin by means of a drag-slat conveyor system or other approved systems. The conveyor shall be of a continuous type designed to prevent spillage and to remove the mix from the plant as fast as it is produced. The maximum allowable storage time for unheated surge bins shall be two hours.

(3) General Requirements for Storage Silos and Surge Bins:

a. Transporting the Mix from the Pugmill: The mix may be transported directly from the pugmill to the storage silo or surge bins by means of the conveyor system or it may be trucked from the pugmill to the site of the storage silo or surge bin and then transported into the bin by means of the conveyor system, as long as the mix remains within ±15°F of the pugmill discharge temperature.

b. Unloading: The storage silo or surge bin unloading gates may be clam gates operating under gravity feed, or any other type gate which will not cause segregation or be detrimental to the mix in any way.

(4) Weighing Scales: Truck-platform scales shall be furnished by the contractor and positioned near the discharge gate in order that the total weight of mix discharged into the truck may be recorded. The scales shall be of sufficient length to weigh the entire unit transporting the mix and shall be the product of a reputable manufacturer and of a simple rugged design with the minimum number of adjustments consistent with the accuracy required, all as approved by the engineer. Suitable provision shall be taken to protect all moving parts and to level the equipment. The scales shall be accurate to ½ of one percent of the loads applied.

The contractor shall have the scales certified by the State Bureau of Weights and Measures prior to their use and in the event there is cause to believe that the scales are performing incorrectly, he shall furnish additional certification.

The scales shall be equipped with an approved automatic printer system which will print the weight of the transporting unit both unloaded and loaded. The printed weight of the loaded truck less the printed weight of the truck when empty shall be used as a basis for issuing haul tickets for each load. The printed weights

from the automatic printer system at the batch plant shall be used for verification only.

501.08 HAULING EQUIPMENT. Vehicles used for the transportation of hot mix asphalt from the plant to the site of the work shall have tight metal bottoms and shall be free from dust, screenings, petroleum oils and volatiles of other mineral spirits which may affect the mix being hauled. The truck beds shall be painted or sprayed at least once a day or as often as required with lime-water, soap solution or other approved materials. After this operation, the truck bed shall be elevated and thoroughly drained; no excess solution shall be permitted.

The trucks used for transporting of the mixture will be of such size that the lay-down machine or the paver being used will be capable of pushing them with ease without affecting the surface smoothness or the edge of the material. Any distortions in the surface finish resulting from improper unloading of the mixture shall be corrected immediately or removed and replaced. During placement of the final or top surface course, and when the mixture is being placed directly on the apron of the spreader, the trucks used for transporting the mixture shall be limited to loads of 15 tons or less.

Trucks shall be provided with covers of canvas or other material of sufficient size and weight to protect the load during adverse weather conditions.

When variations in size, speed and condition of trucks are such as to interfere with orderly operation, the engineer may order suitable substitutions to be made.

501.09 BITUMINOUS PAVERS. Bituminous pavers shall be one of two types: (1) the conventional self-powered spreading and finishing machine. (2) the self-powered spreading and finishing machine with electronic screed and slope control devices used in conjunction with a 30-foot traveling stringline or with an erected stringline as specified by the plans, special provisions or as directed by the engineer.

(a) **Conventional Pavers:** Bituminous pavers shall be capable of laying mixtures within the tolerances specified. A screed or strike-off assembly shall be used, distributing the mixture either over the entire width or over such partial width lanes as may be practicable. The assembly shall be adjustable to give the cross section shape as indicated on the plan typical sections. The screed shall be equipped with a heater.

Pavers shall be equipped with hoppers and distributing screws to place the mix evenly in front of adjustable screed. They shall be equipped with a quick and efficient steering device and shall be capable of traveling both forward and in reverse.

Pavers shall be capable of spreading mixes to required thickness without segregation or tearing.

Unless otherwise specified, when leveling is required by the plans, a blade grader may be used when approval is given by the engineer.

In shoulder construction, modified conventional spreaders or widener spreaders shall be provided.

(b) Bituminous Pavers with Electronic Screed Control: This type paver shall meet the same requirements as described above for conventional pavers and shall be equipped with automatic screed and slope control devices capable of laying the mixture to grade within the tolerances specified, distributing the mixture over the entire width or over such partial width lanes as may be practicable. Pavers shall be equipped with two sensors when specified.

The pavers shall be equipped to work from an erected stringline or a traveling stringline that will accurately reflect, for a 30-foot length, the average grade of the surface on which it is to be operated. Pavers shall also be equipped with a shoe attachment to control the grade of a lane being placed adjacent to a previously placed lane.

If a malfunction occurs in the electronic screed control device during lay-down operations, work may continue for the balance of that day on any course other than the final surface course. Any overrun resulting from placing material without the electronic screed control device shall be borne by the contractor. If a screed control device malfunctions during final surface course paving operations, plant operations shall be discontinued immediately and shall not be resumed until the screed malfunction has been remedied. Material in transit may be placed, provided all surface and grade tolerances are met.

501.10 ROLLERS. Rolling equipment shall consist of 10 ton three-wheel rollers, 10 ton tandem rollers, high intensity self-propelled pneumatic-tire rollers unless otherwise approved. Approval of other rollers will be at the discretion of the Department. A second tandem roller may be used in lieu of the three-wheel roller.

All rollers shall be capable of reversing without backlash. When necessary, additional rollers of an approved design shall be furnished.

Steel wheel rollers shall be equipped with adjustable scrapers to keep the rollers clean and with efficient means of keeping the wheels wet to prevent the mixture from sticking to the rollers. Rollers shall also be free of flat areas, openings or projections which will mar the surface of the pavement.

High intensity pneumatic-tire rollers shall be self-propelled and shall have 2 axles. The roller shall be capable of applying a range of contact or ground pressure from 50 to 90 psi. Tires will be smooth without any treads. All tires *of the same roller shall be of equal size and diaimeter* and shall be arranged in such a manner that the gap between the tires of one axle will be covered by the tires of the other. The pneumatic rollers shall be equipped with cocoa mats or suitable scrapers to prevent pickup. Suitable devices will also be provided to keep the mats damp.

When Type 3 or 5 mix is specified, in addition to the requirements given above, the high intensity pneumatic-tire rollers shall be capable of exerting a wheel load of 4,000 pounds.

501.11 INCIDENTAL EQUIPMENT AND HAND TOOLS. Power revolving brooms or power blowers and distributors shall be provided and maintained in a satisfactory working condition.

Tamping irons used to consolidate the edges of the binder and wearing courses shall be of sufficient weight to compact the edges to the same degree as the body of the pavement. Satisfactory mechanical equipment may be used instead of tamping irons.

The asphalt distributor shall be equipped with pneumatic tires of such width and design so that the load produced on the road surface shall not be detrimental to the previous course. The distributor shall be equipped with suitable manifold and appliance so designed as to distribute evenly heated material within the temperature range specified with positive controlled heat and temperature at all times, and shall be equipped with thermometers to indicate the temperature of the material in the tank. The distributor shall be so designed as to maintain a constant and uniform pressure upon the bituminous material as it passes through the nozzles.

Sufficient and proper screens shall be installed between the tank and the nozzles, and the screens shall be cleaned frequently to prevent clogging of the nozzles. The distributor shall be equipped with devices and charts to provide for accurate and rapid determination and control of the amount of bituminous materials being applied per square yard of surface under the operating conditions, and shall have a tachometer, reading speeds in feet per minute. The distributor shall be so designed as to apply bituminous material at the specified rate.

