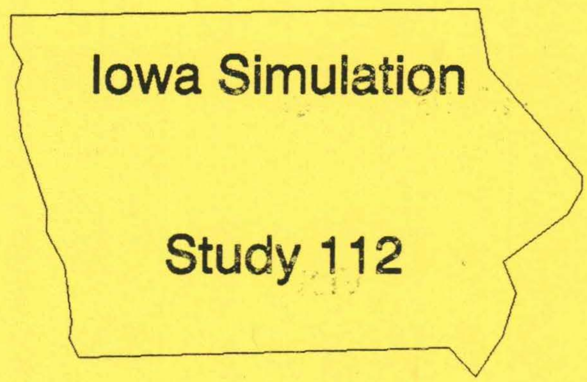
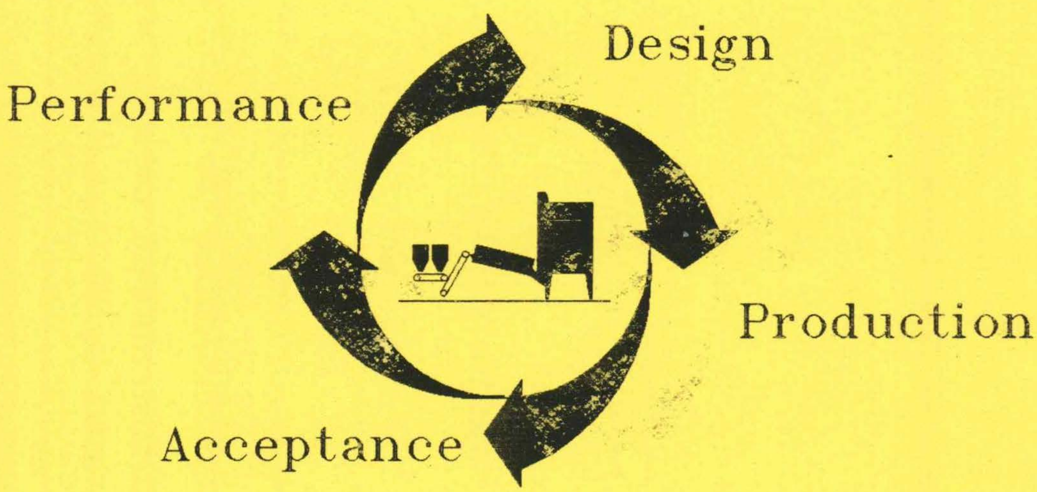
Field Management of Asphalt Mixes

DEMONSTRATION PROJECT No. 74





Demonstration Projects Program

Demonstration Project No. 74

Field Management of

Asphalt Mixes

Study No. 112 Iowa

Mix Verification

and

Acceptance Simulations

September 22 to October 25, 1989

The data presented in this report was collected for simulation purposes only. The test procedures do not necessarily correspond to those procedures followed by the State Highway Agency and cannot be used for control purposes. The simulation is intended to demonstrate certain innovative concepts in field management of asphalt mixes.

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EXECUTIVE SUMMARY

BACKGROUND

Improved field management of asphalt mixes is an area to which both engineers and contractors are giving additional emphasis. Once the engineer has established the criteria for performance and approved the proposed mix design, there are many places in the plant operation for mix-related problems to develop - from stockpiling through the cold feeds to the discharge of the mix. Mix-related problems need to be identified and corrected before tons of material are placed on the roadway.

To demonstrate this concept and other innovations, the Federal Highway Administration's Demonstration Projects Program (FHWA-DPP) has developed DP #74 "Field Management of Asphalt Mixes." The project has been divided into three modules:

Module I	-	Test Equipment and Procedures
Module II	-	Field Simulation Studies
Module III	-	Workshop Activities

At the invitation of the Iowa Department of Transportation (IADOT), the Demonstration Project's mobile asphalt laboratory relocated to a plant site situated in eastern Iowa. The demonstration was conducted from September 22 to October 25, 1989.

The project centers around a completely equipped mobile laboratory. The laboratory is 41' X 8' and weighs 11 tons. The laboratory was brought onto an active paving project site. Laboratory personnel performed the latest testing procedures on field produced mixes in simulation studies. They also demonstrated the latest computer software packages on asphalt mix design and pavement construction.

PURPOSE

The major purpose of the visit was to demonstrate the verification of mix design properties after production had started, to the State DOT and other interested parties. The mix tested at this plant site was a binder mix, with recycled asphalt milled from the project, and used for an overlay on a state primary road project. The mix contained 1/2" nominal maximum size aggregates.

CONCLUSIONS

The mix verification process highlighted the differences of the mix produced by the plant from that produced in the lab during the original mix design. The mix verification process indicated that the plant was producing an acceptable mix.

After the mixes had been verified in the field, the void properties did an effective job of identifying mix fluctuations.

Two statistically based acceptance plans were also demonstrated. Under the Gradation Plan for all the material tested 86% was within simulation limits. Under the Void Plan for all the material tested, 87% was within simulation limits.

The statistically based void acceptance plan using quality level analysis gave a sound overall picture of production.

The nuclear asphalt content gauge proved to be an accurate and useful tool for determining the asphalt content of plant produced mixes.

I. Introduction

A. Improved field management of asphalt mixes is an area to which both engineers and contractors are giving additional emphasis . Once the engineer has established the criteria for performance and approved the proposed mix design, there are many places in the plant operation for mix-related problems to develop - from stockpiling through the cold feeds to the discharge of the mix. Mix-related problems need to be identified and corrected before tons of material are placed on the roadway.

B. Pavement distress in the form of stripping, bleeding, rutting, and raveling can and are causing premature deterioration of pavement sections. This leads to poor ride, skid problems, and an increased cost for maintenance and reconstruction.

C. There are many major research efforts underway to address these problems. However, many State Highway Agencies (SHA) are also reexamining their current mix design and field control procedures. From this reexamination, new and innovative developments have been made in field management of asphalt concrete mixes. Application of these new developments can help reduce the problems that are causing the premature failure of the Nations's roadways.

D. One innovation - incorporation of mix design properties into a field quality control and quality assurance system - can help identify mix related problems before tons of material are placed on the roadway. These properties include Voids in Mineral Aggregate (VMA), and Voids in Total Mix (VTM). If these properties were determined in a field lab, the engineer would have the information necessary to make effective changes to the mix.

E. To demonstrate this concept and other innovations, the Federal Highway Administration's Demonstration Projects Program (FHWA-DPP) has developed DP #74 "Field Management of Asphalt Mixes." The project has been divided into three modules:

Module I - Test Equipment and Procedures
Module II - Field Simulation Studies
Module III - Workshop Activities

F. The project centers around a completely equipped mobile laboratory. The laboratory is 41' X 8' and weighs 11 tons. The laboratory will be brought onto active paving project sites of requesting SHAs. Once set up, the laboratory personnel will perform the latest testing procedures on field-produced mixes in simulation studies. They will also demonstrate the latest computer software packages on asphalt mix design and pavement construction. Additionally, the project personnel will provide technical assistance to SHAs desiring to evaluate equipment and techniques for longer periods of time.

II. Demonstration Background

A. At the invitation of the Iowa Department of Transportation the Demonstration Project's mobile asphalt laboratory relocated to a plant site situated in eastern Iowa.

B. The plant was a Cedar Rapids portable drum mix plant with a baghouse dust collection system returning 100% of fines collected. The dryer was fired with an propane fueled burner. The cold feeds were controlled by belt feeders volumetrically proportioned by computer. A load cell was located on the collection belt prior to introduction of aggregates to the dryer. Built-up partitions had been installed on the feeder hoppers to prevent material spillage from one hopper to another. Two RAP cold feeders were used with a collecting belt and load cell to control proportioning. The RAP was prescreened prior to being loaded into the cold feed hoppers.

C. The plant was equipped with a 75-ton capacity surge hopper. Load cells on the surge hopper provided for automated truck loadout and ticket printing. Production rate averaged 200 - 225 tons per hour. Transport trucks were tandem dump trucks.

D. The major purpose of the visit was to demonstrate the verification of mix design properties to the State DOT and other interested parties. The mix tested at this plant site was a binder course being used for overlay on a primary state route highway project. The mix contained 1/2" nominal maximum size aggregate.

E. The demonstration was conducted from September 22 to October 25, 1989.

III. Materials

A. The HMA was a 75 blow design mix used for leveling.

B. Aggregates were designated as 3/4" Washed Crushed Limestone; Manufactured Sand; Reclaimed Railroad Ballast Sand; Recycled Asphalt Pavement (RAP).

1. AASHTO T-176 Sand Equivalency was performed on the -#4 material of the combined cold feed aggregates. The sand equivalent value was found to be 94. This value is well above the FHWA Technical Advisory (T 5040.27) recommended minimum value of 45. The test results are included in appendix A.

C. AC-5, viscosity graded asphalt cement was used in production. See Figure #1 for a plot of the temperature-viscosity curve.

D. No antistripping additives were used in the HMA on this project.

E. The original mix design was performed by the SHA. See Appendix A for reports and material test data.

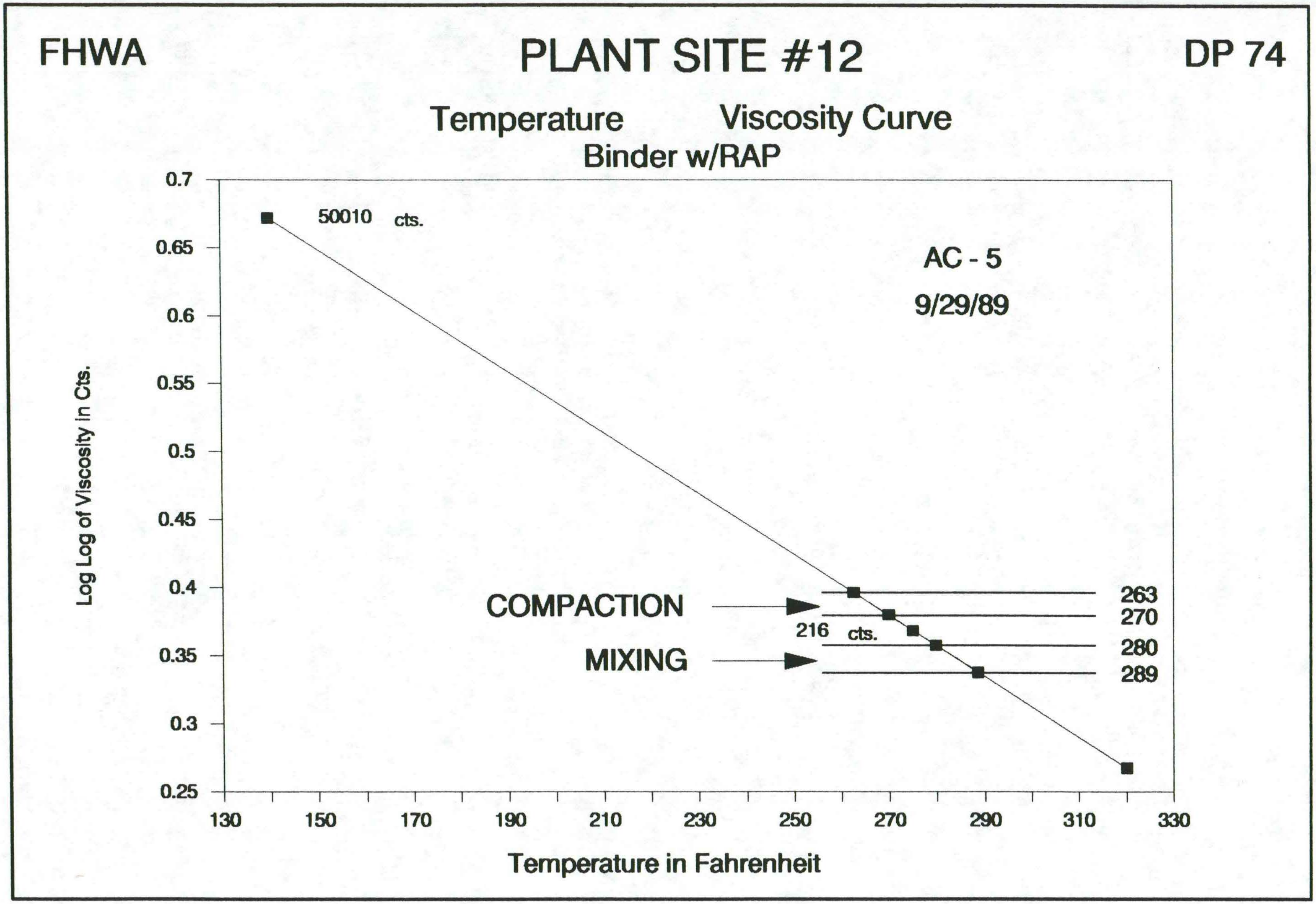

FHWA
PLANT SITE #12
DP 74
Temperature Viscosity Curve
Binder w/RAP
50010 cts.
AC - 5
9/29/89
COMPACTION
MIXING
216 cts.
263
270
280
289
Log Log of Viscosity in Cts.
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
130
150
170
190
210
230
250
270
290
310
330
Temperature in Fahrenheit

Figure #1

IV. Testing

A. Frequency:

A target of four tests per lot was used for this simulation study. A lot was defined as a day's production. Random numbers were employed to determine when to obtain samples based on a day's production time of 8 hours.

B. Sampling was conducted according to AASHTO T 168. Twenty-eight sublots of mix "Binder w/RAP" (BR) were sampled and tested from truck beds at the plant site by DPP lab personnel.

V. Individual Tests :

1. AASHTO T 30 Mechanical Analysis of Extracted Aggregate.

2. AASHTO T 166 Bulk Specific Gravity of Compacted Bituminous Mixtures.

3. AASHTO T 209 Maximum Specific Gravity of Bituminous Paving Mixtures, Rice Method.

   a. DPP uses AASHTO T-209, Maximum Specific Gravity of Bituminous Paving Mixtures, to determine the maximum gravity of samples. This test includes a supplemental procedure for mixtures containing porous aggregate not completely coated. DPP also uses this supplemental procedure to determine the SSD weight for the HMA test sample.

   b. The sample is spread before an electric fan to remove surface moisture. The sample is weighed at 15 minute intervals and when the weight loss is less than 0.5g for this interval it is considered to be surface dry.

   c. Maximum specific gravity results are often lower if the Rice Dry-Back Method is performed. The results of the VTM calculations will also be lower when the Dry-Back Method is used. The amount of change in the VTM will vary depending of the amount of absorption of moisture into the mix sample during the evacuation process.

4. AASHTO T 164 Quantitative Extraction of Bitumen from Bituminous Paving Mixtures, Method E, Vacuum Extraction.

5. AASHTO T 269 Percent Air Voids in Compacted Bituminous Paving Mixtures.

6. AASHTO T 245 Resistance to Plastic Flow of Bituminous Paving Mixtures using the Marshall Apparatus.

7. ASTM D 4125 Asphalt Content of Bituminous Mixtures by the Nuclear Method.

8. ASTM D 4867, (NCHRP Report 274) Determining the Effect of Moisture and Antistripping Additives on Bituminous Paving Mixtures, the Root-Tunnicliff Method.

9. ASTM D 4867 Root Tunnicliff Moisture Sensitivity Test:

   a. DPP has been using this test method to determine if mixes as produced by the plant are susceptible to stripping. The test method is similar to the Lottman Method, but does not require the use of a freeze-thaw cycle in the conditioning of the samples. Because there is no freeze-thaw cycle this test method is much easier to perform in the field. The method can be used as a quick check to assure that any antistripping additives, if used, are effective.

   b. One test was conducted on a sample of plant produced mix. The wet/dry tensile strength ratio of the test specimens was 83.6% with no stripping visually observed. This test should be conducted several times during the life of the project to determine if the results would remain consistent. See Appendix A for test data.

A. Test Equipment

1. Marshall Compaction Pedestal:

   a. A correlation between the DPP compaction hammer and the SHA's plant site testing laboratory was not performed. The SHA plant site mobile lab trailer did not contain a marshall compaction hammer and pedestal. Daily Marshall specimens, for density control, were compacted at the SHA District lab.

2. Nuclear Asphalt Content Gauge:

   a. The Nuclear gauge was calibrated by sampling the aggregates from plant stockpiles. Each of four stockpiles were sampled and sieve analysis determined. The aggregates were then re-blended to match the Design Job Mix Formula (JMF).

   b. A comparison of the nuclear asphalt content gauge against the vacuum extraction test was perform for 28 split samples of asphalt mix. The average difference between the two test methods was 0.049%, with a standard deviation of the difference of 0.119. These numbers indicate that the nuclear gauge and the vacuum extractor were giving equivalent test results.

   c. See Appendix B for the calibration data and Case Study 89-74-06, a comparison of the nuclear gauge determination of the asphalt content verses the vacuum extraction results. See Figure 2 for a plot of the nuclear gauge verses the extraction results.

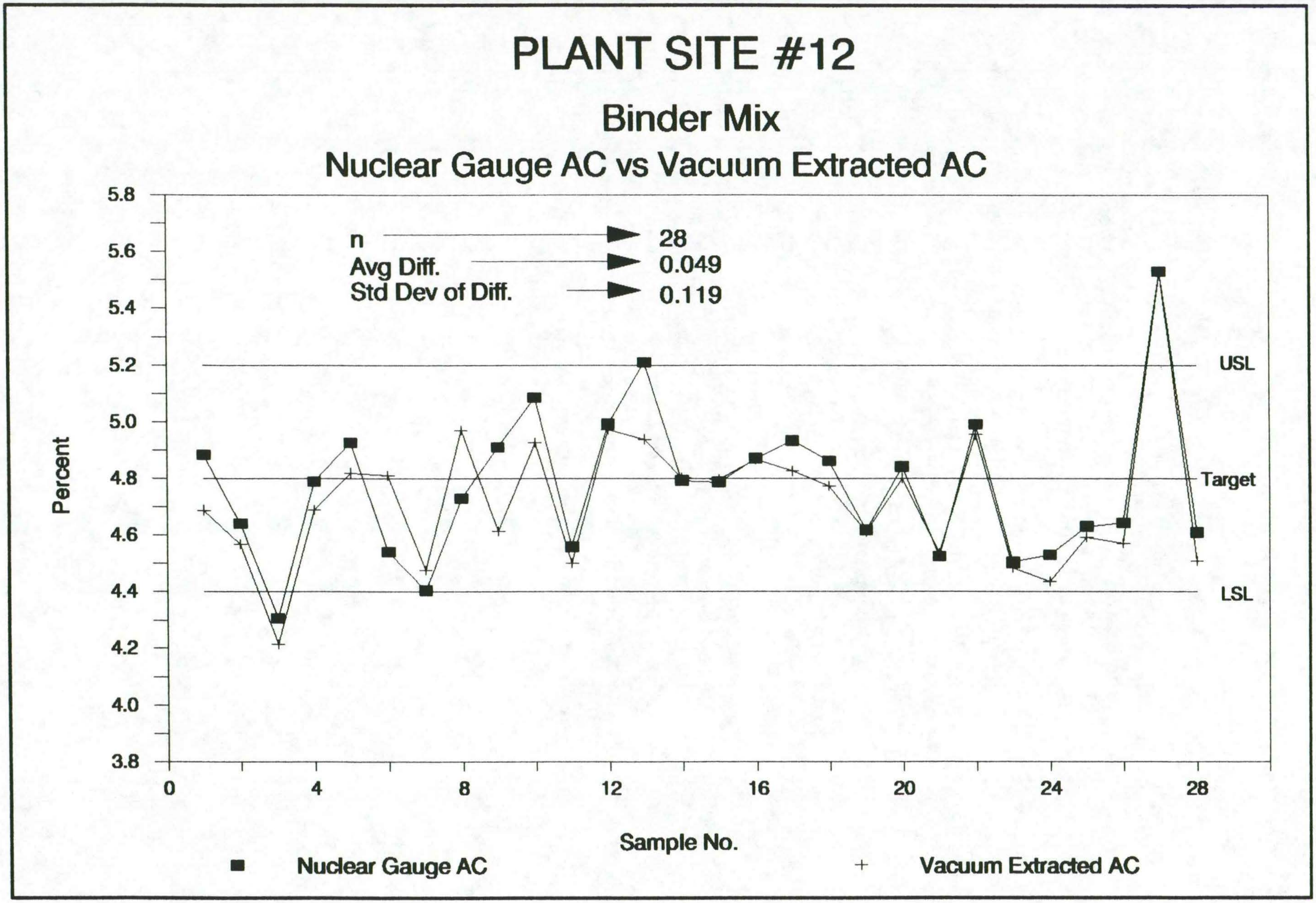

PLANT SITE #12
Binder Mix
Nuclear Gauge AC vs Vacuum Extracted AC
n
28
Avg Diff.
0.049
Std Dev of Diff.
0.119
USL
Target
LSL
Percent
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
0
4
8
12
16
20
24
28
Sample No.
Nuclear Gauge AC
Vacuum Extracted AC

Figure #2

VI. Mix Verification Simulation

A. Background

1. A significant element of Demonstration Project No. 74 is the verification of the mix properties and the Job Mix Formula (JMF) at the start of plant production. This verification is done during the first day's production. See Appendix D for details of the verification process.

2. The original mix design, IADOT #ABD9-0212, was changed prior to the beginning of production. The cold feed proportions were changed from 20% to 25% RAP; from 39% to 40% 3/4" Limestone; from 23% to 19% Manufactured Sand; from 18% to 16% Reclaimed Railroad Ballast Sand; and the Asphalt content was lowered from 5.7 to 4.8%. The mix verification used the revised JMF for gradation verification. The mix design void property targets for the 4.8% asphalt content were interpreted from the original mix design, which established the optimum asphalt content to be 5.7%.

3. On the first day's production, the contractors operations did not start until late in the day and only two samples were obtained. Due to the limited number of samples collected on the first day of production, the mix verification was performed on the following day's production. Four complete sets of Marshall tests and extracted gradations were compared with the approved mix design.

B. **Surface Mix (S) Mix Results**

1. Following are the test data from the verification process. See Figure 3 for a plot of the JMF and the average verification gradation on a 45 power chart. See Figures 4 for a plot of void properties and key sieves for the verification test results.

Sieves	**Design JMF**	**Verification Gradation**
3/4"	100%	100%
1/2"	91%	90%
3/8"	79%	79%
#4	57%	56%
#8	40%	39%
#16	---	28%
#30	18%	19%
#50	---	10%
#100	---	6%
#200	4.9%	5.0%

Mix Properties

Property	**Design**	**Verification**
AC Content:	4.8%	4.6%
Max Sp Gr:	2.459	2.453
Bulk Sp Gr:	2.291	2.342
VTM:	6.8%	4.5%
VMA:	16.6%	14.8%
VFA:	58.8%	69.5%
Stability:	3468	2996
Flow:	7	10

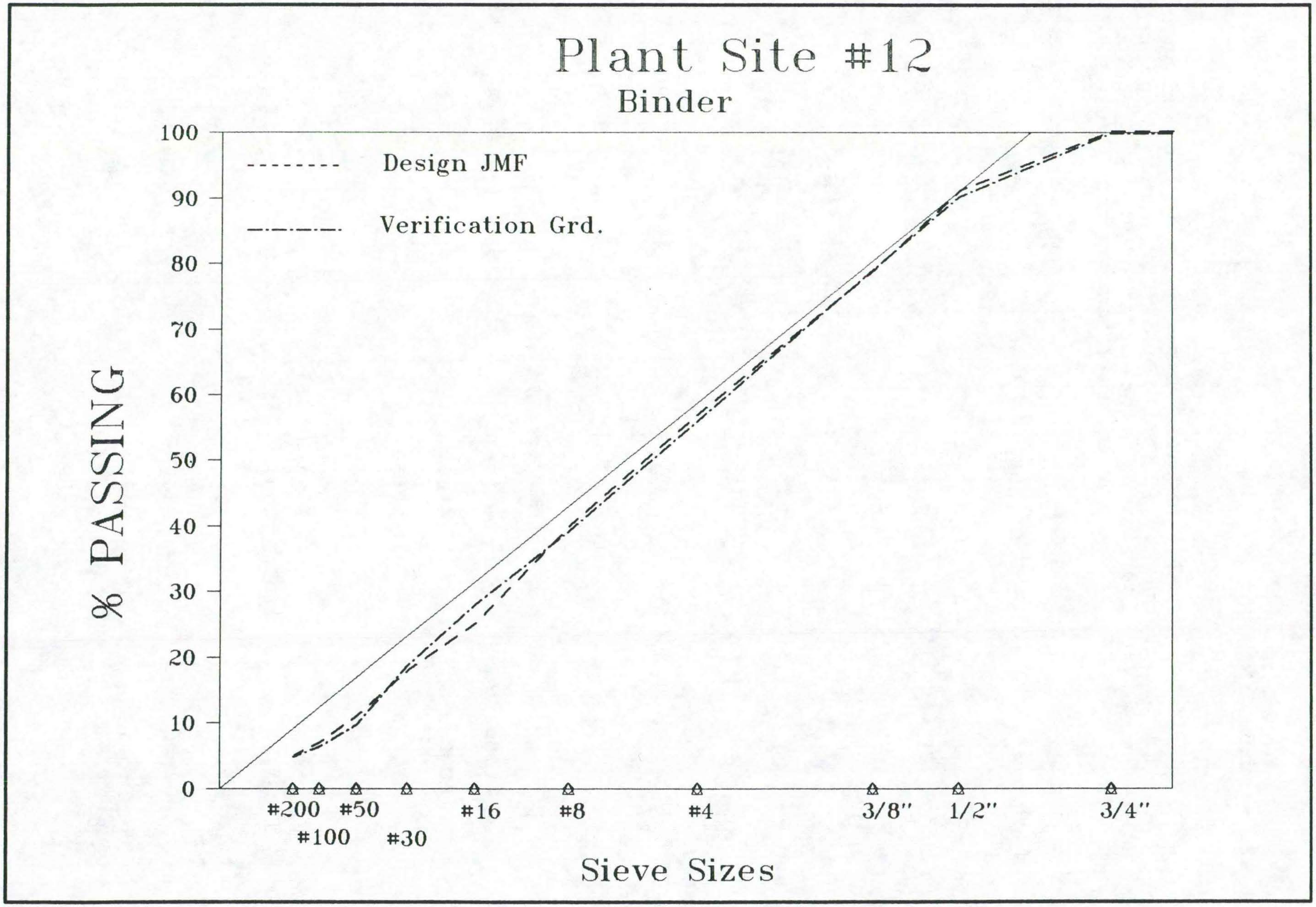


Figure #3: 45 Power Plot of Avg. Verification Grd. vs JMF

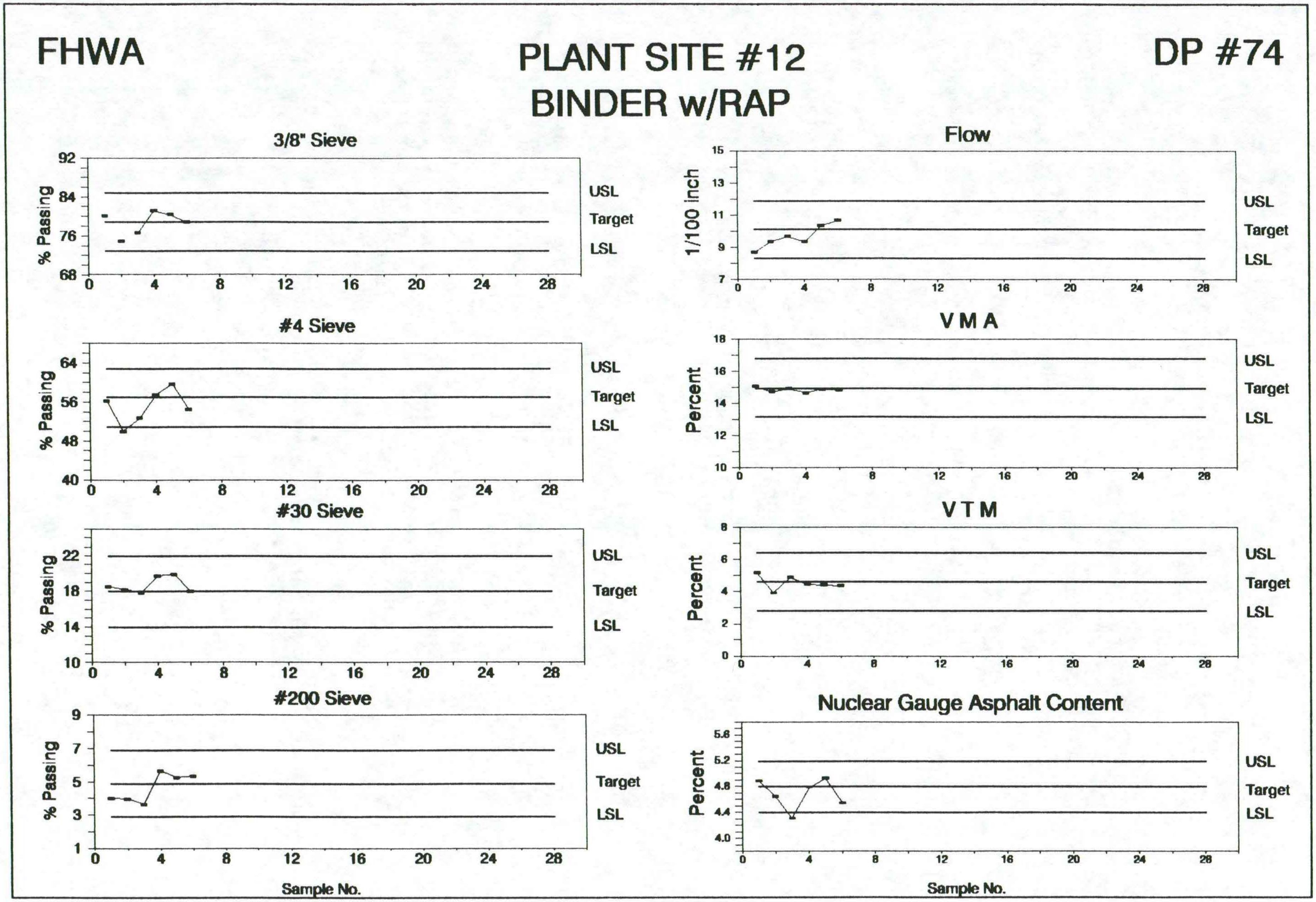


Figure #4: Plot of key verification sieves and void properties.

2. The 45 power plots, for both the mix design JMF and the mix verification gradation, depict gradations that are on the coarse side of the maximum density line. Mixes with this type gradations typically will be less sensitive to minor variations during production.

3. The gradation determined from the mix verification process for the "Binder w/RAP" mix showed virtually no variation from the design JMF. The verification average gradation was 1% lower than the JMF for the #4, #8, and #30 sieves, with 100% within simulation limits for all sieves, as measured by quality level analysis. The asphalt content was 0.2% below the target of 4.8%, with 79% of the material within simulation limits.

4. The average results of the first four tests indicated that all of the void properties and the Flow to be out of simulation limits. The void property targets were interpreted from the original mix design values based on 4.8% asphalt content. Quality level analysis for the asphalt content was 79%; VTM was 0%; VMA was 54%; and Flow was 0%; within simulation limits. The plant produced mix did not meet the original mix design, however, the mix was within the Asphalt Institutes recommended design parameters.

5. From the verification test results and observations, a recommendation of **"GO WITH CHANGES"** would be made for this mix. The recommended changes would be to establish the average mix verification properties as the production targets, essentially, a paperwork change.

6. Any recommendations for change to the original mix design and job mix formula are based on general design parameters. **Before any change is considered for a mix, past history of the performance of the aggregate and design JMF must be considered.**

7. The JMF was not changed and the following data, for the acceptance simulations uses the averages of the verification test results as targets.

VII. Acceptance Simulations

A. Demonstration Projects acceptance plan on extracted gradation

The DPP plan uses Quality Level Analysis - Standard Deviation Method to estimate the percent of the lot within specifications limits. For this study a lot was considered to be one day's production. Four extracted gradations were run per lot. The results from these gradations were used to determine the percent within simulation limits. See Appendix D for the specification.

B. Demonstration Projects acceptance plan on void properties

The DPP plan uses Quality Level Analysis - Standard Deviation Method to estimate the percent of the lot within specifications limits. For this study a lot was considered to be one day's production. Four field Marshalls were run per lot. The void properties from the Marshall samples were used to determine the percent within simulation limits. See Appendix D for the specification.

C. Acceptance Results Surface mix

1. For each acceptance plan, the test results were grouped into 7 lots based on 4 tests per lot, with a minimum of 3 and a maximum of 6 tests per lot. See Appendix E for acceptance simulation data.

	FHWA-DPP Grad. Plan		**FHWA-DPP Void Plan**	
Lot	**Percent Within Simulation Limits**	**Causes**	**Percent Within Simulation Limits**	**Causes**
1	88%	AC, 3 sieves	88%	AC, Flow
2	89%	AC	89%	AC
3	96%	AC	96%	AC
4	91%	AC	91%	AC
5	100%	---	100%	---
6	100%	---	100%	---
7	59%	5 sieves, AC	68%	AC,VTM,Flow

VIII. Discussion

A. Mix Verification

1. The mix verification done by FHWA on the first full day of production demonstrated that the mix, as produced by the plant, did not match the original mix design. The mix as produced did meet general design criteria.

2. The variations in properties from mix design to production can be due to several different causes. These causes include changes in the aggregate source or variations in the crushing operation. Also, a change in the asphalt source can change mix properties. However, none of these causes appears to be the reason for the variations observed at this plant site.

3. Investigation of fines collected from the baghouse, at this plant site indicate they were possibly acting as asphalt extenders. A hydrometer analysis indicated that over 50% of the fines sampled from the baghouse for the aggregate used on this project were smaller than 10 microns. Fines smaller than 10-20 microns can act as asphalt extenders and give the mix an appearance of being over asphalted. Coarser graded fines above the 20 micron size normally tend to increase the mixture's asphalt cement demand and give the mix a dry appearance. These ultra fine particles in the mix may have caused the reduction in voids. The SHA by decreasing the asphalt content from 5.7% to 4.8%, kept the void properties of the mix within acceptable limits. See Appendix C for Particle Size Analysis of the baghouse fines. See Figure 7 for a plot of the particle size analysis.

B. Acceptance

1. Target void properties used in the Quality Level Analysis were the average test results obtained during the mix verification process

2. For gradation and asphalt content, 86% of the mix produced and tested, was within simulation limits as calculated by the statistically-based quality level analysis standard deviation method. Looking at the results for the individual lots, the gradation plan showed production to be consistent. The asphalt content and the #4 sieve exhibited the most fluctuation during production. The benefit of the quality level analysis standard deviation method, is that the actual percentage of material within set tolerance limits is determined and an overall picture of production can be seen. See Figure 5 for a plot of the average simulation gradation verses the JMF on a 45 power chart.

3. For void properties, 87% of the mix produced and tested, was within simulation limits as calculated by the statistically-based quality level analysis standard deviation method. The void properties fluctuated following the fluctuations of the gradations indicating the consistency of the mix. The added benefit of a quality control acceptance program using void properties is that the effect of production fluctuations on the mix properties can be measured.

4. Overall, the test results indicate that a specification requiring mix verification and using voids properties would provide good quality control of a mix. See Figures 6 for plots of the test data for key sieves and void properties.

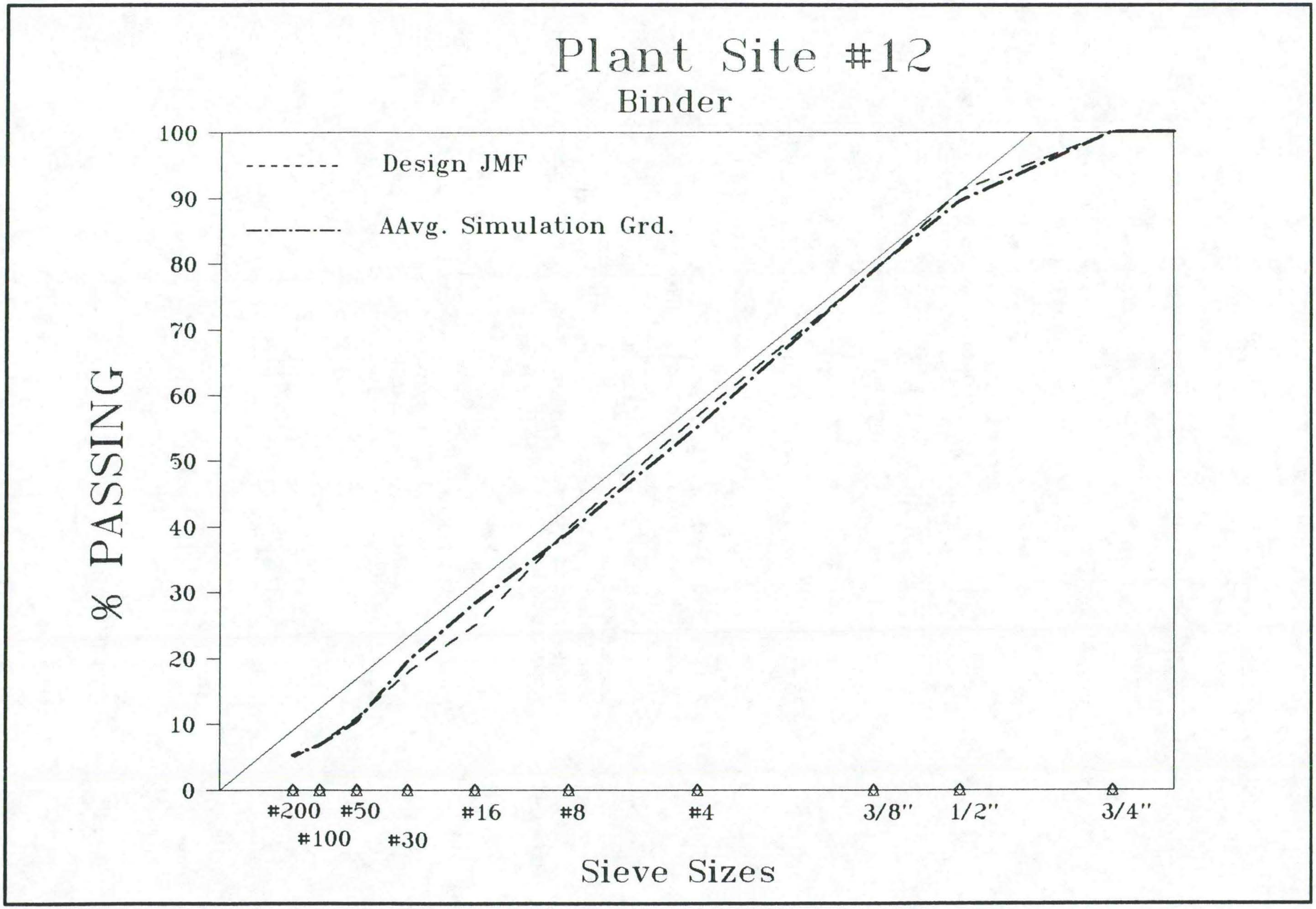


Figure #5: 45 Power Plot of Avg. Simulation Grd. vs JMF

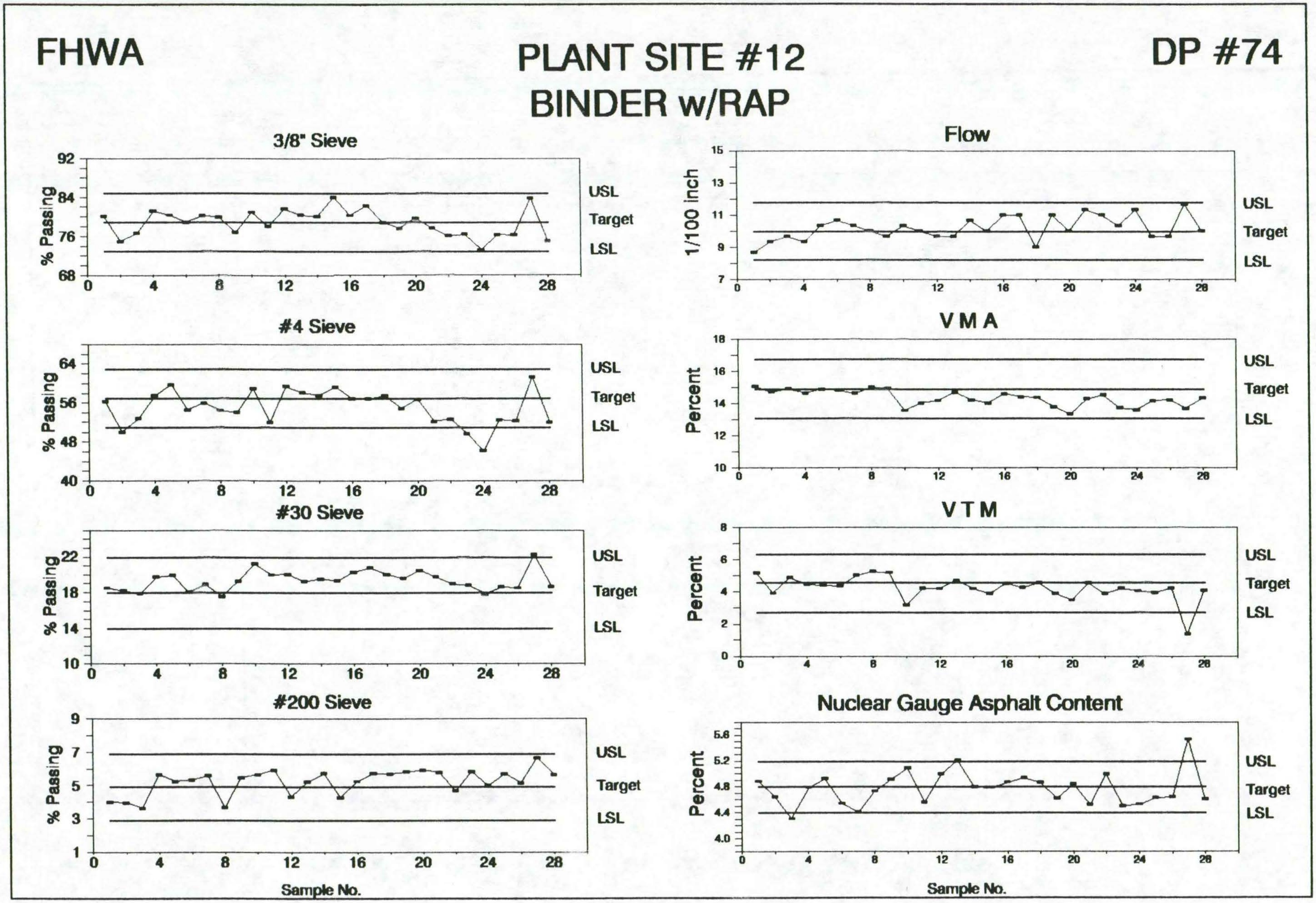
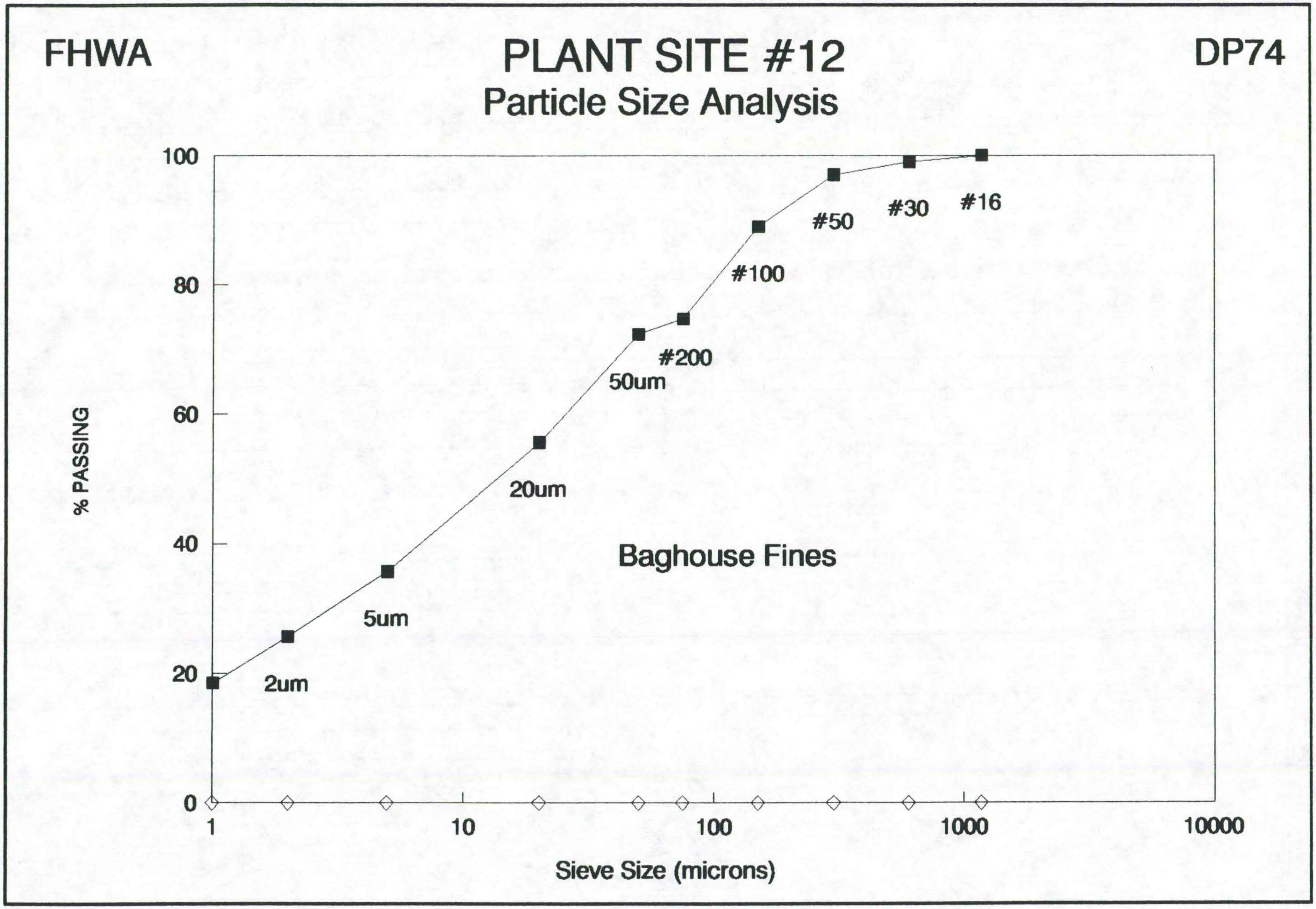