501.12 CONDITIONING OF EXISTING SURFACE. The surface to be covered shall be swept clean and free from all dust and dirt, caked clay and loose foreign material by means of revolving brooms or other approved mechanical sweepers supplemented by hand brooms, as directed.

When the bituminous mixture is to be placed on an existing pavement, the contractor shall, in addition to cleaning the surface as required above, remove excess joint filler from the surface. This does not relieve the contractor from maintaining, at his expense, the existing pavement.

Contact surfaces of curbs, gutters, manholes, longitudinal joints and other structures shall be painted with a thin uniform coating of tack coat before the bituminous mixture is placed against them.

The condition of the base shall be approved prior to the placing of the mixture.

501.13 PREPARATION OF BITUMINOUS MATERIAL. The bituminous material shall be heated to the temperature specified in the job mix in a manner that will avoid local overheating and provide a continuous supply of the bituminous material to the mixer at a uniform temperature at all times.

501.14 PREPARATION OF AGGREGATES. The aggregates for the mixture shall be dried and heated to the temperature required in the job mix. Flames used for drying and heating shall be properly adjusted to avoid damage to the aggregate and to avoid soot or oil coating on the aggregate.

The aggregate, immediately after heating and drying, shall be screened into 2 or more fractions as specified and conveyed into separate compartments ready for batching and mixing with bituminous material.

501.15 MIXING. The dried aggregates shall be combined in the mixer, in the amount of each fraction of aggregates required to meet the job mix formula. The bituminous material shall be measured or gaged and introduced into the mixer in the amount specified by the job mix formula.

After the required amounts of aggregate and bituminous material have been introduced into the mixer, the materials shall be mixed until a complete and uniform coating of the particles and a thorough distribution of the bituminous material throughout the aggregate is secured. Dry and wet mixing time shall be submitted by the contractor on the basis of a single determination and will conform to the minimum requirements given in Subsection 501.02(c).

501.16 JOINTS. The longitudinal joints in one layer shall offset that in the layer immediately below by approximately 3 inches; however, the joint in the top layer shall be at the centerline of the pavement if the roadway comprises 2 lanes of width, or at lane lines if the roadway is more than 2 lanes.

Transverse joints shall be formed by cutting back on the previous run to expose the full depth of the course. Transverse joints in succeeding courses shall be offset at least 2 feet. When directed, a brush coat of bituminous material shall be used on contact surfaces of transverse joints just before additional mixture is placed against the previously rolled material.

501.17 PAVEMENT SAMPLES. The contractor shall furnish for testing, when required, samples cut from the completed work. The area of pavement so removed shall be replaced with new mixture and refinished. No additional compensation will be allowed for furnishing test samples and replacing the areas with new pavement.

Samples of the finished roadway will be taken by the contractor in presence of the engineer's representative from areas selected by the engineer. Saws or core drills of an approved type will be required. The size of each sample shall be approximately 4 inches by 4 inches square or 4 inches in diameter.

501.18 REQUIREMENTS AND TOLERANCES FOR ACCEPTANCE.

(a) ***Job Control Testing:*** The control testing for surface tolerance will be the responsibility of the Department. The control testing will be required only on the binder course or shoulder mixes. The binder course will be defined as the last course to be laid prior to the wearing course.

The allowable variation in surface finish, cross slope and grade of the binder or shoulder mix shall not exceed the applicable values shown in Table III. If the plans and/or special provisions require the use of an automatic screed control device, then the allowable variation shown in Part A of Table III shall apply. If the use of an automatic screed control device is not required then the allowable variation shown in Part B of Table III shall apply.

The finished surface shall be tested by the engineer in both the longitudinal and transverse directions for conformance to the specifications for surface finish. The contractor shall furnish a 10 foot rolling straight edge acceptable to the engineer for testing in the longitudinal direction and a 10 foot static straight edge for testing in the transverse direction.

In the longitudinal direction, one path in each lane will be selected at random in accordance with LDH Sampling Manual. The lot will be divided into five equal sections and 200 feet of each section will be randomly selected and tested with the 10 foot rolling straight edge. The engineer may decide to test the entire lot. If the lot is less than 1,000 linear feet, then the entire lot will be tested.

The variations in the surface when tested for the tolerance shown in Table III shall not show more than 3 percent outside of the tolerance for a given lot. In the event that greater than 3 percent is outside the tolerance then the entire lot will be checked and the deviations corrected. In the transverse direction, random sites will be selected for testing. The variations of the surface from the testing edge contacts with the surface shall not exceed the applicable values shown in Table III. The variation in surface finish allowed by Table III shall apply to a 10 foot length.

(1) Cross Slope: When the plans or typical section require the section to be constructed to a specified cross slope, tests for conformance shall be run at selected locations, using a string line, slope board or other comparable method. The variation of the cross slope shall not exceed the applicable values shown in Table III. The variation in cross slope allowed by Table III shall apply to the width of one lane.

(2) Grade: When the plans require the pavement to be constructed to a grade, tests for conformance shall be run at selected locations, using a string line or other comparable method. Maximum deviation from grade shown on the plans, or as altered by the engineer, shall not exceed the values shown in Table III. If the engineer finds that the pavement as constructed is consistently above or below the proposed finish grade for a reasonably long segment, he may, for the sole purpose of determining conformance to the grade tolerance specified in Table III, use a new grade approximately parallel to and above or below the established grade; in which case, any required transition in grade or vertical curve at each extremity of the segment will be in accordance with the best design requirements. The variation in grade allowed by Table III shall apply to only one longitudinal line such as the center line, outside edge of pavement, etc. The engineer shall designate the longitudinal line to which this variation shall apply.

Table III

Type Mix	Allowable Variation							
	Part A — With Automatic Screed Control				Part B — Without Automatic Screed Control			
	Surface Finish				Surface Finish			
	Longitudinal	Transverse	Cross Slope	Grade (1)	Longitudinal	Transverse	Cross Slope	Grade (1)
BC 1, 2, 4	¼"	¼"	½"	½"	⅜"	⅜"	1"	½"
BC 3	¼"	¼"	⅜"	½"	¼"	¼"	⅜"	½"
Shoulder Mixes	—	—	—	—	3/16"	3/16"	¾"	¾"
Base Course	3/16"	3/16"	¾"	¾"	3/16"	3/16"	¾"	¾"

(1) Applicable only when grade is specified.

The intent of this specification is that 97 percent of all surface tolerance measurements per lot conform to this specification and that no single surface tolerance measurement exceed the specification requirements by more than ½ of the tolerance specified. If less than 97 percent meet these tolerances, all deficient areas shall be corrected.

(3) Correction of Deficient Areas: Any irregularities in the hot mix binder, shoulder course or base course may be corrected by either skin patching, featheredging, wedge course construction, or full depth patching, where appropriate, and where it can be completed in a satisfactory manner at no additional expense to the Department.

(b) Acceptance Testing: The acceptance testing will be required only on the wearing course. The surface shall be tested by the engineer, with a 10 foot rolling straight edge at stratified randomly selected longitudinal and transverse locations in accordance with LDH Sampling Manual. At the start of each project the rolling straight edge shall be calibrated by the District Laboratory according to LDH Designation: TR 603.

All testing will be made in a longitudinal direction.

A lot shall constitute one day's production of bituminous mix. The lot will be divided into five equal segments.

In each segment a 200 foot section will be randomly se-

lected and tested with the rolling straight edge. The per cent non-compliance shall be computed by adding the linear feet of each of the 200 foot sections of the lot that do not conform to the applicable tolerances given in Table IV, dividing that sum by 1000 (or the length of the lot if the lot is less than 1000 feet) and multiplying by 100 to convert to percent. If the lot is less than 1000 linear feet then the entire lot will be tested. The engineer may decide to test the entire lot for surface smoothness.

The surface tolerance for the wearing course shall be as shown in Table IV. When the total depth of mixture constructed consists of a single lift then Part B of Table IV shall apply for acceptance.

Table IV

Type Mix	Part A — With Automatic Screed Control — Surface Finish Longitudinal	Part B — Without Automatic Screed Control — Surface Finish Longitudinal
WC 1, 2, 4	1/8"	3/16"
WC 3	1/8"	1/8"

Whenever sections of pavement do not meet the requirements for surface tolerance, an adjustment in the unit price for the lot of the mixture shall be made as outlined in Subsection 502.12.

(c) Tolerances for acceptance of Type 5 base course or shoulder mixes when measured and paid for by cubic yard (net section):

(1) Surface Tolerances: The Type 5 base course when placed directly under Portland cement concrete pavement shall be finished in such manner that the Portland cement concrete pavement shall conform to the acceptance requirements of Section 601.

Type 5 base course other than under Portland cement concrete pavement and shoulder mixes shall conform to the surface tolerances as specified under Table III, and the material shall be placed in such a manner that the surface tolerances of the succeeding layers will be met.

(2) Thickness and Width Tolerances: Thickness and width of completed sections will be determined in accordance with LDH Designation: TR 602, except that acceptance measurements will be made at random locations to represent 1,000-foot sections in lieu of 500-foot sections.

Width of base course shall not vary from plan width in excess of minus 3 inches on each side of the roadway center line. Thickness measurements made at 3 locations in each section shall not vary in excess of the following tolerances for any individual test. Over-thickness will be waived.

Plan Thickness	Under-Thickness
4" and under	¼"
Over 4"	½"

If an individual test for thickness or width exceeds allowable tolerances, 2 additional tests will be made within 5 feet of the location of the failing test, and the average of the 3 tests will be used as the value for that location. Areas showing deficiencies beyond allowable tolerances shall be corrected at the contractor's expense.

501.19 *METHOD OF MEASUREMENT.* The asphaltic concrete will be measured as prescribed under Subsection 502.11.

501.20 BASIS OF PAYMENT. The accepted quantity of asphaltic concrete used in plant mix bituminous pavement will be paid for as provided in Subsection 502.12.

Section 502

Asphaltic Concrete Pavement

502.01 DESCRIPTION. This work shall consist of a base course, binder course and a wearing course or a combination of these courses, each consisting of a mixture of mineral aggregate and bituminous material with silicone added, applied hot on the prepared base in accordance with these specifications.

The type of mixture furnished shall be as indicated on the plans or if more than one type is indicated, whichever type the contractor elects, but in any event shall be one of the following 5 types:

(a) **Type 1 mix** shall be composed of the following:

(1) Wearing Course: Crushed gravel, crushed slag, crushed granite or a combination of these materials, sand, mineral filler and bituminous material.

(2) Binder Course: Crushed gravel, crushed stone, crushed granite, crushed slag or a combination of these materials, sand, mineral filler and bituminous material.

(b) **Type 2 mix** shall be composed of crushed clam shell, crushed reef shell or a combination thereof, sand, mineral filler (when needed) and bituminous material.

(c) **Type 3 mix** shall be composed of the following:

(1) Wearing Course: Crushed gravel, crushed slag, crushed granite combined with crushed gravel, slag, granite, stone or other approved types of screenings, sand, mineral filler and bituminous material.

(2) Binder Course: Crushed gravel, crushed slag, crushed stone, crushed granite or a combination of these materials, sand, mineral filler and bituminous material.

(d) **Type 4 mix** shall be composed of expanded clay aggregate, sand, mineral filler and bituminous material.

(e) **Type 5 mix—Base Course:**

(1) Mix 5A shall be composed of gravel, slag, granite, stone, reef shell, clam shell or expanded clay, sand, mineral filler (when needed) and bituminous material.

(2) Mix 5B shall be composed of gravel, slag, granite, stone, reef shell, clam shell, expanded clay, sand and bituminous material; or pit run sand clay gravel and bituminous material.

The thickness of courses shall be in approximate conformity with the plan typical sections unless otherwise specified. In the event the plans and/or proposal provides for both binder and wearing courses, the contractor will be permitted, at his option, to substitute wearing course material for binder course material at no change in unit price. Should the contractor elect to make such substitution, the mixture will be laid in layers of such thickness that the compaction and surface requirements are met. No substitutions are allowed for Types 3 and 5 mixtures.

The mineral aggregate and bituminous material in the mixtures shall be combined in such proportions that the mixture shall meet the following requirements by weight:

Mix	Bitumen, Percent	Min. Agg. Percent	% Crushed Ret. on #4	% Mineral Filler Minimum*
Type 1:				
WC	3.5 to 7.0	93.0 to 96.5	75 Min.	3
BC	3.0 to 6.0	94.0 to 97.0	60 Min.	2
Type 2:				
WC & BC	4.5 to 7.5	92.5 to 95.5		As Needed
Type 3:				
WC	3.5 to 7.0	93.0 to 96.5	80 Min.	2
BC	3.0 to 6.0	94.0 to 97.0	60 Min.	2
Type 4:				
WC & BC	6.0 to 8.5	91.5 to 94.0		2
Type 5:				
Base Courses				
(A)	3.0 to 8.5	91.5 to 97.0	As Needed	As Needed
(B)	3.0 to 8.5	91.5 to 97.0		

*When hydrated lime is used only ½ as much filler will be required.

502.02 MATERIALS. The materials and their use shall conform to the requirements of Subsections 501.02 through 501.05.

CONSTRUCTION REQUIREMENTS

502.03 GENERAL. The construction requirements shall be as prescribed in Subsections 501.06 through 501.18.

502.04 PHYSICAL PROPERTIES OF MIXTURE. The contractor shall design his mix with the intent that compacted specimens of the mixture shall conform to the properties in Table V when tested in accordance with LDH Designation: TR 305, for an average of four samples taken from each lot after it is placed in the trucks using random sampling procedures. A lot shall be considered as one day's production of bituminous mix. A stratified random sampling plan shall be utilized such that two of the four samples are obtained during the morning and the other two during the afternoon using LDH Sampling Manual. The time at which these acceptance samples are obtained from the trucks shall be set by the engineer using random number tables.

Compaction of mixtures for Marshall Stability and Flow determination shall be conducted by the engineer's personnel at the plant. The testing and final approval of the mixture will be done by the Department personnel.

When the average of four tests is outside of the acceptance limits specified for the average of the four test results for Marshall Stability, an adjustment in the unit price for the lot of the mixture shall be made as further outlined. No adjustment in the unit price will be made for mixture being outside the limits on the individual results except as noted below.