Figure #6: Plot of key sieves and void properties



FHWA
PLANT SITE #12
DP74
Particle Size Analysis
100
80
60
40
20
0
% PASSING
#16
#30
#50
#100
#200
50um
20um
Baghouse Fines
5um
2um
1
10
100
1000
10000
Sieve Size (microns)

Figure #7

IX. Conclusions

A. The mix verification process highlighted the differences of the mix produced by the plant from that produced in the lab during the original mix design. The mix verification process indicated that the plant was producing an acceptable mix.

B. After the mix had been verified in the field, the void properties did an effective job of identifying mix fluctuations.

C. The statistically based void acceptance plan using quality level analysis gave an overall picture of production.

D. The nuclear asphalt content gauge proved to be an accurate and useful tool for determining the asphalt content of plant produced mixes.

Appendix A

Material Properties

F H W A   D P # 74

ASPHALT CEMENT SPECIFIC GRAVITY

AASHTO T-228

PROJECT	#112	SUPPLIER	KOCH MAT'L.
LOCATION	CEDAR RAPIDS, IA	SUPPLIER LOC.	DUBUQUE,IA
DATE	09/29/89	TYPE/GRADE	AC - 5
TIME	P.M.	SAMPLE LOCATION	TANK
SAMPLE #	1	TECHNICIAN	P.P.

	PYCNOMETER NO. #115		PYCNOMETER NO. #121
A. WT PYCNOMETER (DRY)	32.6		31.57
B. WT PYCNOMETER (WITH H2O)	58.58		57.42
C. WT PYCNOMETER (WITH A.C.)	49.58		48.8
D. WT PYCNOMETER (W/H2O & A.C.)	58.88		57.76
E. SP. GR. of A C	1.018		1.020
AVERAGE SP. GR.		1.019	

REMARKS:

F H W A VACUUM EXTRACTION D P #74

PROJECT: #112 DATE: 09/26/89 SAMPLE OF: R.A.P.
SAMPLE #: RAP#2 SOURCE STOCKPILE SAMPLED BY: ____________
PAY LOT #: N/A TIME: PM TESTED BY: P.P./E.B.

VACUUM EXTRACTION

A. Wt. of sample before extraction	1397.5
B. Wt. of extracted aggregate and filter blanket	1335.3
C. Wt. of filter paper	6.1
D. Wt. of Dia. earth	0.0
E. Wt. of extracted aggregate (B-C-D)	1329.20
F. Wt. of bitumen and moisture (A-E)	68.30
G. Wt. of moisture (A * Percent of Moisture)	0.00
H. Wt. of Bitumen (E - F)	68.30
I. % Bitumen/wt. of aggregate (H/E)	5.14
J. Retention factor	_
K. Adjusted % Bitumen/wt. of aggregate (I+J)	5.14
L. % Bitumen/wt. of mix (K/(100% + K))	4.89

SIEVE ANALYSIS T-30

SIEVE SIZE	WT. RET.	% RET.	% PASS	TARGET VALUE
1 1/2	_	0.0	100.0	_
1	_	0.0	100.0	_
3/4	_	0.0	100.0	_
1/2	3.4	0.3	99.7	_
3/8	29.2	2.5	97.5	_
4	209.4	18.2	81.8	_
8	240.5	36.3	63.7	_
16	202.1	51.5	48.5	_
30	193.2	66.0	34.0	_
50	194.3	80.7	19.3	_
100	79.1	86.6	13.4	_
No.200-	45.8	90.1	9.9	_
Pan	11.5	---	----	
Orig.Wt	1329.2	---	----	----

MOISTURE TEST - AASHTO T-110

M. Wt. of mix	_
N. Volume of xylene	_
O. Ml. of water	0.0
P. % Moist in mix	0.00

F/A RATIO

Q. Wt. Ext. Agg. before wash	1329.2
R. Wt. Ext. Agg. after wash	1209.0
S. total + #200	1197.0
T. Total minus #200 (E-S)	132.2
U. % Pass #200 (T/Q)*100	9.9
V. F/A ratio (U/L)	2.0

REMARKS

MC _
% AC _
COUNT (min) _
BK COUNT _

*Pan + P-200 in filters

F H W A ASPHALT CEMENTS D P # 74

DATE	09/29/89	SAMPLE NO.	1
PROJECT NO.	#112	PROJECT LOCATION	CEDAR RAPIDS
PROJECT NAME	PLANT SITE #12	TECHNICIAN	D.W.

SAMPLE ID

TYPE / GRADE	AC - 5	REFINER	KOCH
LOT NO.	N/A	SHIPPING POINT	DUBUQUE,IA
TANK NO.	N/A	DELIVERY METHOD	TRUCK
PLANT STORAGE TEMP.	290 F	SAMPLE LOCATION	TANK
AC SpG.	1.019		

VISCOSITY @ 275 F		VISCOSITY @ 275 F	
TUBE NO. :	D 729 (#6)	TUBE NO. :	D 730 (#6)
FACTOR :	1.007	FACTOR :	1.012
TIME, SECONDS :	216.55	TIME, SECONDS :	212.38
VISCOSITY :	218.1	VISCOSITY :	214.9
	Avg. Viscosity =	216.5	

VISCOSITY @ 140 F		VISCOSITY @ 140 F	
TUBE NO. :	D110 (#50)	TUBE NO. :	D113 (#50)
FACTOR :	8.89	FACTOR :	9.47
TIME, SECONDS :	56.01	TIME, SECONDS :	52.14
POISES :	497.929	POISES :	493.766
	Avg. Viscosity =	495.847	

Type [Alt] G for Temp. Vis. Plot

PENETRATION @ 77 F	100 gm @ 5 s	PENETRATION @ 77 F	100 gm @ 5 s
PEN. # 1	182	PEN. # 1	188
PEN. # 2	191	PEN. # 2	178
PEN. # 3	183	PEN. # 3	188
AVERAGE	185	AVERAGE	185

REMARKS :

SIEVE ANALYSIS OF AGGREGATE
(AASHTO T-11 & T-27)

Project No. #112 Date: 09/29/89

Proj. Loc. CEDAR RAPIDS,IA Time: PM

Sample No.: 7 Tech: P.P.

Sample Loc. STKPL.@ ALT. PLANT Description:3/4" LMST

BEFORE WASHING		AFTER WASHING			
Agg & Pan	2132	Agg & Pan	2091.2	BEFORE, GMS	2132
Pan	________	Pan	________	AFTER, GMS	2091.2
Agg	2132	Agg	2091.2	WASHED THRU #200	40.8
				TOTAL WT. AGG	2132

U.S. Standard Sieves	Weight Retained GMS	Percent Retained	Percent Passing	Specifications	
2	________	0	100	_____	_____
1 1/2	________	0	100	_____	_____
1	________	0	100	_____	_____
3/4	42.4	2	98	_____	_____
1/2	554.2	28	72	_____	_____
3/8	434.4	48	52	_____	_____
#4	908	91	9	_____	_____
#8	115.8	96	4	_____	_____
#16	15.5	97	3	_____	_____
#30	3.5	97	3	_____	_____
#50	2.7	97	3	_____	_____
#100	2.6	98	2	_____	_____
#200	3.8	98	2.3	_____	_____
Pan	8.3				
Wash Loss	40.8	100.0	-0.0		
TOTAL	2132.0				

Remarks: MAT'L. SAMPLED 09/28/89

SIEVE ANALYSIS OF AGGREGATE
(AASHTO T-11 & T-27)

Project No. #112 Date: 09/27/89

Proj. Loc. CEDAR RAPIDS,IA Time: PM

Sample No.: 2 Tech: D.W.

Sample Loc. STOCKPILE Description:R.R. SAND

BEFORE WASHING		AFTER WASHING			
Agg & Pan	486	Agg & Pan	480.7	BEFORE, GMS	486
Pan		Pan		AFTER, GMS	480.7
Agg	486	Agg	480.7	WASHED THRU #200	5.3
				TOTAL WT. AGG	486

U.S. Standard Sieves	Weight Retained GMS	Percent Retained	Percent Passing	Specifications	
2		0	100		
1 1/2		0	100		
1		0	100		
3/4		0	100		
1/2		0	100		
3/8		0	100		
#4	34.2	7	93		
#8	67.8	21	79		
#16	64.5	34	66		
#30	99	55	45		
#50	154.7	86	14		
#100	53	97	3		
#200	6.7	99	1.3		
Pan	0.8				
Wash Loss	5.3	100.0	0.0		
TOTAL	486.0				

Remarks: ______

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
DEMONSTRATION PROJECTS DIVISION
DP #74

SAND EQUIVALENT
WORK SHEET
AASHTO T 176

SAMPLE #:	1	DATE :	10/05/89
PLANT SITE:	IOWA	PROJECT #:	IA #112
SAMPLE LOC. :	STOCKPILE	TECH :	P.P.

USE ABOUT 3 OUNCES BY VOLUME (about 110 grams)
OF PROPERLY QUARTERED MATERIAL
PASSING THE NO. 4 SIEVE.

SOAKING TIME 10 MIN +/- 1 MINUTE

DETERMINATION	1	2	3	4
CYLINDER NO.	1	2	3	N/A
STARTING TIME	917	919	921	N/A
FINISH TIME	927	929	931	N/A

SEDIMENTATION PERIOD - 20 MINUTES +/- 15 SECONDS

DETERMINATION	1	2	3	4
CYLINDER	1	2	3	N/A
STARTING TIME	937	939	941	N/A
FINISH TIME	957	959	1001	N/A
SAND READING	4.2	4.2	4.3	N/A
CLAY READING	4.5	4.5	4.6	N/A
SAND EQUIVALENT	93.3	93.3	93.5	N/A

$$SE = \frac{\text{SAND READING}}{\text{CLAY READING}} \times 100$$

AVERAGE SE VALUE 94

REMARKS: VIRGIN AGGREGATE ONLY.

SIEVE ANALYSIS OF AGGREGATE
(AASHTO T-11 & T-27)

Project No. #112 | Date: 10/02/89

Proj. Loc. CEDAR RAPIDS,IA | Time: A.M.

Sample No.: 8 | Tech: P.P.

Sample Loc. STOCKPILE | Description:MAN.SAND

BEFORE WASHING
Agg & Pan 492.3
Pan ________
Agg 492.3

AFTER WASHING
Agg & Pan 479.7
Pan ________
Agg 479.7

BEFORE, GMS	492.3
AFTER, GMS	479.7
WASHED THRU #200	12.6
TOTAL WT. AGG	492.3

U.S. Standard Sieves	Weight Retained GMS	Percent Retained	Percent Passing	Specifications	
2	________	0	100	_____	_____
1 1/2	________	0	100	_____	_____
1	________	0	100	_____	_____
3/4	________	0	100	_____	_____
1/2	________	0	100	_____	_____
3/8	________	0	100	_____	100
#4	18	4	96	_____	100
#8	242.4	53	47	_____	50
#16	137.8	81	19	_____	21
#30	53.8	92	8	_____	11
#50	18	95	5	_____	4.1
#100	4.8	96	4	_____	1.9
#200	2.3	97	3.1	_____	2
Pan	2.6				
Wash Loss	12.6	100.0	0.0		
TOTAL	492.3				

Remarks: SAMPLED BY F.H.W.A. 10/02 @ PROJECT SITE PLANT

FORM 955

IOWA DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION
OFFICE OF MATERIALS
PROPORTIONS & PRODUCTION LIMITS FOR AGGREGATES

COUNTY: BENTON **PROJECT NO.:** FN-30-6(49)--21-06 **DATE:** 09/21/89

PROJECT LOCATION: ON US.30 FROM JUCT. 218 EAST 11.69 MILES

TYPE OF MIX: A **CLASS OF MIX:** **COURSE:** BINDER "A-75" **MIX SIZE:** 3/4"

CONTRACTOR: CESSFORD CONST. CO. **TRAFFIC:** 6310 A.D.T.

MATERIAL	IDENT #	% IN MIX	PRODUCER & LOCATION
RAP @ 4.77%AC	ABC9-0197	20	MILLED OFF HWY. 30 EAST OF KEYSTONE E.B.
3/4" W. LMST.	6CR9-350	39	AGGRECON--HENNESSEY QR.--A57030
MANF. SAND	6CR9-351	23	AGGRECON--HENNESSEY QR.--A57030
R.R. SAND	6CR9-350	18	AGGRECON--R.R BALLAST WEST OF ATKINS
CR. LIMESTONE	FORMATION	0	BEDS

TYPE AND SOURCE OF ASPHALT CEMENT: AC TO BE DETERMINED BY DESIGN (KOCH)

GRADATION OF INDIVIDUAL AGGREGATE SAMPLES (Typical, Target, or Average)

MATERIAL	SIEVE ANALYSIS -% PASSING 1-1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
RAP @ 4.77%AC	100	100	100	99	97	78	60	46	34	21	17	14
3/4" W. LMST.	100	100	100	79	45	2.8	0.8	0.7	0.6	0.5	0.4	0.3
MANF. SAND	100	100	100	100	100	100	50	21	11	4.1	1.9	1.5
R.R. SAND	100	100	100	100	100	89	72	57	37	9.6	1.7	1.0
CR. LIMESTONE	100	100	100	100	100	100	100	100	100	100	100	100

PRELIMINARY JOB MIX FORMULA TARGET GRADATION

	1-1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
TOLERANCE			98/100	7	7	7	5		4			2
COMB GRADING	100	100	100	92	78	55	37	24	16	6.9	4.2	3.3
SURFACE AREA C.	TOTAL					0.02	0.04	0.08	0.14	0.30	0.60	1.60
S.A. SQ. FT./LB.	23.54				+2.0	1.0	1.4	2.1	2.5	2.7	3.7	8.1

PRODUCTION LIMITS FOR AGGREGATES APPROVED BY THE CONTRACTOR/PRODUCER

SIEVE SIZE	20.0% RAP @ 4.77%AC		39.0% 3/4" W. LMST.		23.0% MANF. SAND		18.0% R.R. SAND		0.0% CR. LIMESTONE	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2	100.0	100.0	73.0	85.0	100.0	100.0	100.0	100.0	100.0	100.0
3/8	100.0	100.0	39.0	51.0	100.0	100.0	100.0	100.0	100.0	100.0
#4	100.0	100.0	0.0	7.0	97.0	100.0	83.0	95.0	100.0	100.0
#8	100.0	100.0	0.0	5.0	45.0	58.0	67.0	77.0	100.0	100.0
#30	100.0	100.0	0.0	4.0	5.0	16.0	33.0	41.0	100.0	100.0
#200	100.0	100.0	0.0	1.5	0.0	3.5	0.0	2.0	100.0	100.0

COMMENTS: AMES HEINS OPPEDAL MERRITT KUEHL LOHRER LIKE LAB
CESSFORD AGGRECON

"1989-A19"

The above data is furnished for informational purposes only. The Contracting Authority makes no representations as to accuracy, either express or implied, which are to be construed to relieve the Contractor from the responsibility to comply with the specifications.

Signed____________________ Signed____________________

Contractor/Producer Dist. Matls. Engr.

ASTM D 4867   MOISTURE DAMAGE LABORATORY DATA SHEET

Sample No .... R-T #1   Mix Type .. SURFACE
Date Compacted .... 10/04/89   Mix ID..... #112 B
Date Tested .... 10/04/89   Project ... #112
Technician .... E.B.   State ..... IA
Lot .... N/A   Time ...... N/A

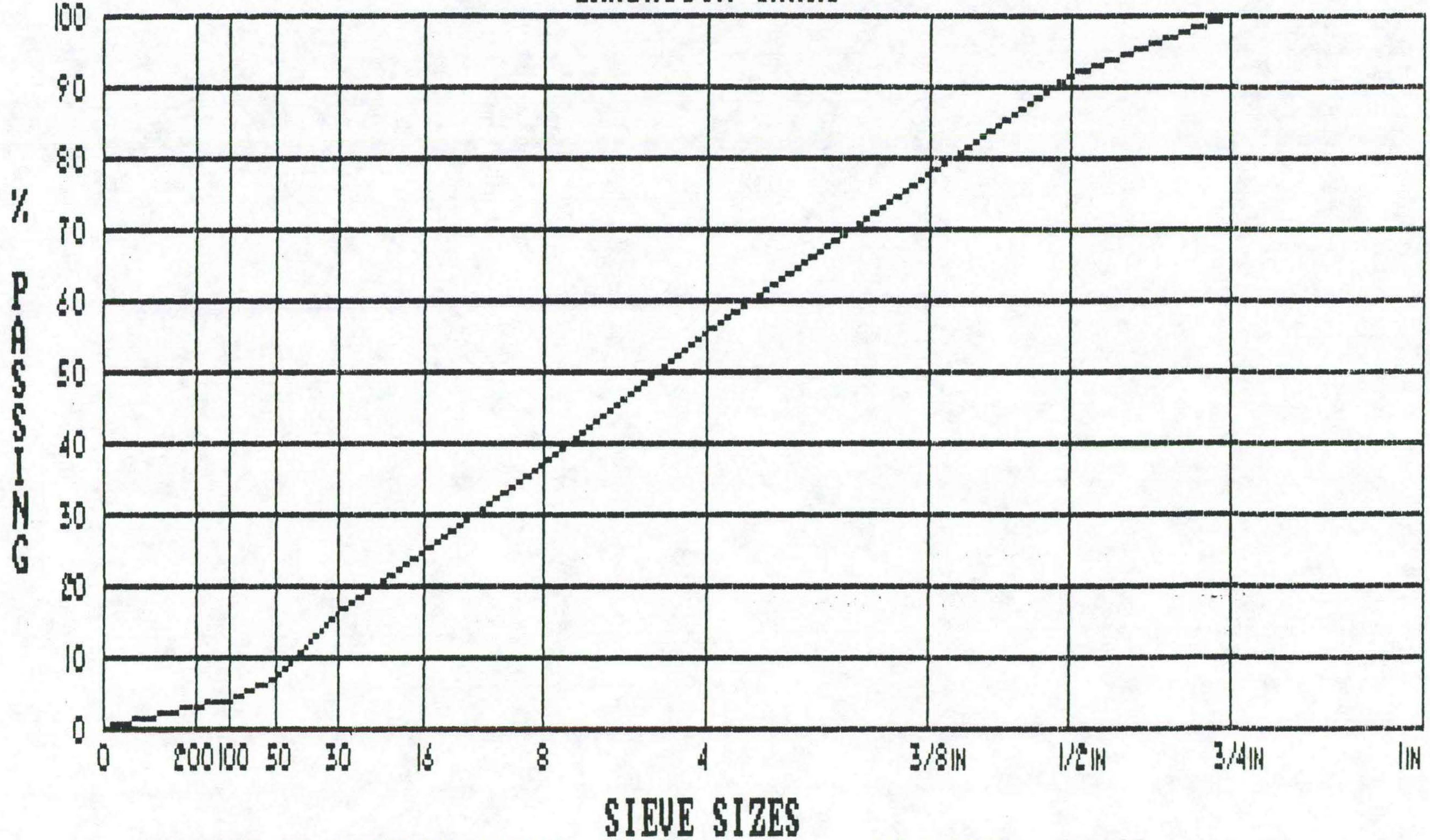
	Test No.	Wet 1	Wet 2	Wet 3	Dry 4	Dry 5	Dry 6
	% AC by Wt. of Mix	4.99	4.99	4.99	4.99	4.99	4.99
a	Diameter "use 4.0"	4	4	4	4	4	4
b	Thickness	2.64	2.62	2.64	2.64	2.67	2.64
A	Dry Wt.	1172.1	1185.5	1179.5	1190.2	1191.1	1181.1
B	SSD Wt.	1182.6	1192.9	1193.9	1200.8	1201	1193.1
C	Wt. in Water	661.4	669	669.3	671.3	672.3	670.3
D	Vol. B-C	521.2	523.9	524.6	529.5	528.7	522.8
E	Bulk Grav. A/D	2.249	2.263	2.248	2.248	2.253	2.259
F	Max Grav. Rice	2.433	2.433	2.433	2.433	2.433	2.433
G	% Air Voids 100(F-E)/F	7.57	6.99	7.59	7.61	7.40	7.14
H	Vol. Air Voids GxD/100	39.45	36.64	39.81	40.31	39.14	37.35
XX	Load lbs.	-----	-----	-----	1625	1225	1225
XX	Dry Tensile Strength psi	-----	-----	-----	97.96	73.02	73.85
	After 5 min. at 20" Hg Vacuum Saturation in 77 deg. F Water						
I	SSD Wt.	1207.9	1213.2	1220.8	-----	-----	-----
J	Wt. in Water	687.8	696.9	697.4	-----	-----	-----
K	Vol. I-J	520.1	516.3	523.4	-----	-----	-----
L	Increased Water I-B	25.3	20.3	26.9	-----	-----	-----
M	% Sat. (L/H)x100	64.13	55.40	67.58	-----	-----	-----
N	% Swell ((K-D)/D)*100	-0.21	-1.45	-0.23	-----	-----	-----
	After 24 hrs. Soak in 140 deg. F water plus 1 hr. in 77 deg. water						
O	Wt. in Water	693.3	697.7	701.6	-----	-----	-----
P	SSD Wt.	1219.6	1225.8	1231.5	-----	-----	-----
Q	Vol. P-O	526.3	528.1	529.9	-----	-----	-----
R	Water Increase	37	528.1	37.6	-----	-----	-----
S	% Sat. R/H x100	93.79	1441.26	94.45	-----	-----	-----
T	% Swell ((Q-D)/D)*100	0.98	0.80	1.01	-----	-----	-----
XX	Load lbs	975	1175	1175	-----	-----	-----
XX	Wet Tensile Strength psi	58.78	71.38	70.84	-----	-----	-----
XX	AVG. Tensile Strength WET	-----	67.00	-----	-----	-----	-----
	AVG. Tensile Strength DRY	-----	81.61	-----	-----	-----	-----
XX	Tensile Strgh. Ratio WET/DRY	-----	82.09	-----	-----	-----	-----
	% Visual Stripping		0				