When it is not possible to sample the whole lot (four samples) due to unfavorable circumstances caused by plant breakdown or inclement weather or other causes, then the acceptance limits will be as shown in Table V as based on the number of tests made during the time the plant was in operation. In no event will the number of tests or samples be less than four for eight hours of plant operation and less than two for four hours of operation.

In the event the plant operates for less than four hours and only one sample has been obtained, then the mix will be accepted on the basis of limits for one sample.

When the average of the number of tests representing the period the plant was in operation for the day is outside the acceptance limits for Marshall Stability shown in Table V for the average of the number of samples tested during the day, an adjustment in the unit price for the lot of the mixture represented by the number of samples shall be made as further outlined in Subsection 502.12. No adjustment in the unit price shall be made for mixes being outside the limits on the flow for the average of the lot or the individual test result.

502.05 HANDLING OF AGGREGATES. Coarse and fine aggregates shall be stored at the plant in such a manner that the separate sizes will not become intermixed.

The aggregate screenings shall be stored at the plant in separate stockpiles.

When stockpiling, the material shall be placed in such a manner as to minimize segregation of aggregate sizes.

Blending of aggregates in stock piles or on the ground at the plant site shall not be permitted.

(a) **Drying:** The aggregate shall be heated and dried to provide a paving mix meeting the requirements of these specifications.

The quantity of the material fed through the drier shall, in all cases, be held to an amount which can be adequately heated and dried. In the event proper drying is not achieved and the quality of the mix is impaired the contractor shall adjust the rate of production of the drier, as required to obtain satisfactory results. The discharge chute of the drier and the discharge end of the asphalt line shall be equipped with pyrometric or thermometric devices, acceptable to the engineer, to assure that proper temperatures are being maintained.

(b) **Screening:** Aggregates shall be screened into sizes such that they may be recombined into a gradation meeting the requirements of the job mix formula.

(c) **Hot Aggregate Storage:** Hot screened aggregate shall be stored in bins as required in Subsection 501.07. Storage shall be accomplished in such a manner as to minimize segregation and loss of temperature of the aggregate. In the event the plant operation is interrupted and the temperature of the material in the hot storage cools to 25°F

Table V

Type of Mix	Acceptance Limits for Marshall Stability Average of: (Samples)				Control Limits for Flow Average of: (Samples)			
	4	3	2	1	4	3	2	1
Type 1, 2, 4								
AC-3, BC & WC	1200 Min.	1150 Min.	1050 Min.	900 Min.	15 Max.	15 Max.	15 Max.	18 Max.
AC-5, BC & WC	1100 Min.	1050 Min.	1000 Min.	800 Min.	15 Max.	15 Max.	15 Max.	18 Max.
Type 3								
AC-3 BC	1400 Min.	1350 Min.	1250 Min.	1050 Min.	15 Max.	15 Max.	15 Max.	18 Max.
AC-3 WC	1700 Min.	1600 Min.	1500 Min.	1250 Min.	15 Max.	15 Max.	15 Max.	18 Max.
Type 5 Base Course								
AC-3(A)	1200 Min.	1150 Min.	1050 Min.	900 Min.	15 Max.	15 Max.	15 Max.	18 Max.
AC-3(B)	800 Min.	750 Min.	700 Min.	600 Min.	15 Max.	15 Max.	15 Max.	18 Max.
*AC-5(B)	800 Min.	750 Min.	700 Min.	600 Min.	15 Max.	15 Max.	15 Max.	18 Max.
**Shoulder, BC & WC All types	1000 Min.	950 Min.	900 Min.	800 Min.	8-18	8-18	8-18	6-20

*AC-5 When used under concrete pavement and the mix will be tested using 50 blows of the compaction hammer.
**Shoulder mixes will be tested using 50 blows of the compaction hammer.

or more below the specified mixing temperature, the bins shall be pulled and the material discarded.

502.06 PREPARATION OF ASPHALT AND AGGREGATES. The asphalt and aggregate at the time of mixing shall be heated to a temperature of not less than 275°F and not more than 350°F.

The temperature of the bituminous mixtures, when discharged from the mixer shall be within the limits prescribed in Table II of Subsection 501.02.

The dried mineral aggregate for any of the various type mixtures shall be combined in the plant in the proportionate amount of each fraction of aggregate required to meet the job mix formula. The bituminous material shall be measured and introduced into the mixer. Prior to adding bituminous material, the combined mineral aggregate shall be thoroughly mixed dry, after which the proper amount of asphalt shall be sprayed over the mineral aggregate and mixed to produce a homogeneous mixture in which all particles of the mineral aggregate are uniformly coated. The mixing time shall be submitted by the contractor in the job mix formula and approved by the engineer. Suitable locking means shall be provided for this regulation.

Aggregate contaminated with carbon or oil will be rejected.

502.07 TACK COAT. Before constructing each course, a tack of the width indicated on the plans shall be applied if needed at the rate specified by the engineer, but not to exceed 0.05 gallon per square yard. When the bituminous mixture is placed on an asphalt surface, the tack coat may be eliminated if directed. The responsibility for the protection of the tack coat shall rest with the contractor, and spot-patching required shall be made at no extra cost.

The tack coat shall meet the requirements of Section 503.

Asphaltic concrete shall not be applied on the bituminous surfaced or primed base until the surface or tack coat has completely cured to the satisfaction of the engineer.

In the event asphaltic concrete is to be placed on an aggregate type base course, the contractor shall use bituminous primer as described in Section 504 in lieu of the tack coat required herein.

In the event the primer has dried out or is otherwise

insufficient prior to laying the asphaltic concrete, the contractor shall, at his expense, re-prime the base or apply a light tack coat as directed; however, in any event, the primed surface shall be completely cured to the satisfaction of the engineer.

502.08 SPREADING AND FINISHING. Bituminous mixtures, heated and prepared as specified, shall be transported from the mixing plant to the site of the work as specified in Subsection 501.08. No loads shall be sent out so late in the day as to prevent completion of the spreading and compaction of the mixture during daylight, unless artificial light is provided. The mixture shall be delivered at a temperature of not more than 25°F below the minimum allowable temperature of the mixture when discharged from the mixer as specified in Subsection 502.06.

The laying operations shall be conducted in the following manner:

(a) Coordination of Production: The contractor shall coordinate and manage the plant production, the transportation of the mix and the laying operation to achieve a high quality pavement. He shall have sufficient transporting vehicles to insure more or less continuous plant and roadway operation with a minimum idle time between loads. The Department reserves the right to order a halt to operation in the event sufficient hauling vehicles are not available. If less than the optimum number of hauling vehicles are available and it is determined that satisfactory quality can be obtained, the contractor will be permitted to work provided the plant production and the hauling vehicles are coordinated to minimize the effect of idle time between loads.

(b) Mechanical Spreaders: The spreaders used shall be approved self-powered and propelled spreading machines and shall be one of the two types: (1) the conventional mechanical spreader or (2) mechanical spreader with electronic screed and slope control devices used in conjunction with a 30-foot traveling stringline or with an erected stringline as specified by the plans, special provisions or as directed by the engineer.

The approved spreading machine shall be capable of spreading and finishing the base, binder and surface courses to required line, grade and cross section without the use of forms or side supports. Finishing machines shall be operated so that material does not accumulate and remain along the sides of the receiving hopper. Screed shall be equipped with a suitable, controlled heating device to be used as required.