PRODUCTION STARTED USING THIS DESIGN — HOWEVER — MIX PROPORTIONS CHANGED — VOID PROPERTY TARGET FROM THIS DESIGN — JMF CHANGED PRIOR TO PRODUCTION ALSO.

NEW JMF 10/6/89

3/4"	1/2"	3/8"	#4	#8	#30	#200	AC
100	91	79	57	40	18	4.9	4.8%

IOWA DEPARTMENT OF TRANSPORTATION
GRADATION CHART



PROJECT NO.: FN-30-6(49)--21-06 MIX SIZE: 3/4""

TYPE OF MIX: A CLASS OF MIX:

Appendix B

Nuclear Gauge Comparison

Case Studies #

#89 - 74 - 06

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
TEST REPORT - ASPHALT MIX DESIGN
LAB LOCATION - AMES

LAB NO....:ABD9-0212

MATERIAL........:TYPE A RECYCLED
INTENDED USE....:BINDER
PROJECT NO......:FN-30-6(49)--21-06
COUNTY..........:BENTON CONTRACTOR:CESSFORD
SPEC NO.........:1070.00 SIZE......:3/4
SAMPLED BY......: SENDER NO.:
DATE SAMPLED: DATE RECEIVED: DATE REPORTED: 09/29
FROM 218 EAST 11.7 MILES
% ASPHALT ADDED 3.08 4.08 5.09

- -

AGG. SOURCES: MILLED @ 4.77% - PROJECT; CR. LST. & MAN. SAND AGGRECON, HENNESSEY QRY., LINN CO; BALLAST SAND - AGGRECON, WEST OF ATKINS

JOB MIX FORMULA-COMB. GRADATION

1 1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.
		100.0	92.0	78.0	56.0	37.0	25.0	16.0	7.1	4.3	3.

TOLERANCE /100 :

		98	7	7	7	5		4			±

MATERIAL MIX	ABD9-197	A57030	A57030	BALLAST	
% AGGR. PROP.	20.00	39.00	23.00	18.00	0.00

ASPHALT SOURCE AND	KOCH			
APPROXIMATE VISCOSITY POISES	0538			
% ASPHALT IN MIX	4.00	5.00	6.00	0.0
NUMBER OF MARSHALL BLOWS	75	75	75	0
MARSHALL STABILITY - LBS.	3583	3388	3365	0
FLOW - 0.01 IN.	7	7	7	0
SP GR BY DISPLACEMENT (LAB DENS)	2.270	2.305	2.331	0.0
BULK SP. GR. COMB. DRY AGG.	2.614	2.614	2.614	0.0
SP. GR. ASPH. @ 77 F.	1.028	1.028	1.028	0.0
CALC. SOLID SP. GR.	2.521	2.484	2.447	0.0
% VOIDS - CALC.	9.97	7.20	4.76	0.0
RICE SP.GR.	2.475	2.448	2.418	0.0
% VOIDS - RICE	8.28	5.84	3.60	0.0
% WATER ABSORPTION - AGGREGATE	2.05	2.05	2.05	0.0
% VOIDS IN MINERAL AGGREGATE	16.63	16.23	16.18	0.0
% V.M.A. FILLED WITH ASPHALT	40.04	55.62	70.60	0.0
CALC. ASPH. FILM THICK. MICRONS	7.73	10.33	12.92	0.0
FILLER/BITUMEN RATIO	0.00	0.60	0.00	0.0
TEMP=	245			
WT=	7100			
SLOPE=	4.64			
INTER=	-4.65			

A CONTENT OF 5.7% ASPHALT IS RECOMMENDED TO START THE JOB.
THIS IS AN ADDITIONAL 4.8% A.C. 5

COPIES TO:

CENTRAL LAB	R. MONROE	J. SMYTHE
D. HEINS	CESSFORD	W. OPPEDAL
DIST. 6	CEDAR RAPIDS RES.	

Lab-

DISPOSITION:

SIGNED: ORRIS J. LANE

NUCLEAR ASPHALT CONTENT GAUGE

F H W A — D P - #74

CALIBRATION TEST RECORD

PROJECT:	#112	GAUGE MODEL:	3241-C
		GAUGE S/N:	595
LOCATION:	CEDAR RAPIDS, IOWA	PLANT TYPE:	DRUM-MIXER
DATE:	10'04/89	TECHNICIAN:	D.W.

CALIBRATION RECORD

MIX TYPE:	BINDER W/25%	CALIBRATION #:	#112.25
MIX ID:	#112	BACKGROUND #:	2753
DESIGN AC%:	5.1	BLANK AGG WT:	6769.0

AGGREGATES SOURCE	SIZE	AMOUNT	ASPHALT CEMENT SOURCE	TYPE/GRADE
AGGRECON	R.R. SAND	16		
"	MANF. SAND	19		
"	3/4" LMST	40		
CESSFORD	R.A.P.	25	KOCH MAT'L	AC - 5

CALIBRATION CONSTANTS

A1 -25.936938 A2 15.119417 A3 -17.167543

FIT COEFFICIENT 1

SAMPLE PREPARATION

DESIRED AC %:	3.6	4.35	5.1	5.85	6.6
WT DRY AGG:	6769	6769	6769	6769	6769
WT of AC:	253	308	364	421	478
WT of MIX:	7022	7077	7133	7190	7247
WT. MIX USED:	6769	6769	6769	6769	6769
MEAS. % AC:	3.6	4.35	5.097	5.853	3467
MEAS. COUNT:	2925	3081	3259	3467	3742

	ACTUAL AC	COUNT	ACT/DSN DIFF
1	3.6	2925	0
2	4.35	3081	0
3	5.1	3259	-0.003
4	5.85	3467	0.003
5	6.6	3742	0

DESIRED AC CHECK

% ACTUAL:	5.1
% NUCLEAR :	5.107
COUNT:	3260

DEMONSTRATION PROJECTS 74 - FIELD MANAGEMENT OF ASPHALT MIXES

Nuclear Asphalt Content Gauge vs Vacuum Extraction

Case Study #89-74-05 11/89

Background:

During simulation study 112 between 9/22/89 and 10/25/89, FHWA ran AC contents on 28 samples of asphalt mix. ASTM D4125, Asphalt Content of Bituminous Mixtures by the Nuclear Method, was run on one portion and AASHTO T-164, Quantitative Extraction of Bitumen from Bituminous Mixtures, Method E, Vacuum method was run on a split portion.

The mix was used as a binder course and contained 1/2" nominal top size aggregate with RAP . The aggregate was a crushed lime stone.

The Nuclear gauge was calibrated by sampling the aggregates from plant stockpiles. Each of four stockpiles were sampled and a sieve analysis determined. The aggregates were then re-blended to match the Design Job Mix Formula (JMF). A small amount of extracted aggregate from the RAP was used in establishing the original blank sample for this mix. This extracted aggregate was left from the tests done to establish the asphalt content of the RAP. For the calibration samples the actual RAP was added to the virgin aggregate and the additional asphalt needed achieve the desired AC content. Five calibration points set at .75% percent intervals were used to calibrate the gauge. One point was set at the target asphalt content, two below, and two above the target asphalt content.

Objective:

Compare the two tests to determine if there is a difference in the performance of test procedures, with 95% confidence.

Data:

ASPHALT CONTENT - NUCLEAR VS EXTRACTION

	NUC (Xa)	EXT (Xb)	Xd=Xa-Xb
n Count	28	28	28
X Average	4.77	4.72	-0.05
s Std. Dev.	0.259	0.248	0.119

FHWA Demonstration Project # 74

Project #112 Mix Type BINDER

State IOWA Mix ID #112 B

Date 10/02/89 Location CEDAR RAPIDS

	Agg. 1	Agg. 2	Agg. 3	Agg. 4	Agg. 5	Agg. 6	Agg. 7	Agg. 8	Total	Target	Specifications	
Descrip.	R.R. SAND	MANF.SAND	LIMESTONE	R.A.P.					Blend			
Sp. Gr.	2.583	2.548	2.48	2.692					2.560			
%of blend	16	19	40	25					100			
Sieves	(Type Alt G to view 45 Power Chart of Blend)											
1 1/2"	100	100	100	100					100.0	100	___	___
1"	100	100	100	100					100.0	100	___	___
3/4"	100	100	99	100					99.6	100	___	___
1/2"	100	100	76	99					90.1	91	___	___
3/8"	100	100	55	97					81.3	77	___	___
#4	94	96	11	81					57.9	54	___	___
#8	80	47	5	64					39.7	36	___	___
#16	67	19	4	48					27.9	25	___	___
#30	46	8	3	33					18.3	17	___	___
#50	14	5	3	19					9.1	7.6	___	___
#100	3	4	3	13					5.7	4.9	___	___
#200	1.4	3.1	2.4	8.5					3.9	4	___	___

Remarks: J.M.F. PROPORTIONS

Test Data:

ASPHALT CONTENT - NUCLEAR VS EXTRACTION

Sample No	NUC (Xa)	EXT (Xb)	Xd=Xa-Xb
1	4.883	4.688	0.19
2	4.641	4.568	0.07
3	4.306	4.215	0.09
4	4.789	4.690	0.10
5	4.927	4.820	0.11
6	4.540	4.812	-0.27
7	4.404	4.476	-0.07
8	4.729	4.970	-0.24
9	4.910	4.613	0.30
10	5.086	4.926	0.16
11	4.558	4.500	0.06
12	4.992	4.973	0.02
13	5.210	4.938	0.27
14	4.793	4.802	-0.01
15	4.788	4.796	-0.01
16	4.871	4.867	0.00
17	4.934	4.826	0.11
18	4.862	4.773	0.09
19	4.618	4.611	0.01
20	4.842	4.801	0.04
21	4.525	4.536	-0.01
22	4.991	4.955	0.04
23	4.504	4.483	0.02
24	4.530	4.436	0.09
25	4.632	4.594	0.04
26	4.644	4.571	0.07
27	5.530	5.527	0.00
28	4.610	4.509	0.10
n Count	28	28	28
X Average	4.77	4.72	0.05
s Std. Dev.	0.259	0.248	0.119

Comparing FHWA Nuclear with Contractor Extraction:

Std. dev. of diff.	=	Sd =	0.119
Student "t" factor	=	t =	2.052
>>>>>>>>>>>>>>>>		u =	.05
>>>>>>>>>>>>>>>>		|Xd| =	.05

If the average difference |Xd| > u, then the test methods differ with regard to actual performance. These numbers indicate that the nuclear gauge and the vacuum extractor were giving equivalent test results.

Discussion:

The average difference between the two test methods was 0.05% with a standard deviation of the difference being 0.119. These numbers indicate that the nuclear gauge and the extraction test were giving equivalent results. However, the standard deviation of the difference is large. This large standard deviation is likely due to the RAP in the mix. Any change in the AC content for the RAP effect will the retention factor for the extraction test.

The extraction test was corrected for asphalt retention by a factor of .2%. This asphalt retention factor was determined from 3 lab prepared samples. A known quantity of asphalt was added to project aggregate blended to the job mix formula. The vacuum extraction test was then run on the lab prepared samples. The difference between the known asphalt in the mix and the results of the extraction test was then calculated. The difference is the retention factor. The average retention from the 3 lab prepared and extracted samples was then used to adjust all the extractions tests run on plant mix samples. If the Asphalt content in the RAP changes it will dramatically change the retention factor

All samples for both test methods were corrected for moisture in the mix. Five hundred grams of the mix from each test sample were placed in a 300°f oven and weighed at 30 minute intervals until a constant weight was obtained. For each sample the same moisture content was used to correct both the nuclear result and the extraction result.

Appendix C

Particle Size Analysis

FOR THE RECORD

Procedure:

1. Choose the level of significance of the test (α).

2. Look up "t" for degrees of freedom = N-1

3. Compute averages and standard deviations.

4. Compute "u" using the following:

$$u = t_{(1-\alpha/2)} Sd/\sqrt{n}$$

   u is the expected interval of the average difference based on the sample standard deviation, the sample size, and the desired confidence interval.

5. If |Xd| > u, then A differs from B in performance.

6. If |Xd| < u, then A does not differ from B in performance.

7. The interval |Xd| (+/-) u is the 100(1- α)% confidence interval for the true difference between the averages of the methods.

Reference: "Experimental Statistics, Handbook 91", US Department of Commerce, Chapter 3.3.1

R

SIEVE ANALYSIS OF AGGREGATE
(AASHTO T-11 & T-27)

Project No. 112 Date: 11/17/89

Proj. Loc. CEDAR RAPIDS,IA Time: N/A

Sample No.: 1/B-2 Tech: E.B./P.P.

Sample Loc. BAGHOUSE Description:BAGHOUSE FINES

BEFORE WASHING		AFTER WASHING			
Agg & Pan	50.33	Agg & Pan	13.02	BEFORE, GMS	50.33
Pan		Pan		AFTER, GMS	13.02
Agg	50.33	Agg	13.02	WASHED THRU #200	37.31
				TOTAL WT. AGG	50.33

U.S. Standard Sieves	Weight Retained GMS	Percent Retained	Percent Passing	Specifications	
2		0	100		
[illegible]		0	100		
[illegible]		[illegible]	100		
[illegible]		[illegible]	100		
[illegible]		[illegible]	100		
[illegible]		[illegible]	100		
#4		0	100		
#8		0	100		
#16	0.07	0	100		
#30	0.28	1	99		
#50	1.06	3	97		
#100	4.02	11	89		
#200	7.04	25	75.2		
Pan	0.54				
Wash Loss	37.3	100.0	0.0		
TOTAL	50.3				

Remarks: SAMPLE "B-2" HYDROMETER MATERIAL

SIEVE ANALYSIS OF AGGREGATE
(AASHTO T-11 & T-27)

Project No. 112 | Date: 11/17/89

Proj. Loc. CEDAR RAPIDS, IA | Time: N/A

Sample No.: 1/A-1 | Tech: E.B./P.P.

Sample Loc. BAGHOUSE | Description: BAGHOUSE FINES

BEFORE WASHING		AFTER WASHING			
Agg & Pan	49.95	Agg & Pan	12.79	BEFORE, GMS	49.95
Pan		Pan		AFTER, GMS	12.79
Agg	49.95	Agg	12.79	WASHED THRU #200	37.16
				TOTAL WT. AGG	49.95

U.S. Standard Sieves	Weight Retained GMS	Percent Retained	Percent Passing	Specifications AVE A-1	A-2
2		0	100		
1 1/2		0	100		
1		0	100		
3/4		0	100		
1/2		0	100		
3/8		0	100		
#4		0	100		
#8		0	100		
#16	0.08	0	100		
#30	0.27	1	99		99.0
#50	1	3	97		97.0
#100	3.88	10	90		~~90.0~~ 89.5
#200	6.9	24	75.7		75.1
Pan	0.56				
Wash Loss	37.2	99.8	0.2		
TOTAL	49.9				

Remarks: SAMPLE "A-1" HYDROMETER MATERIAL

R

R

SIEVE ANALYSIS OF AGGREGATE
(AASHTO T-11 & T-27)

Project No. 110 — Date: 11/17/89

Proj. Loc. CEDAR RAPIDS, IA — Time: N/A

Sample No. 1/B-1 — Tech: E.B./P.P.

Sample Loc. BAGHOUSE — Description: BAGHOUSE FINES

BEFORE WASHING		AFTER WASHING			
Agg & Pan	49.99	Agg & Pan	14.47	BEFORE, GMS	[illegible]
Pan		Pan		AFTER, GMS	14.47
Agg	49.99	Agg	14.47	WASHED THRU #200	35.52
				TOTAL WT. AGG	[illegible]

U.S. Standard Sieves	Weight Retained GMS	Percent Retained	Percent Passing	Specifications	
2		0	100		
1 1/2		0	100		
1		0	100		
3/4		0	100		
1/2		0	100		
3/8		0	100		
#4		0	100		
#8		0	100		
#16	0.12	0	100		100.0
#30	0.23	1	99		99.0
#50	1.07	3	97		97.0
#100	4.48	12	88		88.5
#200	7.25	26	73.7		74.5
Pan	1.26				
Wash Loss	35.5	99.9	0.1		
TOTAL	49.9				

Remarks: SAMPLE "B-1" HYDROMETER MATERIAL

P

R

F. H. W. A. DEMO PROJECT #74

PARTICLE SIZE ANALYSIS
OF SOILS

****

PROJECT # 112 LOCATION CEDAR RAPIDSSAMPLE OF: BAGHOUSE FINES

SAMPLE # 1 SAMPLE I.D. "C" DATE SAMPLED: 10/16/89

DATE TESTED: 11/15-17/89

VALUE "K" = READ FROM TABLE 3 -- 0.01386

SPECIFIC GRAV. OF SOIL = 2.6075

ELAPSED TIME	HYDRO. READING	"L" (table 2)	"K" (table 3)	MAX.PARTICLE DIAMETER	GRAIN DIAMETER
0	1.023	10.2	0.01386	ERR	73.2
2	1.021	10.7	0.01386	0.03206	66.8
5	1.019	11.3	0.01386	0.02084	58.9
15	1.017	11.8	0.01386	0.01229	52.5
30	1.015	12.3	0.01386	0.00887	47.7
60	1.013	12.9	0.01386	0.00643	41.4
250	1.010	13.7	0.01386	0.00324	31.8
1440	1.007	14.4	0.01386	0.00139	22.3

REMARKS: ________

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R

SIEVE ANALYSIS OF AGGREGATE
(AASHTO T-11 & T-27)

Project No. 112 | Date: 11/17/89

Proj. Loc. CEDAR RAPIDS, IA | Time: N/A

Sample No.: 1/A 2 | Tech: E.B./P.P.

Sample Loc. BAGHOUSE | Description: BAGHOUSE FINES

BEFORE WASHING		AFTER WASHING			
Agg & Pan	49.93	Agg & Pan	14.26	BEFORE, GMS	49.93
Pan		Pan		AFTER, GMS	14.26
Agg	49.93	Agg	14.26	WASHED THRU #200	35.67
				TOTAL WT. AGG	49.93

U.S. Standard Sieves	Weight Retained GMS	Percent Retained	Percent Passing	Specifications	
2		0	100		
1 1/2		0	100		
1		0	100		
3/4		0	100		
1/2		0	100		
3/8		0	100		
#4		0	100		
#8		0	100		
#16	0.11	0	100		
#30	0.25	1	99		
#50	1.02	3	97		
#100	3.87	11	89		
#200	7.52	26	74.4		
Pan	1.52				
Wash Loss	35.7	100.1	-0.1		
TOTAL	50.0				

Remarks: SAMPLE "A-2" HYDROMETER MATERIAL

F

R

F. H. W. A. DEMO PROJECT #74

PARTICLE SIZE ANALYSIS
OF SOILS

****

PROJECT # 112 LOCATION CEDAR RAPIDS SAMPLE OF: BAGHOUSE FINES

SAMPLE # 1 SAMPLE I.D. "A" DATE SAMPLED: 10/16/89

DATE TESTED: 11/15-17/89

VALUE "K" = READ FROM TABLE 3 -- 0.01386

SPECIFIC GRAV. OF SOIL = 2.6075

ELAPSED TIME	HYDRO. READING	"L" (table 2)	"K" (table 3)	MAX.PARTICLE DIAMETER	GRAIN DIAMETER
0	1.023	10.2	0.01386	ERR	71.6
2	1.021	10.7	0.01386	0.03206	66.8
5	1.019	11.3	0.01386	0.02084	58.9
15	1.016	12.1	0.01386	0.01245	50.9
30	1.015	12.3	0.01386	0.00887	47.7
60	1.013	12.9	0.01386	0.00643	41.4
250	1.010	13.7	0.01386	0.00324	31.8
1440	1.007	14.4	0.01386	0.00139	22.3

REMARKS: ________

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R

F. H. W. A. DEMO PROJECT #74

PARTICLE SIZE ANALYSIS OF SOILS

****

PROJECT # 112 LOCATION CEDAR RAPIDSSAMPLE OF: BAGHOUSE FINES

SAMPLE # 1 SAMPLE I.D. "B" DATE SAMPLED: 10/16/89

DATE TESTED: 11/15-17/89

VALUE "K" = READ FROM TABLE 3 -- 0.01386

SPECIFIC GRAV. OF SOIL = 2.6075

ELAPSED TIME	HYDRO. READING	"L" (table 2)	"K" (table 3)	MAX.PARTICLE DIAMETER	GRAIN DIAMETER
0	1.023	10.2	0.01386	ERR	73.2
2	1.022	10.5	0.01386	0.03176	68.4
5	1.019	11.3	0.01386	0.02084	60.5
15	1.017	11.8	0.01386	0.01229	54.1
30	1.015	12.3	0.01386	0.00887	47.7
60	1.013	12.9	0.01386	0.00643	41.4
250	1.011	13.4	0.01386	0.00321	33.4
1440	1.008	14.2	0.01386	0.00138	23.9

REMARKS: ________

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Appendix D

Demonstration Projects Program

Guide Specifications

SECTION 401. - HOT-MIX ASPHALT CONCRETE PAVEMENT

401.01 DESCRIPTION

This work shall consist of constructing one or more courses of hot-mix asphalt concrete pavement on a prepared foundation in accordance with these specifications and in reasonably close conformity with the lines, grades, thicknesses, and typical cross sections shown on the plans or established by the Engineer.

Note. 1

Extraction Free Specifications

Since the mid 1960's asphalt extractions and extracted gradations have been the key tests used for quality control and acceptance of asphalt mixes. These tests have served well in assuring consistent, uniform material was produced and placed on the nations highways. However, in the past several years health hazards associated with chlorinated solvents used in the extraction test have come to light. These health hazards are forcing many highway agencies to look for alternative quality control and acceptance tests. In addition to the health problems associated with extraction tests increased demands on the nations highways, due to higher traffic volume and increased loads, have raised doubts about the ability of the extraction test to identify quality material. The Demonstration Project Program Guide Specifications tries to address the problems with extraction tests and proposes what is believed to be an alternative quality control and acceptance program that will serve the highway industry into the 21st century.

401.02 MATERIALS - COMPOSITION OF THE HOT-MIX ASPHALT CONCRETE MIXTURE (JOB-MIX FORMULA).

Note. 2

This portion of the specification establishes the requirements for contractor mix design and quality control.

The asphalt mixture shall be composed of a mixture of aggregate and asphalt material, plus any additives required.

It is the Contractor's responsibility to ensure that, in addition to the aggregate gradation requirements, the produced material will provide an asphalt concrete mixture that conforms to the applicable design parameters listed in Table 401-1.

At least 21 days prior to the production of asphalt concrete pavement, the Contractor shall submit in writing to the Engineer the proposed job-mix formula (JMF) for approval including the following:

(a) The percentage (in units of one percent) of aggregate passing each specified sieve, except the No. 200 sieve, based on the dry weight of aggregate as determined by AASHTO T-11 and T-27.

(b) The percentage (in units of one-tenth of one percent) of aggregate passing the No. 200 sieve, based on the dry weight of aggregate as determined by AASHTO T-11.

(c) The percentage (in units of one-tenth of one percent) of asphalt material to be added, based upon the total weight of mixture.

(d) The value (calculated to the nearest one-tenth) of the fines to asphalt (F/A) ratio.

(e) The proposed percentage of each stockpile to be used, the average gradation of each stockpile, and the proposed target value for each sieve size. The target values and the combined average gradation of all the stockpiles when combined in accordance with the Contractor's recommended stockpile combinations shall be within the gradation ranges for the designated grading.

(f) Additional information required as part of the JMF shall include the following:

(1) The material sources for all ingredients.

(2) The material properties, as listed, for all ingredients:

° The specific gravities of the individual aggregates and asphalt.

° The L.A. Abrasion of the aggregates.

° The Sand Equivalent value of the combined aggregate.

° The Plastic Index of the aggregate.

° The absorption of the aggregates.

° The asphalt temperature/viscosity curves.

(3) The mixing temperature and tolerances of the mix.

(4) The mix design test property values and curves used to develop the job mix in accordance with the Asphalt Institute's Manual Series No. 2 (MS-2).

(5) The plot of the gradation on the FHWA 0.45 power gradation chart.

(6) Target density of the Mix Verification Test section.

Along with the written JMF information, the Contractor shall submit the following material samples:

(g) A minimum 100 pound aggregate sample representing each stockpile. Aggregates when combined in accordance with the Contractor's recommended stockpile combinations shall be within the gradation band defined by the target value plus or minus the allowable deviation for each specification sieve or the material will not be considered representative.

(h) A minimum of five 1-gallon samples of the asphalt proposed for use in the mixture.

(i) When applicable, a 1/2 pint sample of the anti-strip additive proposed, including name of product, manufacturer, and manufacturer's data sheet.

The Engineer will, at no cost to the Contractor, evaluate the proposed job-mix formula and suitability of the materials initially submitted. The asphalt concrete mixture shall conform to the applicable mix class and design parameters listed in Table 401-1 and as specified in the contract.

Should new target values for gradation and/or different combinations of the Contractors' stockpiles be required in order to meet the applicable design parameters specified in Table 401-1, or should a change in source of material be proposed, the new job-mix stockpile combinations and gradation target values shall be submitted by the Contractor for approval by the Engineer prior to production. Approval of the new job mix gradations will require testing and a minimum of 14 days may be required for each evaluation. All laboratory costs incurred as a result of these changes will be assessed to the Contractor.

When a commercial mixing plant is used, its location shall be included with the job-mix formula data. When the Contractor elects to obtain mixtures from more than one plant, the mixture from each plant shall contain materials from approved sources and each shall have an approved job-mix formula. Mixtures produced from different plants shall not be intermingled on the roadway unless the mixtures are produced from the same material sources and the same job-mix formula.

Table 401-1

ASPHALT CONCRETE MIX REQUIREMENTS

Design Parameters	Mix Class A	Mix Class B	Mix Class C
(a) Hveem[1]			
(1) Stabilometer	37 min.	35 min.	30 min.
(2) Cohesionmeter value of 140°F	150 min.	100 min.	50 min.
(3) VTM, percent[2]	3-5	3-5	4-6
(4) VMA	See Table 401-2		
(b) Marshall[3]			
(1) Stability, lbs.	1800 min	1200 min.	1000 min.
(2) Flow, 0.01 inch (0.25 mm)	8-14	8-16	8-18
(3) VTM, percent[4]	3-5	3-5	3-5
(4) VMA	See Table 401-2		
(5) Compaction, number of blows at each side of test specimen	75	50	50

NOTE: The applicable mix design parameters will be specified in the contract.

[1]Hveem Procedures are in accordance with AASHTO T246 and T247 (with a 15 hour cure for compacted specimens, as per the Asphalt Institute's Manual MS-2.)

[2]VTM (Voids in Total Mix) is based on AASHTO T166, T209, and T269. Maximum density will be based on AASHTO T209.

[3]Marshall procedures are in accordance with AASHTO T245.

[4]Dust-asphalt ratio is defined as the percent of material passing the U.S. No. 200 sieve divided by the percent of asphalt (calculated by weight of mix, including asphalt from RAP - recycled asphalt aggregate).

Table 401-2

MINIMUM VOIDS IN MINERAL AGGREGATE (VMA)
MARSHALL OR HVEEM MIX DESIGN

U.S. Standard Sieve Designation* (AASHTO M 92)	Minimum Voids in Mineral Aggregate, VTM, % **	
	Marshall	Hveem
No. 8	21	19
No. 4	18	16
3/8 inch	16	14
1/2 inch	15	13
3/4 inch	14	12
1 inch	13	11
1½ inch	12	10
2 inch	11.5	9.5

*The largest sieve size listed in the applicable specification upon which any material is permitted to be retained.

**VMA to be determined in accordance with TAI Manual Series No. 2(MS-2).

401.03 Aggregate.

Note 3.

> This section has been intentionally left blank because it is unrelated to an extraction free specification.

401.04 Asphalt.

Note 4.

> This section has been intentionally left blank because it is unrelated to an extraction free specification.

401.05 Mineral Filler.

Note 5.

> This section has been intentionally left blank because it is unrelated to an extraction free specification.

401.06 ASPHALT CONCRETE MIXING PLANT.

Note 6.

> This section requires the automation and computer control of the asphalt mix plant. These requirements are to promote consistency in production and assist in quality management.

401.06.A MATERIAL BINS

For the purpose of this article, the word "bin" shall be defined as any structure in which materials are stored. The following requirements shall apply to any bin upon which, or beneath which, it is necessary for an inspector to work while performing any part of his sampling or inspection duties.

These requirements shall apply to bins used in connection with the production and delivery of materials, and to bins used in connection with the proportioning of materials for mixtures.

Each part of each bin, including foundations and connections, shall have adequate strength to withstand any stress to which it may be subjected while in use.

All moving parts or conveyors and other machinery, near which it is necessary for an inspector to pass or stand in the performance of his duties, shall be adequately protected by properly designed guards.

Unless other provisions are afforded for conveniently obtaining accurate samples of materials, it will be assumed that it will be necessary for an inspector to obtain samples from the discharge end of conveyors discharging into bins from which material is drawn into vehicles delivering material to the site of the work or to proportioning plants.

Stairs or ladders and walkways of adequate width and strength shall be provided for an inspector to reach points where material is to be sampled and places where proportioning of materials can be adequately inspected. Where the height to which an inspector will be required to climb is greater than 10 feet, a stair with handrails shall be provided. If it is impractical to provide a stair, then an enclosed ladder shall be provided. If a stair, ladder, or walkway would otherwise be exposed to falling material, it shall be protected from such falling material.

Where aggregates may become contaminated with foreign materials such as burlap, paper, or boards, the upper area of all compartments of aggregate bins shall be covered by substantial grillages having openings not larger than 8 inches square.

401.06.B WEIGHING EQUIPMENT AND PROCEDURES

Note 7.

> This section is referenced under plant calibration 401.06.C.14. The weighing equipment and procedures are used to calibrate the plants automatic systems.

This article describes equipment and procedures to be used when payment for an item of the contract is based on actual weight. The quantity shall be determined by weighing loaded trucks on platform scales, by weighing in weigh hoppers, or by counting batches. A means is also provided for converting volume measurement to weight.

401.06.B.1 Weighing Equipment

Weighing equipment used for determination of pay quantities shall be of a type adapted to its method of use. Scales shall be accurate to 2 pounds per 1,000 pounds of weight and, when at equilibrium, shall be sensitive to a weight change equal to two of the minimum gradations but not more than 20 pounds.

Scales for weighing loaded trucks shall meet requirements of the weights and measures governing agency. They shall be of sufficient length to weigh at one time the maximum truck and trailer combination, or separate scales shall be so situated that both truck and trailer can be weighed at the same time.

The Contractor shall have available upon request at the job site, at least 10 standard 50-pound test weights for the purpose of testing and calibrating weighing equipment. When necessary, suitable cradles or platforms shall be provided for applying the test loads.

For truck weighing, the scale equipment shall include a mechanical ticket printer. All trucks to be weighed shall be initially tared before being loaded. Each truck shall be tared daily thereafter, preferably on a random basis. A tare weight for the previous day shall be used until a new tare weight is determined.

A scale ticket shall accompany each load. The ticket shall be furnished to the Engineer for project records. Tickets shall also be furnished for determining tare weights, verification weighing, and check weighings. The tickets shall identify the project number, date, and type of material.

For truck weighing, the ticket shall show the gross, tare, and net weights. When the quantity from an asphalt batch plant is determined by batch weights and count of batches in a load, each component of the batch shall be included on the ticket.

Check weighings on certified scales shall be made as often as the Engineer deems necessary.

The Engineer may check the operation of the scales at any time.

Verification weighing of previously loaded trucks may be made, on the same scale, at any time when directed by the Engineer. When Procedure 1 or 2, Paragraph 401.06.B.2, is used for weighing loaded trucks, the check weight should not be less than the initial weight by more than 20 pounds for each weighing. When other procedures are used for weighing loaded trucks, the check weight should not be less than the initial weight by more than 60 pounds.

When the material is not weighed in the truck, both verification and check weighing may be made on nearby truck scales, and a tare weight also determined with a suitable fuel adjustment, and the net checkweight should not be less than the initial weight by more than 100 pounds. If not within these tolerances, the Engineer may reduce the weights of loads previously weighed on that scale that day and the previous day by the difference greater than the specified tolerance. Check weighing and weight adjustments may also be based on tare weights: a fuel adjustment will be allowed, if appropriate. Check and verification weighings shall be made at no additional cost to the Contracting Authority.

401.06.B.2 Optional Procedures for Asphaltic Mixtures Aggregates

When the item quantity for hot asphalt-aggregate mixture or any aggregate is in tons and measurement of the finished mixture is by weight, this paragraph specifies additional requirements and conditions for three measurement procedures. These apply to the mixtures described in automatic or semiautomatic weighing (Procedure 1 or Procedure 2), shall be used for weighing these mixtures or aggregates when to be furnished in quantities of 10,000 tons or more from a single source, for a project. Volume measurement (Procedure 3) will be allowed for quantities of 300 tons or less at the Contractor's option, and may be allowed for other small quantities or infrequent loads by agreement between the Contractor and the Engineer.

Procedure 1 Automatic Weighing

The scale shall be self-balancing and shall include an automatic weight recorder. All scale tickets shall be printed automatically with the gross weight and as appropriate, tare weight, empty weight of the weigh hopper after each discharge, or batch weight and batch count, and an automatic net weight as a true weight.

Procedure 2 SemiAutomatic Weighing

The scale may be manual or self-balancing. Equipment shall include an automatic weight recorder which will not print until the scale is balanced, and which prints the gross weight, or if appropriate, the batch weights and the number of batches. For weigh hoppers, the printout shall include the empty weight after each discharge.

Procedure 3 Volume Measurement

The quantity will be determined by volume measurement. The Engineer will convert the volume of the truck load to weight using a weight per unit volume determined by weighing at least one representative load in each truck, and at no additional cost to the Contracting Authority. Each truck load shall be struck off level. There shall be a ticket with each load indicating the volume or the calculated weight.

For asphalt plants, the Contractor shall furnish to the Engineer each day a total quantity of mixture used for the project; also, if mixture is produced for other work or wasted, the Contractor shall furnish to the Engineer a total quantity of that mixture and shall identify the quantity of asphalt cement used in the mixture.

For aggregates, the Contractor may furnish to the Engineer each day a total quantity of aggregate used on the project.

401.06.C PLANT EQUIPMENT FOR HOT ASPHALT MIXTURES

The plant equipment shall proportion each aggregate, dry and heat the aggregate, except mineral filler, proportion the aggregate and hot asphalt, and mix all materials. The plant may be of a batch type, continuous type, or drum-mixing type, and it shall be equipped to produce uniform mixtures of required composition, heated to the desired temperature. The plant shall conform to the following requirements for the respective type.

401.06.C.1 Aggregate Feeders for Dryers or Drum Mixer

Except for mineral filler added without heating, each aggregate shall be accurately fed by a mechanical means to a central elevator or conveyor in the proportion prescribed by the job-mix formula.

Feeders shall be of the belt type, equipped with adjustable gates or adjustable drive systems that can be calibrated and controlled satisfactorily. The feeder throats shall be of sufficient size to insure positive and continuous flow. All feeders shall be mechanically or electrically interlocked during operation. On some types of feeders, revolution counters, capable of registering to a tenth of a revolution, may be necessary for accurate calibration and control and may be required.

When drum-mixing plants are used, the central conveyor shall be equipped with a continuous weighing system with a recorder that can be monitored by the plant operator. The weighing system shall be interlocked with the asphalt control unit.

If a drum-mixing plant is used for recycling, a dual weigh-belt system will be required to control delivery of virgin aggregates and recycled material to the dryer. The system shall be equipped with interlocking control mechanisms in a manner that will assure positive and accurate delivery of recycled and virgin materials in proper proportions at all times. Included in this system shall be recorders that will record the total amount of material being delivered by each belt system separately.

The belt-weighing controls shall be connected to a totalizer which is interlocked with the asphalt delivery system in a manner which will assure that asphalt delivered to the mix is at all times within plus or minus 0.4 percent of the intended asphalt content. The system shall be subject to approval of the Engineer. A schematic diagram of the control system shall be furnished for the Engineer's information, prior to plant calibration.

Note 8.

> The totalizer is to perform as a secondary check for the weighing systems. The values from the totalizer can be compared against truck scales, aggregate and asphalt deliveries, and laboratory test results.

401.06.C.2 Dryer and Drum Mixer

The plant shall be equipped with means for drying and heating the aggregate and/or mixture. Heating shall be controlled to avoid injury to the aggregate and asphalt. Operation of the equipment shall be controlled so the desired temperature is maintained as specified.

401.06.C.3 Screens.

The plant shall be equipped with adequate means to remove objectionable oversize and foreign material from the aggregate before entering into the hot-aggregate bin.

401.06.C.4 Bins

The plant shall have hot-aggregate bins of sufficient capacity to insure uniform and continuous operation. The aggregate storage shall be provided with sufficient ventilation by means of a stack or connection to the dust-collection system so that moisture from the hot aggregate will be removed before condensing in the aggregate storage.

When mineral filler is added without heating, adequate additional dry storage shall be provided for the mineral filler, and provisions shall be made for proportioning the filler uniformly in the desired proportion for the mixture. When drum-mixing plants are used, hot-aggregate bins will not be required.

401.06.C.5 Equipment for Heating and Storing Bituminous Materials

Unless the AC is supplied to the project from transports measured by weight, duplicate storage facilities shall be provided, each of sufficient capacity to permit complete unloading of a tank car or truck transport at a single operation. Filling and withdrawal of material from each tank shall be conducted as a separate definite operation which will permit the Engineer to measure the quantity of asphalt used from each tank for each cycle of operation. Each storage tank shall be installed and maintained in a level position. Measurement devices and gaging tables shall be furnished so accurate determinations of quantities used and stored can be made at regular intervals.

Suitable means shall be provided for maintaining the specified temperature of the asphalt in the pipe lines, meters, weighing buckets, spray bars, and other containers and flow lines.

The system shall include a spigot for removing asphalt samples from the delivery line to the mixer before the asphalt is metered into the mixer or weighed.

401.06.C.6 Asphalt Control Unit

Satisfactory means, by weighing metering, or volumetric measurements, shall be provided to obtain the proper amount of asphalt. All measuring devices shall be operated within a delivery tolerance of 1.5 percent.

401.06.C.6.a Asphalt Control Unit - Batch Plants

The quantity of AC for each batch shall be weighed on springless dial scales or shall be measured by an approved automatic batch-metering system.

The means of heating shall be sufficiently flexible so it will not affect the weighing. The container shall be so arranged that it will deliver the AC in a thin, uniform sheet or in multiple streams the full width of the mixer, except in the case of a mixer into which the AC is sprayed. If deposited on a flow or spreader sheet, such sheet shall be heated and shall have sufficient slope to discharge promptly into the mixer.

401.06.C.6.b Asphalt Control Unit - Continuous Plants

Continuous plants shall use a pump to supply AC to the mixer, so constructed as to be under a positive pressure sufficient to maintain uniform delivery from the pump. The pressure shall be maintained within plus or minus 0.5 pound of the mean operating pressure.

Accurate pressure gages shall be installed in readily accessible locations in lines feeding the metering pump and the mixer spray bars. The gages shall be such size that the normal operating pressure can be easily read to the nearest pound.

The mixer unit shall be equipped with a surge tank or a deaeration chamber for supplying a constant-pressure flow of AC to the metering pump. The surge tank or the deaeration chamber shall be approved by the Engineer and shall be of such dimensions and capacity as to provide the pressure specified. The capacity shall be at least a 6-minute supply of AC at the normal mixing rate of the mixer unit.

The surge tank or the deaeration chamber shall be fitted with baffles and other appurtenances necessary to prevent the incorporation of air bubbles into the AC as the tank is being filled and to make possible the deaeration and escape of any air bubbles that may be present. When the surge- tank system is used, the pressure at the spray bar shall be not greater than 20 psi. When the system with the deaeration chamber is used, the pressure difference between the return line and the spray bar shall be not greater than 20 psi and separate return lines shall be provided for each tank.

401.06.C.6.c Asphalt Control Unit - Drum-Mixing Plants

Drum-mixing plants shall use a pump to supply AC to the mixer, so constructed as to be under positive pressure sufficient to maintain uniform delivery from the pump. The totalizing flowmeter shall be placed in the lines between the metering pump and mixer unit. The asphalt control unit shall be interlocked with the aggregate weighing system specified in the 401.06.C.1 and shall be equipped to automatically adjust for variation in aggregate deliver.