In the event the spreading and finishing operation is interrupted for a period of time and some of the mixture remaining in the trucks, spreader, spreader hopper, and/or on the roadway cools to where it cannot be laid, finished and/or compacted to the same degree of smoothness and with the same texture and density as the un-cooled mixture, the cooled mixture shall be removed and replaced at the contractor's expense.

Heading (b) is expanded to include the following additional requirements for mechanical spreaders when electronic screed control is required.

(1) Electronic Screed Control with 30-Foot Traveling Stringline: The initial lane of each course to be laid, whether it be wearing, leveling, base, binder, or a combination of any of these courses, shall be constructed in the approximate lifts shown on the plans using the traveling stringline method; however, if field conditions warrant, the portion of the leveling course required to level isolated depressions may be placed without the electronic screed control device.

After the initial lane of each course is finished and compacted, the adjacent lane or lanes on that course shall be laid to the grade of the initial lane, using a small (approximately 6") shoe to control grade and controlling the cross slope with the slope control device.

If field conditions warrant, the traveling stringline may be used to control the grade of any adjacent lane on all courses with the exception of the final wearing course.

In cases where both of the outside edges of the lane being placed are flush with previously placed material, the slope device shall not be used.

When three or more contiguous lanes are to be constructed, the order of construction shall be as directed, and courses placed in lanes which are not adjacent to a lane previously placed with the traveling stringline shall be constructed using the traveling stringline.

In superelevated curves, the cross slope shall be changed from that specified for tangents to that specified for superelevation in gradual increments as the paver is in motion so that smooth transition in grade is obtained. This change in cross slope shall be accomplished within the transition distance specified.

(2) Electronic Screed Control with Erected Stringline: The initial lane of the first course to be laid, whether it be leveling, base, binder or a combination of any of the three, shall be controlled by an erected stringline referenced to grade stakes established by the engineer; however, if field conditions warrant, the portion of the leveling course required to level depressions may be placed without the electronic screed control device.

The paver shall be positioned and operated to closely follow the established line. Only one sensor and the slope control device are necessary for normal crown on tangents. Superelevated curves will require the use of two sensors and two erected stringlines to obtain proper grade and slope; however, if the electronic screed control device furnished by the contractor is equipped with a dial or other device which can be conveniently used to change the cross slope in small increments, superelevated curves may be constructed using this device and one erected stringline.

After the initial lane of the first course is finished and compacted, the adjacent lane or lanes on the first course will be laid to the grade of the inital lane, using a small (approximately 6") shoe to control grade and controlling the cross slope with the slope control device.

If field conditions warrant, the traveling stringline may be used to control the grade of any adjacent lane on all courses with the exception of the final wearing course.

In superelevated curves, erected stringlines will be used to control the grade of the edge opposite the initial lane; however, if the electronic screed control device furnished by the contractor is equipped with a dial or other device which can be conveniently used to change the cross slope in small increments, superelevated curves may be constructed using this device and one erected stringline. Subsequent courses may be controlled by use of the traveling stringline attached to the paver, provided all surface and grade tolerances are met on the previous course.

In cases where both of the outside edges of the lane being placed are flush with previously placed material, the slope device will not be used.

In cases where only one course is to be constructed in one lift, the first lane laid will be controlled by use of an erected stringline referenced to grade as described above. The adjacent lane or lanes will be controlled as described above.

When three or more contiguous lanes are to be constructed, the order of construction shall be as directed, and subsequent first course lanes which are not adjacent to a previously placed initial lane shall be considered an initial lane.

Transfer of the asphaltic mixture from the haul truck to the spreader may be made by direct unloading into the spreader hopper, by use of approved mechanical loading devices or by direct dumping on the pavement. When the mixture is dumped directly on the pavement, approved loading equipment will be used to transfer the mixture into the finishing machine, and the equipment shall be constructed and operated in such a manner that substantially all of the mixture deposited on the roadbed is picked up without contamination by foreign material. In any case, the equipment will be so designed and operated that the finishing machine will place the mixture to the required line, grade and surface without resorting to hand finishing. Any operation of the equipment resulting in the accumulation and subsequent shedding of this accumulated material into the asphaltic mixture will not be permitted.

Equipment which leaves tracks or indented areas which cannot be corrected in normal operations, or which produces flushing or other permanent blemishes or fails to produce a satisfactory surface shall not be used.

Longitudinal joints and edges shall be constructed to reasonably true line markings. Lines shall be established by the engineer parallel to the centerline of the proposed roadway, and stringlines or other devices will be placed by the contractor for the paver to follow in placing individual lanes. The paver shall be positioned

and operated to closely follow the established line. In backing trucks against the spreader, care shall be taken not to jar the finisher out of its proper alignment. Delivery of material to the paver shall be at a uniform rate and in an amount well within the capacity of the paving and compacting equipment.

As soon as the first load of material has been spread, the texture of the unrolled surface shall be checked to determine its uniformity. The adjustment of the screed, tamping bars, feed screws, hopper feed, etc., shall be checked frequently to assure uniform spreading of the mix to the proper line and grade and adequate initial compaction. Segregation of materials shall not be permitted. If segregation occurs, the spreading operation shall be immediately suspended until the cause is determined and corrected.

Longitudinal and transverse joints shall be formed as provided in Subsection 501.16.

Any irregularities in alignment left by the paver shall be corrected by trimming directly behind the machine. Immediately after trimming, the edges of the course shall be thoroughly compacted by tamping. Distortion of the pavement during this operation shall be avoided.

Edges against which additional material is to be placed shall be reasonably formed to lines and approximately vertical. Any irregularities in the surface of the pavement course shall be corrected directly behind the paver. Excess material forming high spots shall be removed. Indented areas shall be filled with hot mix and finished reasonably smooth. Casting of material over the surface shall not be permitted whenever wearing course is being laid.

The outside edge of the freshly laid mixture shall be tamped behind the spreader prior to rolling to reasonably vertical edge whenever base or binder courses are being laid, and to approximately 45° beveled edge when the wearing courses are being laid.

In the event the spreading and finishing operation is interrupted for a period of time and some of the mixture remaining in the trucks, spreader, spreader hopper, loading equipment and/or on the roadway cools to where it cannot be laid, finished and/or compacted to the same degree of smoothness and with the same texture and density as the uncooled mixture, the cooled mixture shall be removed and replaced at the contractor's expense.

(c) **Hand Spreading:** In small areas where the use of mechanical finishing equipment is not practical, the mix may be spread and finished by hand. Approved wood or steel forms, rigidly supported to assure reasonably correct grade and cross section, may be used. In such instances, measuring blocks and intermediate strips shall be used to aid in obtaining the required cross section. Placing by hand shall be performed carefully; the material shall be distributed uniformly to avoid segregation of the coarse and fine aggregates. During the spreading operation, all material shall be thoroughly loosened and uniformly distributed. Material that has formed into lumps and does not break down readily shall be rejected. Following placing and before rolling, the surface shall be checked and all irregularities corrected.

502.09 COMPACTION. After spreading and striking off and while still hot, each course shall be thoroughly and uniformly compacted by rolling.

The highest contact pressure that will give the required density will be used for the pneumatic roller.

The pneumatic-tire roller shall be kept approximately 6 inches from the unsupported center line joint when only one lane is in place. However, when both lanes are down, it shall be overlapped at least 6 inches to get additional sealing of the joint.

Additional rollers may be required as necessary to meet the compaction and smoothness requirements.