Except when approved by the Engineer in writing, the plant shall be operated with automatic controls. The asphalt control unit shall be equipped so the plant operator can monitor and adjust the flow rate of aggregate or AC.

401.06.C.7 Thermometer Equipment

An accurate, registering pyrometer or other approved thermometric instrument shall be installed in the discharge chute of the dryer or drum mixer in such a manner that the temperature of the heated aggregate or mixture is automatically indicated. This instrument shall be located where it is in clear view of the plant or dryer operator and readily accessible to the inspector.

401.06.C.8 Control of Mixer Capacity and Mixing Time

The plant shall be equipped with positive means to govern the time of mixing and to maintain it at a constant rate.

401.06.C.9 Dust Collector

Proper housings, mixer covers, and dust- collecting systems and returns shall be installed and properly maintained. Dust collected by dry-type collection systems may be returned to the hot aggregate mixture with approval of the Engineer. When wet-type collection systems are used or when material is wasted from dry-type collection systems, the Contractor shall dispose of all waste materials in a suitable manner.

Note 9.

> Storage silos similar to thoughts used for the addition of lime into the mix could also be used to return collected fines. Fines form the dust collection system could be stored in a silo at the plant and then metered back into hot aggregate mixture.

401.06.C.10 Hot-Aggregate Proportioning

Batch plant equipment shall include a means for accurately weighing the mineral filler and dried aggregate from each bin in a weighing hopper, suspended on scales, which is of ample size to hold a full batch without hand raking or running over. The weighing hopper shall be supported so it will not be easily thrown out of alignment or adjustment. Gates, both on bins and hopper, shall be constructed so as to prevent leakage when closed.

Aggregate scales shall be operated within a delivery tolerance of 1.0 percent for each aggregate.

Continuous plants shall be equipped with a suitable feeder or feeders for uniformly feeding the dried aggregate into the mixer at the rate desired.

Each feeder shall be equipped with a rectangular gate with one dimension adjustable by positive mechanical means and fitted with a lock. An indicator shall be provided to show the gate opening in inches. Means shall be provided to indicate when the material supply to this feeder is running low. Mineral filler which is added cold shall be proportioned separately from a hopper and arranged to be fed uniformly into the heated aggregate before delivery to the feeder for the mixer.

The requirements of this Paragraph do not apply to drum-mixing plants.

401.06.C.11 Mixer

The mixer shall comply with the following:

401.06.C.11.a Batch Mixer

A batch mixer shall be a twin- shaft pugmill and shall be capable of producing a uniform mixture within the job mix or other specified limits. The clearance of the blades from all fixed and moving parts shall not exceed 3/4 inch, and the orientation of the blades shall be as recommended by the manufacturer. If not enclosed, the mixer shall be equipped with a dust hood to prevent loss of dust by dispersion. The mixer shall be so constructed as to prevent leakage of contents until the batch is to be discharged.

The mixer shall have an accurate time lock to control the operation of a complete mixing cycle by locking the weighing hopper gate when the mixer is charged and until the mixer gate is closed at the completion of the cycle; also, it shall lock the outlet of the AC delivery system throughout the dry-mixing period and the mixer gate throughout the dry- and wet-mixing periods.

The dry-mixing period is the interval of time between the opening of the weighing-hopper gate and the application of AC; the wet-mixing period is the interval of time between the application of AC and the opening of the mixer gate. Control of the timing shall be flexible and capable of being set at intervals of not more than 5 seconds. A mechanical batch counter shall be installed as part of the timing device and shall be so designed as to register only completely mixed batches.

For recycling, batch plant equipment shall be modified to provide for accurate proportioning of the recycled material and for adding it directly into the weigh hopper with weighing as a separate increment of the total batch, and with no preheating necessary. The recycled material may also be accurately proportioned over a weigh-belt including a "totalizer" and "flow-rate meter" and added to the hot elevator leading to the hot bins, with no preheating necessary. This is the heat transfer method. When used, the new aggregate shall be superheated so that, when combined with the recycled material, the temperature of the resultant mixture will meet all maximum and minimum requirements for mixing and placing the hot mixture. Each plant so modified shall initially be subject to general approval of the Engineer.

In any method where preheating is being done, the equipment must be specifically designed for this purpose.

Any proportioning system shall also meet the requirements of 406.06.C.1.

401.06.C.11.b Continuous Mixer

A continuous mixer shall be an approved twin-shaft pugmill capable of producing uniform mixtures within the job-mix or other specified limits. The paddles shall be of a type adjustable for angular position on the shafts and reversible to retard the flow of mix. The mixer shall be equipped with a discharge hopper holding approximately one ton and discharging intermittently by means of quick-acting gates. Distance to the receiving vehicle shall be so regulated as to minimize segregation.

Satisfactory means shall be provided to afford positive interlocking control between the flow of aggregate from the bins and the flow of AC from the meter or other proportioning source. This control shall be accomplished by interlocking mechanical means or by any positive method for accurate control. The equipment shall include an accurate revolution counter, operating continuously during production.

The plant shall be equipped with positive means to govern and maintain constant the time of mixing.

401.06.C.11.c Drum Mixer

A drum mixer shall be capable of producing uniform mixtures within the job-mix or other specified limits. The aggregate, AC, and additives, when furnished, shall be introduced continuously and uniformly and shall be subject to control of the plant operator. The mixture shall be discharged continuously and uniformly onto an elevator or conveyor that discharges into a hot-mixture storage unit meeting requirement of 401.06.C.12. The mixing shall be continued until the AC is uniformly distributed, and the aggregate particles are uniformly coated.

For recycling, drum-mixing equipment shall be modified to process recycled mixtures in accord with Paragraph 404.06.C.11.a.

The plant may be modified so that a pugmill coater is added to the drum mixer. When so modified, the coater must be inclined and positioned as an integral built-in unit, located between the drum and the hot elevator of the plant setup. The AC, and additives when furnished, shall be introduced continuously and uniformly at the lower end of the coater, subject to control by the plant operator. Each plant so modified shall be initially subject to general approval of the Engineer.

401.06.C.12 Hot-Mixture Storage

When the hot mixture is not to be hauled immediately to the project and placed, suitable bins shall be provided. Such bins shall be either surge bins to balance production capacity with hauling and placing capacity or storage bins which are heated or insulated and which have a controlled atmosphere around the mixture. Either type of bin shall be round or octagonal in shape, shall be designed for the intended use, shall fill using an enclosed system unless skip conveyors are used, shall dump material directly into trucks through quick-opening and quick-closing gates, and shall not result in significant segregation damage, or cooling. Affixed to each bin and visible to the loading operator shall be an indicating or control device which will allow control of material remaining in the bin. When surge bins are used, the holding time shall be limited to 4 hours.

If storage bins are used, the holding time shall be within limitations imposed by the Engineer, based on laboratory tests of the stored mixture. Except for a sampling program established by the Engineer, hot mixture placed in storage bins shall be used the same working day it is produced, until a testing program is completed.

401.06.C.13 Safety Requirements.

Adequate and safe stairways to the mixer platform and guarded ladders to other plant units shall be placed at points required for accessibility to sampling locations and other plant operations. All gears, pulleys, chains, sprockets, and other dangerous moving parts shall be thoroughly guarded and protected. Ample and unobstructed space passage shall be maintained at all times in and around the truck-loading space. This space shall be kept free from drippings from the mixing platform. Bins shall comply with requirements of 401.06.A.

401.06.C.14 Plant Calibrations

Note 10.

> This section is to assure that all the automatic equipment that has been incorporated into the plant works properly. Plant calibration should be done every 30 to 40 days or whenever there is a major change in materials.

Personnel, scales, test weights, and equipment for calibration of the plant and for verifying accuracy of proportions shall be furnished by the Contractor. Sufficient space shall be provided between aggregate feeds and elevators to permit taking of samples of the discharge for accurate calibration and control of rate of feed. Samples of sufficient size, for calibration and checking of proportions, shall be weighed; truck sampling and weighing will be acceptable.

The Engineer shall be afforded an uninterrupted opportunity to witness the calibration of the equipment between 7:00 a.m. and 6:00 p.m. on working days. This schedule limitation will be modified, if necessary, for work to be done under an accelerated work schedule. The Engineer's representative shall indicate his witnessing by signing the calibration documents and charts.

When the plant is completely assembled and before any mixture is produced, each aggregate feed shall be calibrated throughout a range wide enough to more than cover the proportion of that material required in the job-mix formula.

For continuous and drum-mixing plant, the AC metering pump shall be calibrated at the operating temperature and with the outlet under pressure equal to that occurring in normal operations.

Each plant scale and metering system shall be calibrated before work on a project or group of tied projects begins. The Engineer may waive calibration of permanent plant scales when a satisfactory operational history is available. The Engineer may require any scale or metering system to be recalibrated if operations indicate it is necessary.

Calibration curves shall be posted in the plant laboratory for convenient reference in selecting gate settings for control of gradation. New calibration curves shall be made each time there is a change in size or source of any aggregate being used.

401.07 HAULING EQUIPMENT.

401.08 ASPHALT CONCRETE PAVERS.

401.09 WEATHER LIMITATIONS.

401.10 CONDITIONING OF EXISTING SURFACE.

Note 11

The above sections have intentionally been left blank because they are unrelated to an extraction free specification.

401.11 CONTROL OF ASPHALT MIXTURE

401.11.A General

All materials will be inspected, tested and approved by the Engineer prior to incorporation in the work. Any work in which materials not previously approved are used shall be performed at the Contractor's risk and may be considered as unauthorized and unacceptable and not subject to the payment provisions of the contract.

Materials will be sampled and tested by a qualified representative of the Contracting Agency unless otherwise specified in the special provisions. Copies of all test results will be furnished to the Contractor's representative at the Contractor's request.

Whenever a reference is made in the specifications to a Federal Specification, or to a specification or test designation of the American Association of State Highway and Transportation Officials, the American Society for Testing and materials, or any other recognized national organization, it shall mean the year of adoption or latest revision of the specification or test designation in effect on the day the advertisement for bids for the work is dated.

401.11.B CONTRACTOR QUALITY CONTROL

Note 12.

> Contractor quality control is the next logical step in the advancement of the highway industry. With changes in equipment and material it is only the owner/operator that truly knows his equipment and how to make the most out of it. By having the contractor perform quality control testing the contracting agency can perform separate and distinct acceptance test. With the additional information gained from the contractors quality control and the contraction agencies acceptance tests better engineering judgments can be made to correct problems and improve the final product.

401.11.B.1 General

Quality control measures sufficient to produce materials of acceptable quality are the responsibility of the Contractor; however, the specifications for hot mix asphalt require specific quality control requirements. The Contractor is required to provide and maintain a Quality Control Plan, hereinafter referred to as Plan, along with all the personnel, equipment, supplies and facilities necessary to obtain samples, perform and document tests, and otherwise assure the quality of the product.

The Contractor shall be prepared to discuss and present, at the pre-construction conference, his understanding of the quality control responsibilities for specific items as included in the contract. The Contractor shall submit the Plan, for the appropriate items, to the Engineer for approval, with the proposed JMF, as defined in section 401.02.

The Contractor shall not start work on the subject items without an approved Plan. No partial payment will be made for materials subject to specific quality control requirements without an approved Plan. As a part of the process for approving the contractor's plan, the Engineer may require the Contractor's technician to perform testing of samples to demonstrate an acceptable level of performance.

The Contractor shall perform process control sampling, testing and inspection during all phases of the work and shall perform the process control sampling, testing and inspection at a rate sufficient to assure that the work conforms to the contract requirements. The Contractor shall provide the Engineer a certification stating that all of the testing equipment to be used is properly calibrated and will meet the specifications applicable for the specified test procedures.

The Plan, shall meet the requirements of all the appropriate Subsections and the requirements specified below. The Plan may be operated wholly or in part by a supplier or an independent organization; however, the Plan's administration, including compliance with the Plan and its modification, shall remain the responsibility of the Contractor.

401.11.B.2 Elements of the Plan

The Plan shall address all elements which affect the quality of the asphalt concrete including:

(A) Mix Design
(B) Aggregate Production
(C) Quality of Components
(D) Stockpile Management
(E) Proportioning
(F) Mixing, including addition of Mineral Admixture, if required
(G) Placing and Finishing
(H) Joints
(I) Compaction

The Plan shall also address management and coordination of activities of the personnel assigned to this function.

401.14.B.3 Plan Administrator and Technicians Qualifications

The Plan shall include the use of the following:

- **Plan Administrator**

The individual administering the plan must be a full time employee of the Contractor or a consultant engaged by the Contractor. In either case, the individual employed shall have full authority to institute any and all actions necessary for the successful operation of the plan. The individual administering the plan should not report to the plant or project superintendent, but to the Contractor's quality control manager. The Contractor's employee or consultant may supervise the quality control plan on more than one project if that person can be at the job site within one hour after being notified of a problem.

- **Process Control Technician (PCT)**

This person will be expected to utilize laboratory test results and other quality control practices to assure the quality of aggregates and other mix components and adjust and control mix proportioning to meet the mix design(s). The Plan shall detail the frequency of each type of test, when and how corrective actions are to be taken, and the means of documentation.

The PCT shall be responsible for periodically inspecting all equipment utilized in proportioning and mixing to assure its proper operating condition and to assure that proportioning and mixing is in conformance with the mix design and other requirements. The Plan shall set forth how these duties and responsibilities will be accomplished and documented.

At least one full time individual will be required to perform this function. If more than one individual is required to accomplish these requirements, the Plan shall so note. Included also shall be the criteria utilized by the PCT to reject unsatisfactory materials.

- **Quality Control Technician (QCT)**

This person will be expected to assure that the individual and combined materials meet the requirements of the specifications. In addition, this person shall be responsible for periodically inspecting all equipment utilized in placing, finishing and compacting to assure its proper operating condition and to assure placing, finishing, joint construction and compaction is in conformance with the specifications. The Plan shall set forth how these duties and responsibilities will be accomplished and documented.

At least one full time individual will be required to perform this function. If more than one individual is required, the Plan shall so note. Included also shall be the criteria utilized by the QCT to reject unsatisfactory materials and to stop and have corrected unsatisfactory construction practices.

- **Qualifications**

The Plan Administrator shall meet at least one of the following requirements:

a. Professional Engineer registered in State with one year of highway paving experience acceptable to the Department.

b. Engineer-in-Training certified by the State with two years of highway paving experience acceptable to the Department.

c. An individual with three years of highway paving experience acceptable to the Department and with a Bachelor of Science Degree in Civil Engineering, Civil Engineering Technology or Construction.

d. Construction Materials Technician certified at Level III by NICET.

e. Highway Materials Technician certified at Level III by NICET.

f. Highway Construction Technician certified at Level III by NICET.

g. A NICET certified Engineering Technician in Civil Engineering Technology with five years of highway paving experience acceptable to the Department.

The Process Control Technician (PCT) and Quality Control Technician (QCT) shall meet one of the following criteria:

h. Construction Materials Technician certified at Level II or higher by NICET in appropriate subfield.

i. Those listed under a through g above, meeting the criteria for Plan Administrator, if they have a demonstrated proficiency in performing the appropriate test(s) or inspection function.

j. Construction Materials Technician trainee under direct observation of an individual listed in h or i above.

401.11.B.4 Quality Control Laboratory

The Plan must include a laboratory or laboratories meeting the requirements of the AASHTO Reference Materials Laboratory (AMRL) or equivalent. It is expected that the laboratory will be located onsite at the asphalt plant facility so as to minimize temperature loss of samples and to expedited the availability of test results.

Laboratory facilities shall be kept clean and all equipment shall be maintained in proper working condition. The Engineer shall be permitted unrestricted access to inspect and review the Contractor's laboratory facility. The Engineer will advise the Contractor in writing of any noted deficiencies concerning the laboratory facility, equipment, supplies, or testing personnel and procedures. When the deficiencies are serious enough to be adversely affecting test results, the incorporation of the materials into the work will be halted immediately and will not be permitted to resume until the deficiencies are satisfactorily corrected.

401.11.B.5 Sampling

The Plan shall contain a statistical-based procedure of random sampling which provides that all material being produced have an equal chance of being selected for sampling and testing. The Engineer shall be provided the opportunity to witness all sampling.

When directed by the Engineer, the Contractor shall sample and test any material which appears inconsistent with similar material being sampled, unless such material is voluntarily removed and replaced or corrected by the Contractor. All sampling shall be in accordance with standard AASHTO, ASTM or Contracting Agency procedures.

401.11.B.6 Testing

All testing shall be performed in accordance with the process control and acceptance test procedures applicable to the specified contract items or other methods set forth in the Quality Control Plan and approved by the Engineer. Should process control acceptance test procedures not be applicable to quality control tests, the plan shall stipulate which tests procedures will be utilized. The Contractor shall provide copies of all test results to the Engineer upon request. Test results shall be furnished to the Engineer on forms furnished by or otherwise meeting the approval of the Engineer.

Tests results shall be conducted immediately after sampling, with results generally available within two hours, but at no time later than 12 hours after sampling.

401.11.B.7 Records

The Contractor shall maintain complete testing and inspection records and make them available to the Department for review and copies as requested.

Linear control charts shall be maintained by the Contractor. Control charts shall be posted in a location satisfactory to the Engineer and shall be kept up to date at all times. As a minimum, the control charts shall identify the project number, the contract item number, the test number, each test parameter, the upper and/or lower specification limit applicable to each test parameter, and the Contractor's test results. The Contractor shall use the control charts as part of a process control system for identifying production and equipment problems and for identifying potential pay factor reductions before they occur. If the Contractor's projected data, during production, indicates a potential problem and the Contractor is taking no satisfactory corrective action, the Engineer may halt production or acceptance of the material.

The Department reserves the right to check the records of the PCT and QCT at any time. The Department may take and test samples at any time to confirm the effectiveness of the activities of the PCT and QCT.

401.11.C ASPHALT MIX VERIFICATION

401.11.C.1 General

It is the intent of the verification process for the Contractor to perform job mix and placement control testing at the start of plant production and in conjunction with the calibration of the plant for the JMF submitted as required in 401.02. It should be recognized that the aggregates used in production by the plant may not satisfy the gradation requirements or produce a mix that meets the mix design requirements. In those instances, it will be necessary to reevaluate and redesign the mix using plant-available aggregates. Specimens should be prepared and the optimum asphalt content determined in the same manner as for the original design tests.

Note 13.

> For end result specifications to work the contractor must first prove that the product to be delivered will meet design requirements. Mix verification is the point in the production process where the contractor proves to the contracting agency his material meets specifications. If mix verification is not performed on a project a continual game of catchup can go on while trying to correct any problems. In some cases the project could be completed before problems are corrected. The mix verification process requires the proper information be collected and the product evaluated before full production begins and allows for corrections to be made.

Prior to full production, the Contractor shall produce approximately 500 tons of material according to the job mix formula to be placed as a test section. The depth of material placed for the test section shall be the same as that specified for the construction of the course which it represents. The underlying grade of pavement structure upon which the test section is to be constructed shall be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section shall be the same type and weight to be used on the remainder of the course represented by the test section.

If the test section should prove to be unsatisfactory, the necessary adjustments to the mix design, plant operation, and/or rolling procedures shall be made. Additional test sections, as required, shall be constructed and evaluated for conformance to the requirements of the specifying agency. When test sections do not conform to requirements, the pavement shall be removed and replaced at the Contractor's expense. A marginal quality test section that has been placed in an area of low traffic may be left in place. If a second test section also does not meet specification requirements, both sections shall be removed at the Contractor's expense. Full production shall not begin without the Engineer's approval. Test sections shall be paid for under standard pay items for the material being placed.

401.11.C.2 Testing

The completed mixture shall be sampled at the plant. Four samples shall be taken on the 500 tons produced for the verification test section. The samples shall be taken in accordance with procedures contained in AASHTO T-168, Sampling Bituminous Paving Mixtures. Testing shall be in accordance with the Marshall Method procedures contained in Chapter III of the Asphalt Institute Manual Series No. 2 (MS-2), current edition. The following is a listing of AASHTO test procedures to be run on each sample taken from the Plant:

T 245 Resistance to Plastic Flow of Bituminous Paving Mixtures.

T 269 Percent Air Voids in Compacted Bituminous Paving Mixtures.

T 166 Bulk Specific Gravity of Bituminous Paving Mixtures.

T 209 Maximum Specific Gravity of Bituminous Paving Mixtures, Rice Method.

T 176 Plastic Fines in Graded Aggregates.

ASTM D4125 Asphalt Content of Bituminous Mixtures by the Nuclear Method.

T 11 Amount of Material Finer Than the 200 Sieve in Aggregate.

T 27 Sieve Analysis of Fine and Coarse Aggregates.

or

T 164 Quantitative Extraction of Bitumen from Paving Mixtures.

T 30 Mechanical Analysis of Extracted Aggregate.

Acceptance of the mix for the test section shall be in accordance with Section 401.19. The Percent in Compliance for the test section as calculated in accordance with section 106.05 shall be 85 percent.

Note 14.

This section does allow the optional use of the extraction test for verification purposes. Extraction tests done during the mix verification can be used to establish a correlation between cold feed gradations and extracted gradations. the test can also be used as a verification of the nuclear asphalt content gauge calibration.

401.11.C.3 Compaction Test Strip

During placement of the test section, a minimum 300 linear foot section shall be used to form a compaction test strip. The compaction test strip shall not include the first 500 linear feet of the test section. The test strip is for the purpose of verifying project density requirements. The test strip shall be placed in accordance with the requirements of the specifying agency.

Rolling of the test strip shall be continued until no appreciable increase in density is obtained by additional roller coverages as determined by the nuclear density gauge. Upon completion of the rolling, the mean density of the test strip shall be based upon 10 tests taken at randomly selected sites within the test strip area using the portable nuclear moisture density gauge device and correlated with cores cut from those sites.

The results from the density test strip shall be compared against the average maximum specific gravity value determine from the mix verification samples. The unit weight determined from the density test strip should be between 92 and 96 percent of the unit weight determined by the maximum specific gravity. In those instances where the average density from the test strip does not fall between 92 and 96 percent of the average maximum specific gravity, it shall be necessary to reevaluate the roadway compaction operation and/or asphalt mix.

401.11.D CONTROL OF ASPHALT MIXTURE (VOID PROPERTIES AND ASPHALT CONTENT)

The asphalt mixture furnished by the Contractor shall conform to the Mix Design JMF and void properties, established during the Mix Verification as determined in subsection 401.11.C, and within the allowable deviations from the target values. The allowable deviations from the target values for the JMF and void properties of the mix shall be as shown in Table 401.3. The allowable deviation from the target value for the asphalt content shall be (+/-) 0.4 percent.

Table 401

Allowable Deviations from Target Void Properties

Asphalt Content Void Properties	Allowable Deviation from Target Value
VTM	1.8
VMA	1.8
Flow	1.8

Allowable Deviations from Job Mix Target Values

Asphalt Content Gradations (Sieve Size)	Allowable Deviation from Target Value
No. 8	6
No. 16	4
No. 30	4
No. 50 & 40	3
No. 100	3
No. 200	2

The minimum mandatory testing shall be as follows:

<u>MINIMUM MANDATORY TESTING</u>

PROCESS CONTROL

(Void Properties and Asphalt Content)

Material	Test	Location	Frequency	Split Sample	Notes
Aggregates for Asphalt Mixes	Sand Equivalent AASHTO T 176	On Site On Site	1 per 5,000 tons but not less than 1 per week	Yes	Sampled just prior to mixing with asphalt
feed	Gradation of aggregate AASHTO T 11 AASHTO T 27	On Site	4 per each day of production	Yes	Sampled from plant cold or hot bins
	Moisture Content of aggregate AASHTO T 255	On Site	2 per each day of production	Yes	Sampled from plant cold feed belt
Asphalt Cement	Viscosities AASHTO T 201 AASHTO T 202	Optional	1 per 1,000 tons but not less than 1 per day of production	Yes	Sampled from pugmill line

MINIMUM MANDATORY TESTING (Cont.)

ACCEPTANCE

(Void Properties and Asphalt Content)
Split

Material	Test	Location	Frequency	Sample	Notes
Asphalt Mix	Asphalt Content ASTM 4125 Nuclear Method	On Site	4 per each day of production	Yes	Sample may be from behind paver or from hauling unit
	Maximum Theoretical Density AASHTO T 209	On Site	4 per each day of production	Yes	A portion of the same sample as the AC Content test
	Marshall Molded Samples - AASHTO T 245 and density - AASHTO T166 AASHTO T269	On Site	4 per each day of production 1 set of 3 samples at design blows per side.		A portion of the same sample as the AC Content test
	Core Density AASHTO T 166 Method C or Nuclear Density ASTM D2950	On Site	1 per 1,000 lane feet of each course		Duplicate sample when requested

401.12 PLACING AND FINISHING.

401.13 COMPACTION.

401.14 JOINTS, TRIMMING EDGES, AND CLEANUP.

401.15 PAVEMENT SAMPLES.

The Contractor shall cut core samples from the compacted pavement for testing. Coring shall be in accordance with AASHTO T 230, Method B, except the core diameter shall be 4 inches, 6 inches, or both as specified by the Engineer. The cores will be used to determine pavement density in accordance with Subsection 401.17 and when applicable, used to determine pavement thickness in accordance with Subsection 401.19. Refilling the sample holes with suitable material and compacting the material shall be performed by the Contractor under the supervision of the Engineer.

401.16 ACCEPTANCE SAMPLING AND TESTING OF ASPHALT CONCRETE MIXTURES (VOID PROPERTIES AND ASPHALT CONTENT)

Acceptance samples shall be taken by a random method from each lot. Acceptance of the specified mixes for void properties will be made using The Void in Total Mix (VTM), Voids in Mineral Aggregate (VMA), Flow, and asphalt content. The target values used for acceptance shall be those established during the Mix Verification under subsection 401.11(b). Acceptance sampling and testing of asphalt mixtures will be as specified in subsection 401.11(c). The test results of the acceptance samples will be evaluated using quality levels from which a pay factor will be determined in accordance with Subsection 106.05.

The final pay factor for this item will be the lowest pay factor determined from the void property tests, asphalt content, and compaction test, as determined in subsections 401.16 and 401.17. A lot is considered to be one day's production.

Based on the test results and other specification criteria, the Engineer will determine the acceptability of material for incorporation in the work. The Engineer will identify materials which are unquestionably defective and might jeopardize the serviceability of the work. Such material shall be removed and replaced or otherwise corrected by the Contractor.

Materials which contain minor defects, but are deemed acceptable by the Engineer, may also be removed and replaced or otherwise corrected at the option of the Contractor. If left in place, such materials may contribute to reduced payment for the total production of that item. If removed, the quantity will include all material in the questioned sublot, unless a smaller isolated quantity is identified by the Engineer.

The final pay factor may be subject to reduction due to reduced pay factors for other characteristics.

401.17 ACCEPTANCE SAMPLING AND TESTING OF ASPHALT CONCRETE MIXTURES (COMPACTION)

Acceptance sampling and testing of asphalt mixture (compaction) will be in accordance with subsection 401.11. Minimum mandatory testing will be as specified in subsection 401.11.

The density of the pavement will be determined from the cores obtained in accordance with Subsection 401.15. The specific gravity of the cores shall be determined in accordance with AASHTO T 166, Method A, except the paraffin coating is deleted, and will be converted to density by multiplying by 62.4 pounds per cubic foot.

The in place density of the compacted hot mix asphalt shall be between 92 and 96 percent of the maximum theoretical density, AASHTO T 209, as determined during the mix design verification testing. Normally, in order not to obtain defective material, a mean value of at least 94 percent of Maximum Theoretical Density (MDT) will be required. The mean is defined as the average of the core densities per lot. A lot is defined as one day's production for each pay item.

Acceptance samples will be taken by the Contractor at locations randomly selected by the Engineer at a frequency of at least one test for each 1,000 lane feet. These samples shall be 6-inch diameter cores cut full depth if required to obtain satisfactory test samples. The test layer will then be removed in a satisfactory manner. Cooling of the pavement prior to coring and/or cooling of the removed cores for layer separation may be required. Ice, dry ice, or CO_2 may be used for cooling. An alternate means of testing is with the use of a nuclear moisture density gauge, correlated during the placement of the density test strip.

401.18 ACCEPTANCE TESTING OF ASPHALT CONCRETE MIXTURES (SURFACE TOLERANCE).

401.19 ACCEPTANCE TESTING OF ASPHALT CONCRETE MIXTURES (THICKNESS).

401.20 ACCEPTANCE SAMPLING AND TESTING OF ASPHALT.

401.21 METHOD OF MEASUREMENT.

401.22 BASIS OF PAY

Note 15.

> The above sections have intentionally been left blank because they are unrelated to an extraction free specification.

106.5 STATISTICAL EVALUATION OF MATERIALS FOR ACCEPTANCE

When the specifications provide for material to be sampled and tested on a statistical basis, the material will be evaluated for acceptance in accordance with this Subsection. All test results for a lot will be analyzed collectively and statistically by the Quality Level Analysis - Standard Deviation Method using the procedures listed to determine the total estimated percent of the lot that is within specification limits. Quality Level Analysis is a statistical procedure for estimating the percent in compliance to a specification and is affected by shifts in the arithmetic mean ($\overline{X}$) and by the sample standard deviation (s). Analysis of each test parameter will be base on an Acceptable Quality Level (AQL) of 90.0 and a producer's risk of .10 . AQL may be viewed as the lowest percent of specification material that is acceptable as a process average. The producer's risk is the probability that when the Contractor is producing material at exactly the AQL, the materials test results will show it is below the AQL.

If less than three samples have been obtained at the time a lot is terminated, the material in the shortened lot will be included as a apart of an adjacent lot.

The Engineer may reject any quantity of material which appears to be defective based on visual inspection or test results. Such rejected material shall not be used in the work and the results of tests run on the rejected material will not be included in the lot acceptance tests.

Quality Level Analysis - Standard Deviation Method Procedures are as follows:

(a) Determine the arithmetic mean ($\bar{X}$) of the test results:

$$\bar{X} = \frac{\sum x}{N}$$

where $\sum$ = summation of

x = individual test value

n = total number of test values

(b) Compute the sample standard deviation(s):

$$s = \sqrt{\frac{n\sum(x^2) - (\sum x)^2}{n(n - 1)}}$$

where, $\sum(x^2)$ = summation of the squares of individual test values.

$(\sum x)^2$ = summation of the individual test values squared.

(c) Compute the upper quality index (Q_u):

$$Q_u = \frac{USL - \bar{X}}{s}$$

where, USL (upper specification limit) = target value plus allowable deviation.

(d) Compute the lower quality index (Q_L):

$$Q_L = \frac{\bar{X} - LSL}{s}$$

where, LSL (lower specification limit) = target value minus allowable deviation.

(e) Determine P_u (the percent within the upper specification limit which corresponds to a given Q_u) from Table 106-1. Note: If a USL is not specified, P_u will be 100.

(f) Determine P_L (the percent within the lower specification limit which corresponds to a given Q_L) from Table 106-1. Note: If an LSL is not specified, P_L will be 100.

(g) Determine the Quality Level (the total percent wihtin specification limits).

Quality Level = $(P_u + P_L) - 100$

Table 106-1

QUALITY LEVEL ANALYSIS BY THE STANDARD DEVIATION METHOD				
P_U or P_L Percent within Limits for Positive Values of QU or QL	Upper Quality Index Q_U or Lower Quality Index Q_L			
	n=3	n=4	n=5	n=6
100	1.16	1.50	1.79	2.03
99	--	1.47	1.67	1.80
98	1.15	1.44	1.60	1.70
97	--	1.41	1.54	1.62
96	1.14	1.38	1.49	1.55
95	--	1.35	1.44	1.49
94	1.13	1.32	1.39	1.43
93	--	1.29	1.35	1.38
92	1.12	1.26	1.31	1.33
91	1.11	1.23	1.27	1.29
90	1.10	1.20	1.23	1.24
89	1.09	1.17	1.19	1.20
88	1.07	1.14	1.15	1.16
87	1.06	1.11	1.12	1.12
86	1.04	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04
84	1.01	1.02	1.01	1.01
83	1.00	0.99	0.98	0.97
82	0.97	0.96	0.95	0.94
81	0.96	0.93	0.91	0.90
80	0.93	0.90	0.88	0.87
79	0.91	0.87	0.85	0.84
78	0.89	0.84	0.82	0.80
77	0.87	0.81	0.78	0.77
76	0.84	0.78	0.75	0.74
75	0.82	0.75	0.72	0.71
74	0.79	0.72	0.69	0.68
73	0.76	0.69	0.66	0.65
72	0.74	0.66	0.63	0.62
71	0.71	0.63	0.60	0.59
70	0.68	0.60	0.57	0.56
69	0.65	0.57	0.54	0.53
68	0.62	0.54	0.51	0.50
67	0.59	0.51	0.47	0.47
66	0.56	0.48	0.45	0.44
65	0.52	0.45	0.43	0.41

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

Table 106-1 (continued)

QUALITY LEVEL ANALYSIS BY THE STANDARD DEVIATION METHOD

P_U or P_L Percent within Limits for Positive Values of QU or QL	Upper Quality Index Q_U or Lower Quality Index Q_L			
	n=3	n=4	n=5	n=6
64	0.49	0.42	0.40	0.39
63	0.46	0.39	0.37	0.36
62	0.43	0.36	0.34	0.33
61	0.39	0.33	0.31	0.30
60	0.36	0.30	0.28	0.27
59	0.32	0.27	0.25	0.25
58	0.29	0.24	0.23	0.22
57	0.25	0.21	0.20	0.19
56	0.22	0.18	0.17	0.16
55	0.18	0.15	0.14	0.14
54	0.14	0.12	0.11	0.11
53	0.11	0.09	0.08	0.08
52	0.07	0.06	0.06	0.05
51	0.04	0.03	0.03	0.03
50	0.00	0.00	0.00	0.00

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

Appendix E

Data Demonstration Projects

Acceptance Plans

F H W A QUALITY LEVEL ANALYSIS DP #74

AGGREGATES

Item No. #112-B Calculations for Percent Lot VERIFICATION
Description BINDER W/RAP Within Simulation Limits Quantity N/A
Date 10/12/89 Calcs. by C P
Project # 112 State IA

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
3	10/10/8	4.306	100	87.8	76.7	52.8	37.2		17.9			3.63
4	10/10/8	4.789	100	92.7	81.2	57.5	40.7		19.7			5.65
5	10/10/8	4.927	100	89.5	80.4	59.7	42.2		19.9			5.23
6	10/10/8	4.540	100	91.1	78.9	54.6	37.2		18			5.32
COUNT N		4	4	4	4	4	4		4			4
AVERAGE X		4.641	100	90	79	56	39		19			5.0
STD. DE s		0.3	0.0	2.1	2.0	3.1	2.5		1.1			0.9
Qu = (USL-X)/S		2.0	ERR	3.2	2.8	2.2	2.6		2.8			2.2
Ql = (X-LSL)/S		0.9	ERR	2.5	3.1	1.7	2.1		4.5			2.3
Pu from table		100	ERR	100	100	100	100		100			100
Pl from table		79	ERR	100	100	100	100		100			100

QUALITY LEVEL
(Pu + Pl)-100* 79 * ERR * 100 * 100 * 100 * 100 ******* 100 ************* 100

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the
the lowest value shown under quality level. 79 Percent

Remarks________

MIX DESIGN VERIFICATION GRADATION
75 BLOW DESIGN

F H W A — QUALITY LEVEL ANALYSIS — DP #74

AGGREGATES

Item No.	#112-B	Calculations for Percent	Lot	1
Description	BINDER W/RAP	Within Simulation Limits	Quantity	N/A
Date	10/12/89		Calcs. by	C P
Project	# 112		State	IA

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
1	10/09/8	4.883	100	90.0	80.1	56.2	39.0	27.6	18.5	9.2	5.7	4.0
2	10/09/8	4.641	100	87.6	75.0	50.0	36.1	26.8	18.2	9.0	5.6	4.0
3	10/10/8	4.306	100	87.8	76.7	52.8	37.2	27.0	17.9	8.7	5.2	3.6
4	10/10/8	4.789	100	92.7	81.2	57.5	40.7	29.1	19.7	10.6	7.1	5.6
5	10/10/8	4.927	100	89.5	80.4	59.7	42.2	29.9	19.9	10.4	6.9	5.2
6	10/10/8	4.540	100	91.1	78.9	54.6	37.2	26.6	18.0	9.8	6.8	5.3
COUNT	N	6	6	6	6	6	6	28	6	28	28	6
AVERAGE	X	4.681	100	89.8	78.7	55.1	38.8	28.3	18.7	10.3	6.7	4.6
STD. DE	s	0.2	0.0	1.9	2.4	3.5	2.4	1.56	0.9	0.81	0.73	0.9
Qu = (USL-X)/S		2.2	ERR	3.7	2.6	2.3	3.1		3.7			2.6
Ql = (X-LSL)/S		1.2	ERR	2.5	2.4	1.2	2.0		5.3			2.0
Pu from table		100	ERR	100	100	100	100		100			100
Pl from table		88	ERR	100	100	88	99		100			99

QUALITY LEVEL

(Pu + Pl)-100* 88 * ERR * 100 * 100 * 88 * 99 ******* 100 ************* 99

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 88 Percent

Remarks________

F H W A — QUALITY LEVEL ANALYSIS — DP #74

VOIDS

Calculations for Percent Within Simulation Limits

Item No. # 112-B — Lot: VERIFCATN

Description BINDER W/RAP — Quantity: N/A

Date 10/13/89 — Calcs. by: C P

Project # 112 — State: IOWA

TARGET		4.8	6.8	16.6	7.0
USL		5.2	8.6	18.4	8.8
LSL		4.4	5.0	14.8	5.2
SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
3	10/10/89	4.306	4.9	14.9	9.7
4	10/10/89	4.789	4.4	14.6	9.3
5	10/10/89	4.927	4.4	14.9	10.3
6	10/10/89	4.540	4.3	14.8	10.7
COUNT	N	4	4	4	4
AVERAGE	X	4.641	4.5	14.8	10.0
STD. DEV.	s	0.3	0.2	0.1	0.6
Qu = (USL-X)/S		2.0	16.9	30.4	-2.0
Ql = (X-LSL)/S		0.9	-2.0	0.1	7.9
Pu		100	100	100	0
Pl		79	0	54	100
QUALITY LEVEL (Pu + Pl)-100	***	79 ***	0 ***	54 ***	0

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 0 Percent

REMARKS:

F H W A — QUALITY LEVEL ANALYSIS — DP #74

AGGREGATES

Item No.	#112-B	Lot	3
Description	BINDER W/RAP	Quantity	N/A
Date	10/12/89	Calcs. by	C P
Project	# 112	State	IA

Calculations for Percent Within Simulation Limits

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
10	10/17/8	5.086	100	90.5	81.0	58.9	42.4	30.9	21.2	11.5	7.5	5.6
11	10/17/8	4.558	100	88.4	78.1	52.0	37.8	28.2	20.0	11.1	7.5	5.9
12	10/17/8	4.992	100	91.1	81.7	59.4	42.8	30.5	20.1	10.0	6.1	4.3
COUNT	N	3	3	3	3	3	3		3			3
AVERAGE	X	4.879	100	90.0	80.3	56.8	41.0		20.4			5.3
STD. DE	s	0.3	0.0	1.4	1.9	4.2	2.8		0.7			0.9
Qu = (USL-X)/S		1.1	ERR	5.0	2.5	1.5	1.8		2.3			1.9
Ql = (X-LSL)/S		1.7	ERR	3.6	3.8	1.4	2.5		9.2			2.8
Pu from table		96	ERR	100	100	100	100		100			100
Pl from table		100	ERR	100	100	100	100		100			100

QUALITY LEVEL
(Pu + Pl)-100* 96 * ERR * 100 * 100 * 100 * 100 ******* 100 ************* 100

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 96 Percent

Remarks________

F H W A — QUALITY LEVEL ANALYSIS — DP #74

AGGREGATES

Item No.	#112-B	Calculations for Percent		Lot	2
Description	BINDER W/RAP	Within Simulation Limits		Quantity	N/A
Date	10/12/89			Calcs. by	C P
Project	# 112			State	IA

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
7	10/11/8	4.404	100	89.8	80.3	56.0	38.6	27.7	18.9	10.3	6.9	5.6
8	10/11/8	4.729	100	91.1	80.0	54.5	38.0	26.7	17.6	8.5	5.1	3.7
9	10/11/8	4.910	100	87.6	76.8	54.0	38.9	28.2	19.3	10.3	6.8	5.5
COUNT	N	3	3	3	3	3	3		3			3
AVERAGE	X	4.681	100	89.5	79.0	54.8	38.5		18.6			4.9
STD. DE	s	0.3	0.0	1.8	1.9	1.0	0.5		0.9			1.1
Qu = (USL-X)/S		2.0	ERR	4.3	3.1	8.0	16.2		3.8			1.9
Ql = (X-LSL)/S		1.1	ERR	2.6	3.1	3.8	9.8		5.1			1.9
Pu from table		100	ERR	100	100	100	100		100			100
Pl from table		89	ERR	100	100	100	100		100			100
QUALITY LEVEL (Pu + Pl)-100*		89 *	ERR *	100 *	100 *	100 *	100 *	*******	100	******	*******	100

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 89 Percent

Remarks________

F H W A — QUALITY LEVEL ANALYSIS — DP #74

AGGREGATES

Item No.	#112-B	Calculations for Percent	Lot	5
Description	BINDER W/RAP	Within Simulation Limits	Quantity	N/A
Date	10/12/89		Calcs. by	C P
Project	# 112		State	IA

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
16	10/21/8	4.871	100	91.8	80.4	56.9	40.2	29.3	20.3	10.6	6.7	5.3
17	10/21/8	4.934	100	91.7	82.4	56.9	40.9	29.9	20.8	11.1	7.2	5.7
18	10/21/8	4.862	100	89.0	79.0	57.5	41.1	29.5	20.0	10.5	7.0	5.7
COUNT	N	3	3	3	3	3	3		3			3
AVERAGE	X	4.889	100	90.8	80.6	57.1	40.7		20.4			5.6
STD. DE	s	0.0	0.0	1.6	1.7	0.4	0.5		0.4			0.3
Qu = (USL-X)/S		7.9	ERR	3.9	2.5	16.3	10.3		4.3			5.1
Ql = (X-LSL)/S		12.5	ERR	3.6	4.4	16.9	13.2		16.8			10.1
Pu from table		100	ERR	100	100	100	100		100			100
Pl from table		100	ERR	100	100	100	100		100			100

QUALITY LEVEL
(Pu + Pl)-100* 100 * ERR * 100 * 100 * 100 * 100 ******* 100 ************* 100

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the
the lowest value shown under quality level. 100 Percent

Remarks________

F H W A — QUALITY LEVEL ANALYSIS — DP #74

AGGREGATES

Item No.	#112-B	Calculations for Percent	Lot	4
Description	BINDER W/RAP	Within Simulation Limits	Quantity	N/A
Date	10/12/89		Calcs. by	C P
Project	# 112		State	IA

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
13	10/20/8	5.210	100	88.0	80.4	58.1	40.1	28.5	19.2	10.0	6.6	5.2
14	10/20/8	4.793	100	89.2	80.1	57.6	40.9	28.9	19.5	10.5	7.2	5.7
15	10/20/8	4.788	100	92.0	84.1	59.3	41.1	29.2	19.3	9.5	5.8	4.3
COUNT	N	3	3	3	3	3	3		3			3
AVERAGE	X	4.930	100	89.7	81.6	58.4	40.7		19.4			5.1
STD. DE	s	0.2	0.0	2.1	2.2	0.9	0.6		0.1			0.7
Qu = (USL-X)/S		1.1	ERR	3.5	1.6	5.3	9.5		18.3			2.5
Ql = (X-LSL)/S		2.2	ERR	2.3	3.9	8.3	12.0		37.1			3.0
Pu from table		91	ERR	100	100	100	100		100			100
Pl from table		100	ERR	100	100	100	100		100			100