Rolling shall be conducted in such sequence and by methods that will obtain the specified density and smoothness requirements. Each roller shall be operated by a competent, experienced operator and, while the work is under way, shall be kept as nearly as practicable in continuous operation.

The motion of the roller at all times shall be slow enough to avoid displacement of the hot mixture. Any displacement occurring as a result of the reversing of the direction of the roller or from any other causes shall be immediately corrected. To prevent adhesion of the mixture to the roller, the

wheels shall be kept properly moistened, but excess water will not be permitted.

Along forms, curbs, headers and walls and at other places not accessible to the roller, the mixture shall be thoroughly compacted with hot hand tampers or with mechanical tampers to obtain a satisfactory density.

The surface of the mixture after compaction shall be smooth and true to the established crown and grade within the tolerances specified. Any mixture that becomes loose, broken, contaminated or in any way defective shall be removed and replaced with fresh hot mixture which shall be immediately compacted to conform with the surrounding area.

Rolling shall continue until all roller marks are eliminated. Upon completion of the rolling procedure, five pavement samples shall be obtained from each compacted lot at locations determined in accordance with the stratified random sampling plan within 24 hours after placement of the mix. In the event this falls on a day the contractor's crews are not working then the sampling will be done the following day. A lot shall be considered as the number of linear feet of mix laid during the day's operation. The linear feet laid during the day shall be subdivided into five sections of approximately equal length and one sample shall be obtained from each of the five sections using random number tables. In no event will the number of samples representing a full day's production or a fraction thereof be less than five. The density requirement for individual samples and for the average of five samples shall be as prescribed in Table VI when determined in accordance with LDH Designation: TR 304.

Payment will be made as outlined in Subsection 502.12 of these specifications. No adjustment in the unit price will be made for density tests outside the limits for individual test.

In the event the sampling location as determined by random sampling procedures indicates obvious bad spots that are to be replaced or falls within two feet of the edge of the pavement, then an additional sampling location shall be determined and used. Any section that is obviously bad and may be detrimental to the roadway shall be corrected or replaced regardless of whether it was selected by random or visual observation.

Table VI

Type of Mix		Acceptance Limits Average 5 Samples	Control Limits Individual Samples
Traffic Lanes	1 and 4	95% min. of briq. density	92% min. of briq. density (75 blows)
Traffic Lanes	2	92% min. of briq. density	89% min. of briq. density (75 blows)
Traffic Lanes	3-WC & BC	95% min. of briq. density	92% min. of briq. density (75 blows)
Traffic Lanes	5 A	95% min. of briq. density	92% min. of briq. density (75 blows)
Traffic Lanes	5 B	95% min. of briq. density	*92% min. of briq. density (75 blows)
Shoulders	1, 2, 3 & 4	94% min. of briq. density	91% min. of briq. density (50 blows)

*When Type 5 B is to be placed under concrete pavement, briquette density will be obtained by 50 blows of the compaction hammer.

502.10 PROTECTION OF PAVEMENT. Sections of newly finished pavement shall be protected from traffic until the pavement has sufficiently hardened.

502.11 METHOD OF MEASUREMENT. Measurements will be made by one of the following methods as indicated.

(a) Weight Measurements: Aggregates inclusive of mineral filler, and asphalt will be measured by the ton of 2,000 pounds.

When the mixture is produced in a batch plant, measurement of aggregates and asphalt total weight will be determined from the printed weights as provided in Subsection 501.07, Part A, Paragraph 10.

When the mixture is produced in a continuous mixing plant, measurement of the composite mix will be determined from the printed weights as provided in Subsection 501.07, Part B, Paragraph 9.

When the mixture is supplied from storage silos and surge bins, measurement will be determined from the printed weights as provided in Subsection 501.07, Part C, Paragraph 4.

Haul tickets will be issued for each truck load of material delivered. Material lost, wasted, rejected or applied contrary to these specifications will not be measured for payment.

The estimated quantities shown on the plans and in the proposal are based on Type 1 or Type 3 mixes. Should the contractor elect to use any of the other allowable mix types, as shown on the plans, the quantity actually used will be measured and such quantity multiplied by the factor given below for the type used to obtain the quantity for payment.

Type 1, 2 (Clam Shell) and 3	1.000
Type 2 (Reef Shell)	1.030
Type 4	1.325
Type 5	The appropriate factor for the type of aggregate selected.

The aggregate components for each type mixture may vary due to possible variations in specific gravity. No adjustment will be made for aggregate quantity variation inside the type mixture used.

When a combination of clam shell and reef shell are used for the Type 2 mixture the factor used will be 1.000.

(b) Net Section Measurements: Aggregates inclusive of mineral filler and asphalt will be measured by the cubic yard (net section) as indicated on the plans. Measurements will be based on the typical sections shown on the plans and the length will be measured along the surface at the center line of each roadway. Bituminous mixtures for turnouts, ramps, and other irregular sections, if required on the plans, will be calculated volume as constructed and determined by the engineer.

Shoulders, when shown on the plans to be separate from the roadway, will be measured by the cubic yard (net section) from dimensions shown on the plans; however, the actual length of the completed shoulders will be measured along the edge of shoulder adjacent to the roadway travel lane.

502.12 BASIS OF PAYMENT. The accepted quantity of asphaltic concrete will be paid for at the contract unit price per unit of measurement on a lot basis.

Whenever the mix does not conform to the requirements for acceptance of mixes as provided in Subsections 501.18, 502.04 and 502.09, payment will be made at an adjusted unit price per unit of measurement of asphaltic concrete in accordance with the following.

(a) **Adjustment for Stability:** When the mix is to be accepted on the basis of the average of four, three, two or one Marshall Stability test results, then the payment per unit price shall be made as outlined in Schedule No. 1-A, 1-B, 1-C, or 1-D respectively for the lot.

(b) **Adjustment for Roadway Density:** For roadway density, the payment per unit price shall be adjusted as in Schedule No. 2 for the average of five samples in a lot.

(c) **Adjustment for Surface Tolerance:** For surface tolerances, when measured by a 10 foot rolling straight edge, the payment per unit price shall be adjusted as in Schedule No. 3 for the lot.

(d) **Final Adjustment in Unit Price Per Lot:**

(1) Wearing Course Mixes: The lower percent of contract price shall be used for final adjustment in unit price for mixes deficient in Marshall Stability, roadway density and surface tolerances.

(2) Base, Binder and Shoulder Mixes: The lower percent of contract price shall be used for final adjustment in unit price for mixes deficient in Marshall Stability and roadway density.

Surface tolerances for base, binder and shoulder mixes will be controlled in accordance with Subsection 501.18 for job control testing.

(e) Asphalt Cement: In addition to the price adjustment for the mix, if the asphalt cement furnished does not conform to the specifications, then the final test results for asphalt cement will be applied to the appropriate schedule of Section 902 for Bituminous Materials for price adjustments and an adjustment in unit price shall be made as specified.

Payment will be made under:

Item No.	Pay Item	Pay Unit
502(5)	Asphaltic Concrete (Type ________) (________ Course)	Ton
502(6)	Asphaltic Concrete (Net Section) (Type ________) (________ Course)	Cubic Yard

Schedule No. 1

ADJUSTMENT IN BID PRICE PER UNIT OF MEASUREMENT FOR MARSHALL STABILITY

Type 1, 2, 4 WC, BC Type 5A Base AC-3	Type 1, 2, 4 WC, BC AC-5	Type 3 Binder AC-3	Type 3 Wearing AC-3	Type 5B AC-3 or AC-5	Shoulder Mix AC-5	Percent of Contract Unit Price/Per Lot
A	Average of Four Marshall Stability Results					
1200 & higher	1100 & higher	1400 & higher	1700 & higher	800 & higher	1000 & higher	100% Payment
1100 to 1199	1050 to 1099	1300 to 1399	1550 to 1699	750 to 799	900 to 999	95% Payment
1000 to 1099	900 to 999	1150 to 1299	1350 to 1549	700 to 749	800 to 899	80% Payment
Below 1000	Below 900	Below 1150	Below 1350	Below 700	Below 800	50% or Remove
B	Average of Three Marshall Stability Results					
1150 & higher	1050 & higher	1350 & higher	1600 & higher	750 & higher	950 & higher	100% Payment
1100 to 1149	1000 to 1049	1300 to 1349	1525 to 1599	700 to 749	900 to 949	95% Payment
1000 to 1099	900 to 999	1150 to 1299	1350 to 1524	650 to 699	850 to 899	80% Payment
Below 1000	Below 900	Below 1150	Below 1350	Below 650	Below 850	50% or Remove
C	Average of Two Marshall Stability Results					
1050 & higher	[illegible] & higher	1250 & higher	1500 & higher	700 & higher	900 & higher	100% Payment
1000 to 1049	[illegible] to 999	1200 to 1249	1425 to 1499	650 to 699	850 to 899	95% Payment
900 to 999	[illegible] to 949	1050 to 1199	1250 to 1424	600 to 649	800 to 849	80% Payment
Below 900	[illegible] 900	Below 1050	Below 1250	Below 600	Below 800	50% or Remove
D	One Marshall Stability Test Result					
900 & higher	[illegible] higher	1050 & higher	1250 & higher	600 & higher	800 & higher	100% Payment
Below 900	[illegible]	Below 1050	Below 1250	Below 600	Below 800	50% or Remove

Schedule No. 2

ADJUSTMENT IN BID PRICE PER UNIT OF MEASUREMENT FOR ROADWAY DENSITY

Average of Five Roadway Samples

Type 1, 4, 5B	Type [illegible] WC & B[illegible] Type 5A	*Type 2* WC & BC	Shoulder Mix	Percent of Contract Unit Price/Per Lot
95 & higher	95 & higher	92 & higher	94 & higher	100% Payment
94 to 94.9%	94 to 94.9%	90 to 91.9%	93 to 93.9%	95% Payment
92 to 93.9%	92 to 93.9%	89 to 89.9%	91 to 92.9%	80% Payment
Below 92%	Below 92%	Below 89%	Below 91%	50% or Remove

Schedule No. 3

ADJUSTMENT IN BID PRICE PER UNIT OF MEASUREMENT FOR SURFACE TOLERANCE

Linear Percent of Sample Exceeding Surface Tolerance		Percent of Contract Unit Price/Per Lot
1/8" Tolerance*	3/16" Tolerance*	
0.0 to 1.0	0.0 to 0.50	100% Payment
1.1 to 1.5	0.51 to 0.75	95% Payment
1.6 to 2.5	0.76 to 1.5	80% Payment
2.6 or More	1.6 or More	50% or Remove

*The individual surface tolerance requirements for various types of mixes are given in Subsection 501.18.

APPENDIX B
MISCELLANEOUS TABLES

TABLE B1

PENALTIES FOR VARIOUS ACCEPTANCE CRITERIA AND MINIMUM PAY

PROJ	MIX	LOT	TONS	PAYS	PAYC	PAYT	PAYF
A02	4	3	525		95		95
A06	1	16	1056		95		95
A06	1	19	655		95		95
A07	5	26	1448	80			80
A07	5	29	725	80			80
A08	1	12	223			50	50
A08	1	14	384			95	95
A14	7	11	385		95		95
A14	7	17	910		95		95
A14	7	19	898		80		80
A14	7	20	274		80		80
A19	3	15	578		95		95
A19	3	16	654		95		95
A20	1	2	714			95	95
A20	1	4	700			95	95
A20	1	6	851			80	80
A21	3	13	572		80		80
A21	3	14	375		95		95
A21	3	15	555			95	95
A21	3	16	622			95	95
A21	3	17	623		50		50
A21	3	18	540			50	50
A21	3	19	265			95	95
A21	3	23	552			95	95
A21	4	3	540		95		95
A21	4	5	435		95		95
A21	4	8	690		95		95
A21	4	10	471		95		95
A22	5	36	405			95	95
A22	5	38	562			80	80
A22	5	39	637			80	80
A22	5	40	307			80	80
A23	5	23	574			95	95
A29	5	8	125		80		80
A29	5	9	293		80		80
A29	5	10	502		95		95
A29	7	3	740	95			95
A30	8	10	1254		95		95
A30	8	12	414		95		95
A30	8	21	2041		95		95
A31	1	3	1101		95		95
A31	1	15	1098			95	95
A31	1	24	970		95		95
A32	1	6	1330		95		95
A32	1	9	605		95		95
A32	1	10	1385		80		80
A32	1	11	1483		80		80
A32	1	12	1411		80		80
A32	1	13	1444		80		80
A32	1	14	973		80		80
A32	1	15	1291		80		80
A32	1	16	872		80		80
A32	1	17	392		80		80
A34	1	4	536		80		80
A34	1	6	466		80		80

NOTE: PAYS = % PAY FOR MARSHALL STABILITY
PAYC = % PAY FOR ROADWAY COMPACTION
PAYT = % PAY FOR SURFACE TOLERANCE
PAYF = FINAL PAY (MINIMUM OF PAYS,PAYC,PAYT)
1 TON = 0.91 METRIC TON

TABLE B1 (CONTINUED)

PENALTIES FOR VARIOUS ACCEPTANCE CRITERIA AND MINIMUM PAY

PROJ	MIX	LOT	TONS	PAYS	PAYC	PAYT	PAYF
A35	5	2	446			95	95
A35	5	4	786			95	95
A35	5	5	407			50	50
A35	5	6	566			80	80
A35	5	7	801			80	80
A38	1	3	840			80	80
A38	1	4	795			95	95
A38	1	5	645			95	95
A42	1	14	1300		95		95
A42	1	21	904		95		95
A42	1	22	285		95		95
A42	1	34	574		95		95
A42	1	38	375		95		95
A42	1	40	442		95		95
A42	1	45	512		80		80
A42	1	48	645		95		95
A42	1	51	625		95		95
A42	1	52	774		95		95
A43	1	5	412		95		95
A43	1	7	190		95		95
A45	1	5	294			80	80
A45	1	14	416			80	80
A46	1	14	891		95		95
A46	1	19	1100			95	95
A46	1	25	675		95		95
A49	1	3	522		95		95
A49	1	5	604		95		95
A49	1	6	524		80		80
A49	1	7	510		95		95
A49	1	10	550		95		95
A49	1	13	614		95		95
A49	1	14	556		95		95
A49	1	15	612		95		95
A51	1	11	564		95		95
A51	1	12	482		80		80
A51	2	3	432		95		95
A51	2	5	438		95		95
A51	2	6	354		95		95
A51	2	7	404		95		95
A52	2	28	1375		80		80
A52	2	29	1317		95		95
A54	5	32	1169	95			95
A54	5	37	1155		80		80
A54	5	38	1448		95		95
A54	5	41	1219		95		95
A54	6	3	1131		80		80
A54	6	4	560		80		80
A54	6	5	956		80		80
A54	6	13	1369		95		95
A54	6	17	1510		95		95
A54	6	25	1025		95		95
A54	6	26	629		95		95
A54	6	27	755		80		80
A54	6	28	1133		95		95
A57	1	1	624			95	95

TABLE B1 (CONTINUED)

PENALTIES FOR VARIOUS ACCEPTANCE CRITERIA AND MINIMUM PAY

PROJ	MIX	LOT	TONS	PAYS	PAYC	PAYT	PAYF
A57	1	4	544			95	95
A57	1	6	448			80	80
A57	1	7	624			95	95
A57	1	8	900			95	95
A57	1	9	512			95	95
A58	5	14	904	95			95
A58	5	16	324	95			95
A58	5	17	345	95			95
A58	5	19	348	95	95		95
A58	5	20	371		95		95
A58	5	30	281		95		95
A58	5	32	367	95			95
A59	1	3	585		80		80
A60	1	43	90		95		95
A60	2	27	155		95		95
A61	5	11	980	95			95
A61	5	15	210	80			80
A61	5	24	150		95		95
A61	5	25	135		95		95
A61	5	33	105		95		95
A61	5	34	150		95		95
A61	5	35	135	80	95		80
A61	5	38	675		95		95
A61	5	40	210		95		95
A61	5	41	75		95		95
A62	5	43	570		95		95
A62	5	44	567		95		95
A62	5	46	540			80	80
A62	5	49	237		95		95
A62	5	50	303		80		80
A62	6	16	128		95		95
A62	6	19	272		95		95
A62	6	23	880		95		95
A62	6	24	1180		80		80
A62	6	28	1380		95		95
A64	1	78	705			80	80
A64	1	81	1216		95	95	95
A64	1	82	1021			80	80
A64	1	83	810		95		95
A64	1	89	616			80	80
A64	1	90	315			95	95
A64	1	91	445			80	80
A67	1	10	234		95		95
A67	1	25	341		95		95
A70	1	11	885		95		95
A71	1	4	750		80		80
A71	1	6	955		50		50
A71	1	7	505		80		80
A71	1	18	680			95	95
A72	1	5	213		95		95
A72	1	7	485			50	50
A72	1	8	300		95	80	80
A72	1	9	399		95	95	95
A72	1	11	513			80	80
A72	1	13	720		95		95

TABLE B1 (CONTINUED)

PENALTIES FOR VARIOUS ACCEPTANCE CRITERIA AND MINIMUM PAY

PROJ	MIX	LOT	TONS	PAYS	PAYC	PAYT	PAYF
A72	1	14	1113			80	80
A72	1	16	387			95	95
A72	1	18	297			80	80
A72	1	19	540			50	50
A72	1	20	584			80	80
A72	1	21	153		95		95
A73	1	6	367		95		95
A73	1	12	1077		80		80
A74	5	23	120		80		80
A75	5	4	721		60		80
A76	3	3	870			80	80
A76	3	4	1141			80	80
A76	3	5	450			50	50
A76	3	6	900			95	95
A76	3	7	616			95	95
A76	3	8	505			50	50
A76	3	9	180			50	50
A77	1	8	189			80	80
A78	1	7	768		95		95
A82	1	3	920	80			80
A85	1	2	706		95	80	80
A85	1	4	570			80	80
A85	1	5	946			80	80
A85	1	6	430			80	80
A85	1	9	880			80	80

N=190

TABLE B2

NO. OF LOTS & CORRESPONDING PENALTIES FOR MARSHALL STABILITY

PROJECT	NLOT_50	TONS_50	NLOT_80	TONS_80	NLOT_95	TONS_95
AC7			2	2173		
A29					1	740
A54					1	1169
A58					5	2288
A61			2	345	1	980
A62			1	920		
TOTAL	0	0	5	3438	8	5177

TABLE B3

NO. OF LOTS & CORRESPONDING PENALTIES FOR COMPACTION

PROJECT	NLOT_50	TONS_50	NLOT_80	TONS_80	NLOT_95	TONS_95
AC2					1	525
AC6					2	1711
A14			2	1172	2	1295
A19					2	1232
A21	1	623	1	572	5	2511
A29			2	418	1	502
A30					3	3709
A31					2	2071
A32			8	9251	2	1935
A34			2	1002		
A42			1	512	9	5924
A43					2	602
A46					2	1566
A49			1	524	7	3568
A51			1	482	5	2192
A52			1	1375	1	1317
A54			5	4557	7	8333
A58					3	1000
A59			1	585		
A60					2	245
A61					8	1635
A62			2	1483	7	4034
A64					2	2026
A67					2	575
A70					1	885
A71	1	955	2	1255		
A72					5	1785
A73			1	1077	1	367
A74			1	120		
A75			1	721		
A78					1	768
A85					1	796
TOTAL	2	1578	32	25106	86	53509

NOTE: NLOT_50 = NO. OF LOTS PENALIZED AT 50%
NLOT_80 = NO. OF LOTS PENALIZED AT 80%
NLOT_95 = NO. OF LOTS PENALIZED AT 95%
TONS_50 = TONS PENALIZED AT 50%
TONS_80 = TONS PENALIZED AT 80%
TONS_95 = TONS PENALIZED AT 95%
1 TON = 0.91 METRIC TON

TABLE B4

NO. OF LOTS & CORRESPONDING PENALTIES FOR SURFACE TOLERANCE

PROJECT	NLOT_50	TONS_50	NLOT_80	TONS_80	NLOT_95	TONS_95
A08	1	223			1	384
A20			1	851	2	1414
A21	1	540			4	1994
A22			3	1506	1	405
A23					1	574
A31					1	1098
A35	1	407	2	1367	2	1232
A38			1	840	2	1440
A45			2	710		
A46					1	1100
A57			1	448	5	3204
A62			1	540		
A64			4	2787	2	1531
A71					1	680
A72	2	1025	5	2807	2	786
A76	3	1135	2	2011	2	1516
A77			1	199		
A85			5	[illegible]		
TOTAL	8	3330	28	17678	27	17358

TABLE B5

PERCENT OUTSIDE STANDARD SPECIFICATIONS FOR AGGREGATE

US SIEVE	WEARING COURSE HIGH	WEARING COURSE LOW	BINDER COURSE HIGH	BINDER COURSE LOW
1"	0	0	0	0
3/4"	0	0	0	0
1/2"	0	0	0.55	0
NO4	0.55	0	0	0
NO10	0.33	0	0.11	0
NO40	0.77	0	0.44	0
NO80	0.33	0.11	0	0
NO200	0.55	0.55	0	0.98
% AC	0	0	0	0
% CRUSHED	0	15.96	0	4.41

TABLE B6

PERCENT OUTSIDE THE SPECIFIED MINIMUM FOR STABILITY & COMPACTION

TEST	MIX 1	2	3	4	5	6	7	8
MARSHALL STABILITY, LB	0.15	0	0	0.47	1.49	0.36	0	0.15
ROADWAY COMPACTION, %	0.85	1.05	1.58	1.36	0.93	0	0.39	0