QUALITY LEVEL
(Pu + Pl)-100* 91 * ERR * 100 * 100 * 100 * 100 ******* 100 ************* 100

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 91 Percent

Remarks________

F H W A — QUALITY LEVEL ANALYSIS — DP #74

AGGREGATES

Item No.	#112-B	Lot	7
Description	BINDER W/RAP	Quantity	N/A
Date	10/12/89	Calcs. by	C P
Project	# 112	State	IA

Calculations for Percent Within Simulation Limits

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
23	10/24/8	4.504	100	87.2	76.6	49.7	34.9	26.3	18.8	10.6	7.1	5.8
24	10/24/8	4.530	100	86.9	73.3	46.2	33.4	25.3	17.8	9.8	6.4	5.0
25	10/24/8	4.632	100	86.7	76.4	52.5	37.0	26.9	18.6	10.4	7.0	5.7
26	10/24/8	4.644	100	87.6	76.4	52.3	36.5	26.7	18.5	10.1	6.6	5.2
27	10/25/8	5.530	100	92.9	84.0	61.3	43.6	31.9	22.2	12.2	8.2	6.6
28	10/25/8	4.610	100	86.1	75.1	52.0	36.9	26.9	18.7	10.4	7.0	5.6
COUNT	N	6	6	6	6	6	6		6			6
AVERAGE	X	4.742	100	87.9	77.0	52.3	37.1		19.1			5.7
STD. DE	s	0.4	0.0	2.5	3.7	5.0	3.5		1.6			0.6
Qu = (USL-X)/S		1.2	ERR	3.7	2.2	2.1	2.5		1.8			2.1
Ql = (X-LSL)/S		0.9	ERR	1.2	1.1	0.3	0.9		3.3			4.7
Pu from table		88	ERR	100	100	100	100		99			100
Pl from table		80	ERR	88	85	59	80		100			100
QUALITY LEVEL (Pu + Pl)-100*		68	ERR	88	85	59	80	*******	99	*****	*****	100

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 59 Percent

Remarks________

F H W A — QUALITY LEVEL ANALYSIS — DP #74

AGGREGATES

Item No.	#112-B	Calculations for Percent		Lot	TOTAL
Description	BINDER W/RAP	Within Simulation Limits		Quantity	N/A
Date	10/12/89			Calcs. by	C P
Project	# 112			State	IA

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
COUNT N		28	28	28	28	28	28	28	28	28	28	28
AVERAGE X		4.773	100	89.4	78.9	55.1	39.0	28.3	19.4	10.3	6.7	5.2
STD. DE s		0.259	0.00	1.89	2.70	3.54	2.47	1.56	1.09	0.81	0.73	0.77
Qu = (USL-X)/S		1.6	ERR	4.0	2.3	2.2	2.8		2.4			2.2
Ql = (X-LSL)/S		1.4	ERR	2.3	2.2	1.2	2.0		4.9			3.0
Pu from table		95	ERR	100	99	99	99		99			98
Pl from table		92	ERR	99	98	87	98		100			99
QUALITY LEVEL (Pu + Pl)-100*		87	* ERR *	99 *	97 *	86 *	97	*******	99	*************		97

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 86 Percent

Remarks________

TOTAL QUALITY LEVEL ANALYSIS
for
ALL MATERIAL TESTED

F H W A QUALITY LEVEL ANALYSIS DP #74

AGGREGATES

Item No.	#112-B	Calculations for Percent	Lot	6
Description	BINDER W/RAP	Within Simulation Limits	Quantity	N/A
Date	10/12/89		Calcs. by	C P
Project	# 112		State	IA

SAMP.	DATE	AC	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
TARGET		4.8	100	91.0	79.0	57.0	40		18			4.9
USL		5.2	106	97.0	85.0	63.0	46.0	4.0	22.0	3.0	3.0	6.9
LSL		4.4	94.0	85.0	73.0	51.0	34.0	-4.0	14.0	-3.0	-3.0	2.9
19	10/23/8	4.618	100	88.9	77.7	54.9	39.0	28.2	19.6	10.6	7.1	5.8
20	10/23/8	4.842	100	89.8	79.7	56.7	40.2	29.4	20.5	11.0	7.3	5.9
21	10/23/8	4.525	100	89.8	77.8	52.2	37.5	27.8	19.7	10.8	7.1	5.8
22	10/23/8	4.991	100	89.3	76.2	52.7	37.7	27.5	19.0	9.7	6.1	4.7
COUNT	N	4	4	4	4	4	4		4			4
AVERAGE	X	4.744	100	89.4	77.8	54.2	38.6		19.7			5.6
STD. DE	s	0.2	0.0	0.5	1.4	2.1	1.2		0.6			0.6
Qu = (USL-X)/S		2.2	ERR	16.4	5.0	4.3	6.0		3.8			2.3
Ql = (X-LSL)/S		1.6	ERR	9.6	3.3	1.5	3.7		9.3			4.5
Pu from table		100	ERR	100	100	100	100		100			100
Pl from table		100	ERR	100	100	100	100		100			100
QUALITY LEVEL (Pu + Pl)-100*		100 *	ERR *	100 *	100 *	100 *	100	*******	100	******	*******	100

Type [Alt] Q to calculate quality level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 100 Percent

Remarks________

F H W A QUALITY LEVEL ANALYSIS DP #74

VOIDS

Calculations for Percent Within Simulation Limits

Item No.	# 112-B	Lot	1
Description	BINDER W/RAP	Quantity	N/A
Date	10/13/89	Calcs. by	C P
Project	# 112	State	IOWA

TARGET		4.8	4.5	14.8	10.0
USL		5.2	6.3	16.6	11.8
LSL		4.4	2.7	13.0	8.2
SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
1	10/09/89	4.883	5.2	15.1	8.7
2	10/09/89	4.641	3.7	14.7	9.3
3	10/10/89	4.306	4.9	14.9	9.7
4	10/10/89	4.789	4.4	14.6	9.3
5	10/10/89	4.927	4.6	14.9	10.3
6	10/10/89	4.540	4.9	14.8	10.7
COUNT	N	6	6	6	6
AVERAGE	X	4.681	4.6	14.8	9.7
STD. DEV.	s	0.2	0.5	0.1	0.7
Qu = (USL-X)/S		2.2	3.4	12.3	2.9
Ql = (X-LSL)/S		1.2	3.8	12.9	2.0
Pu		100	100	100	100
Pl		88	100	100	99
QUALITY LEVEL (Pu + Pl)-100	***	88 ***	100 ***	100 ***	99

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 88 Percent

REMARKS:

F H W A

QUALITY LEVEL ANALYSIS
VOIDS
Calculations for Percent
Within Simulation Limits

DP #74

Item No. # 112-B
Description BINDER W/RAP
Date 10/13/89
Project # 112

Lot 2
Quantity N/A
Calcs. by C P
State IOWA

TARGET		4.8	4.5	14.8	10.0
USL		5.2	6.3	16.6	11.8
LSL		4.4	2.7	13.0	8.2
SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
7	10/11/89	4.404	5.0	14.6	10.3
8	10/11/89	4.729	5.3	15.0	10.0
9	10/11/89	4.910	5.2	14.9	9.7
COUNT	N	3	3	3	3
AVERAGE	X	4.681	5.2	14.9	10.0
STD. DEV.	s	0.3	0.1	0.2	0.3
Qu = (USL-X)/S		2.0	9.8	8.5	5.4
Ql = (X-LSL)/S		1.1	21.2	9.0	5.4
Pu		100	100	100	100
Pl		89	100	100	100
QUALITY LEVEL (Pu + Pl)-100	***	89 ***	100 ***	100 ***	100

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 89 Percent

REMARKS:

F H W A — QUALITY LEVEL ANALYSIS — DP #74

VOIDS

Calculations for Percent Within Simulation Limits

Item No.	# 112-B	Lot	3
Description	BINDER W/RAP	Quantity	N/A
Date	10/13/89	Calcs. by	C P
Project	# 112	State	IOWA

TARGET		4.8	4.5	14.8	10.0
USL		5.2	6.3	16.6	11.8
LSL		4.4	2.7	13.0	8.2

SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
10	10/17/89	5.086	3.2	13.6	10.3
11	10/17/89	4.558	4.2	14.0	10.0
12	10/17/89	4.992	4.2	14.2	9.7
COUNT	N	3	3	3	3
AVERAGE	X	4.879	3.9	13.9	10.0
STD. DEV.	s	0.3	0.6	0.3	0.3
Qu = (USL-X)/S		1.1	4.1	8.4	5.4
Ql = (X-LSL)/S		1.7	1.9	2.9	5.4
Pu		96	100	100	100
Pl		100	100	100	100
QUALITY LEVEL (Pu + Pl)-100	***	96 ***	100 ***	100 ***	100

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 96 Percent

REMARKS:

F H W A QUALITY LEVEL ANALYSIS DP #74

VOIDS

Calculations for Percent

Within Simulation Limits

Item No. # 112-B Lot 4

Description BINDER W/RAP Quantity N/A

Date 10/13/89 Calcs. by C P

Project # 112 State IOWA

		% AC	VTM	VMA	FLOW
TARGET		4.8	4.5	14.8	10.0
USL		5.2	6.3	16.6	11.8
LSL		4.4	2.7	13.0	8.2
SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
13	10/20/89	5.210	4.7	14.7	9.7
14	10/20/89	4.793	4.4	14.2	10.7
15	10/20/89	4.788	4.1	14.0	10.0
COUNT	N	3	3	3	3
AVERAGE	X	4.930	4.4	14.3	10.1
STD. DEV.	s	0.2	0.3	0.3	0.5
Qu = (USL-X)/S		1.1	6.6	6.7	3.3
Ql = (X-LSL)/S		2.2	6.0	3.8	3.8
Pu		91	100	100	100
Pl		100	100	100	100
QUALITY LEVEL (Pu + Pl)-100	***	91 ***	100 ***	100 ***	100

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowes3 91 Percent

REMARKS:

F H W A QUALITY LEVEL ANALYSIS DP #74

VOIDS

Calculations for Percent Within Simulation Limits

Item No.	# 112-B	Lot	5
Description	BINDER W/RAP	Quantity	N/A
Date	10/13/89	Calcs. by	C P
Project	# 112	State	IOWA

TARGET		4.8	4.5	14.8	10.0
USL		5.2	6.3	16.6	11.8
LSL		4.4	2.7	13.0	8.2
SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
16	10/21/89	4.871	4.5	14.6	11.0
17	10/21/89	4.934	4.3	14.4	11.0
18	10/21/89	4.862	4.8	14.4	9.0
COUNT	N	3	3	3	3
AVERAGE	X	4.889	4.5	14.5	10.3
STD. DEV.	s	0.0	0.3	0.1	1.2
Qu = (USL-X)/S		7.9	6.4	16.8	1.3
Ql = (X-LSL)/S		12.5	6.5	11.5	1.8
Pu		100	100	100	100
Pl		100	100	100	100
QUALITY LEVEL (Pu + Pl)-100	***	100 ***	100 ***	100 ***	100

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowes3 100 Percent

REMARKS:

F H W A QUALITY LEVEL ANALYSIS DP #74

VOIDS

Calculations for Percent
Within Simulation Limits

Item No.	# 112-B	Lot	6
Description	BINDER W/RAP	Quantity	N/A
Date	10/13/89	Calcs. by	C P
Project	# 112	State	IOWA

TARGET		4.8	4.5	14.8	10.0
USL		5.2	6.3	16.6	11.8
LSL		4.4	2.7	13.0	8.2
SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
19	10/23/89	4.618	3.9	13.8	11.0
20	10/23/89	4.842	3.5	13.3	10.0
21	10/23/89	4.525	4.8	14.3	11.3
22	10/23/89	4.991	4.1	14.5	11.0
COUNT	N	4	4	4	4
AVERAGE	X	4.744	4.1	14.0	10.8
STD. DEV.	s	0.2	0.5	0.5	0.6
Qu = (USL-X)/S		2.2	4.1	4.9	1.7
Ql = (X-LSL)/S		1.6	2.6	1.9	4.6
Pu		100	100	100	100
Pl		100	100	100	100
QUALITY LEVEL (Pu + Pl)-100	***	100 ***	100 ***	100 ***	100

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowes3 100 Percent

REMARKS:

F H W A — QUALITY LEVEL ANALYSIS — DP #74

VOIDS

Calculations for Percent Within Simulation Limits

Item No. # 112-B — Lot 7

Description BINDER W/RAP — Quantity N/A

Date 10/13/89 — Calcs. by C P

Project # 112 — State IOWA

TARGET		4.8	4.5	14.8	10.0
USL		5.2	6.3	16.6	11.8
LSL		4.4	2.7	13.0	8.2
SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
23	10/24/89	4.504	4.2	13.7	10.3
24	10/24/89	4.530	4.0	13.6	11.3
25	10/24/89	4.632	3.9	14.2	9.7
26	10/24/89	4.644	4.2	14.2	9.7
27	10/25/89	5.530	1.3	13.7	11.7
28	10/25/89	4.610	4.1	14.3	10.0
COUNT	N	6	6	6	6
AVERAGE	X	4.742	3.6	14.0	10.4
STD. DEV.	s	0.4	1.1	0.3	0.9
Qu = (USL-X)/S		1.2	2.4	8.2	1.6
Ql = (X-LSL)/S		0.9	0.8	3.0	2.6
Pu		88	100	100	96
Pl		80	78	100	100
QUALITY LEVEL (Pu + Pl)-100	***	68 ***	78 ***	100 ***	96

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowes3 68 Percent

REMARKS:

F H W A

QUALITY LEVEL ANALYSIS
VOIDS
Calculations for Percent Within Simulation Limits

DP #74

Item No. # 112-B
Description BINDER W/RAP
Date 10/13/89
Project # 112

Lot Quantity: TOTAL N/A
Calcs. by: C P
State: IOWA

TARGET		4.8	4.5	14.8	10.0
USL		5.2	6.3	16.6	11.8
LSL		4.4	2.7	13.0	8.2
SAMPLE NO	DATE	% AC	VTM	VMA	FLOW
COUNT	N	28	28	28	28
AVERAGE	X	4.773	4.2	14.3	10.2
STD. DEV.	s	0.259	0.75	0.48	0.74
Qu = (USL-X)/S		1.6	2.8	4.7	2.2
Ql = (X-LSL)/S		1.4	2.0	2.8	2.7
Pu		95	99	100	98
Pl		92	98	99	99
QUALITY LEVEL (Pu + Pl)-100	***	87 ***	97 ***	99 ***	97

Type [Alt] Q to calculate Quality Level.

Total percent within simulation limits for the lot is equal to the the lowest value shown under quality level. 87 Percent

REMARKS:

TOTAL QUALITY LEVEL ANALYSIS
for
ALL MATERIAL TESTED

F H W A

MARSHALL DATA

DEMO PROJECTS #74

STATE: IOWA | MIX TYPE: BINDER W/25% RAP | Sp Gr of AC: 1.019

PROJECT: #112 | No. BLOWS 75 | BULK Sp Gr of AGG.: 2.619

LOCATION: CEDAR RAPIDS | TEST LAB: F.H.W.A. | TARGET COMPCTN TEMP: 266 F

Aggregate Sieve Data

Sample	Date	% AC NUCLR	% AC EXTRAC	Max. S	Bulk S	VTM	VMA	VFA	ADJ.STA	FLOW	TENSIL	F/A	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
MIX DESIGN			4.8	2.459	2.291	6.8	16.6	58.8	3466	7		RATIO	100	91	79	57	40		18	7.6		4.9
1	10/09/89	4.883	4.688	2.466	2.339	5.2	15.1	65.8	3177	8.7	111.9	0.82	100.0	90.0	80.1	56.2	39.0	27.6	18.5	9.2	5.7	4.0
2	10/09/89	4.641	4.568	2.437	2.342	3.9	14.7	73.5	3017	9.3	92.5	0.86	100.0	87.6	75.0	50.0	36.1	26.8	18.2	9.0	5.6	4.0
3	10/10/89	4.306	4.214	2.457	2.337	4.9	14.9	67.4	3200	9.7	82.3	0.93	100.0	87.8	76.7	52.8	37.2	27.0	17.9	8.7	5.2	3.6
4	10/10/89	4.789	4.690	2.457	2.348	4.4	14.6	69.7	2867	9.3	83.9	0.84	100.0	92.7	81.2	57.5	40.7	29.1	19.7	10.6	7.1	5.6
5	10/10/89	4.927	4.819	2.453	2.345	4.4	14.9	70.5	2900	10.3	84.9	1.06	100.0	89.5	80.4	59.7	42.2	29.9	19.9	10.4	6.9	5.2
6	10/10/89	4.540	4.811	2.443	2.337	4.3	14.8	70.7	3017	10.7	93.2	1.17	100.0	91.1	78.9	54.6	37.2	26.6	18.0	9.8	6.8	5.3
7	10/11/89	4.404	4.475	2.463	2.339	5.0	14.6	65.6	3233	10.3	107.3	1.27	100.0	89.8	80.3	56.0	38.6	27.7	18.9	10.3	6.9	5.6
8	10/11/89	4.729	4.969	2.466	2.336	5.3	15.0	65.0	3217	10.0	114.3	0.78	100.0	91.1	80.0	54.5	38.0	26.7	17.6	8.5	5.1	3.7
9	10/11/89	4.910	4.612	2.471	2.343	5.2	14.9	65.3	3100	9.7	88.4	1.12	100.0	87.6	76.8	54.0	38.9	28.2	19.3	10.3	6.8	5.5
10	10/17/89	5.086	4.925	2.463	2.384	3.2	13.6	76.6	3225	10.3	113.7	1.10	100.0	90.5	81.0	58.9	42.4	30.9	21.2	11.5	7.5	5.6
11	10/17/89	4.558	4.500	2.463	2.359	4.2	14.0	69.9	3450	10.0	111.4	1.29	100.0	88.4	78.1	52.0	37.8	28.2	20.0	11.1	7.5	5.9
12	10/17/89	4.992	4.973	2.469	2.365	4.2	14.2	70.5	3033	9.7	110.0	0.86	100.0	91.1	81.7	59.4	42.8	30.5	20.1	10.0	6.1	4.3
13	10/20/89	5.210	4.937	2.473	2.356	4.7	14.7	68.1	2950	9.7	106.3	1.00	100.0	88.0	80.4	58.1	40.1	28.5	19.2	10.0	6.6	5.2
14	10/20/89	4.793	4.802	2.463	2.359	4.2	14.2	70.5	3067	10.7	87.4	1.19	100.0	89.2	80.1	57.6	40.9	28.9	19.5	10.5	7.2	5.7
15	10/20/89	4.788	4.796	2.460	2.364	3.9	14.0	72.4	3150	10.0	86.1	0.90	100.0	92.0	84.1	59.3	41.1	29.2	19.3	9.5	5.8	4.3
16	10/21/89	4.871	4.867	2.462	2.351	4.5	14.6	69.1	3017	11.0	112.1	1.09	100.0	91.8	80.4	56.9	40.2	29.3	20.3	10.6	6.7	5.3
17	10/21/89	4.934	4.825	2.463	2.358	4.3	14.4	70.5	3150	11.0	105.8	1.16	100.0	91.7	82.4	56.9	40.9	29.9	20.8	11.1	7.2	5.7
18	10/21/89	4.862	4.772	2.469	2.357	4.5	14.4	68.5	2883	9.0	98.2	1.17	100.0	89.0	79.0	57.5	41.1	29.5	20.0	10.5	7.0	5.7
19	10/23/89	4.618	4.611	2.462	2.366	3.9	13.8	72.0	3100	11.0	106.8	1.26	100.0	88.9	77.7	54.9	39.0	28.2	19.6	10.6	7.1	5.8
20	10/23/89	4.842	4.801	2.471	2.385	3.5	13.3	74.0	2933	10.0	88.3	1.22	100.0	89.8	79.7	56.7	40.2	29.4	20.5	11.0	7.3	5.9
21	10/23/89	4.525	4.535	2.463	2.351	4.5	14.3	68.2	3033	11.3	99.9	1.28	100.0	89.8	77.8	52.2	37.5	27.8	19.7	10.8	7.1	5.8
22	10/23/89	4.991	4.954	2.451	2.356	3.9	14.5	73.4	2933	11.0	96.5	0.94	100.0	89.3	76.2	52.7	37.7	27.5	19.0	9.7	6.1	4.7
23	10/24/89	4.504	4.483	2.470	2.366	4.2	13.7	69.3	2917	10.3	86.7	1.29	100.0	87.2	76.6	49.7	34.9	26.3	18.8	10.6	7.1	5.8
24	10/24/89	4.530	4.436	2.470	2.370	4.0	13.6	70.3	2883	11.3	89.1	1.10	100.0	86.9	73.3	46.2	33.4	25.3	17.8	9.8	6.4	5.0
25	10/24/89	4.632	4.593	2.453	2.356	3.9	14.2	72.4	2633	9.7	74.7	1.23	100.0	86.7	76.4	52.5	37.0	26.9	18.6	10.4	7.0	5.7
26	10/24/89	4.644	4.571	2.460	2.356	4.2	14.2	70.3	2867	9.7	82.3	1.12	100.0	87.6	76.4	52.3	36.5	26.7	18.5	10.1	6.6	5.2
27	10/25/89	5.530	5.527	2.427	2.394	1.3	13.7	90.1	2600	11.7	77.5	1.18	100.0	92.9	84.0	61.3	43.6	31.9	22.2	12.2	8.2	6.6
28	10/25/89	4.610	4.509	2.452	2.351	4.1	14.3	71.5	2917	10.0	90.3	1.21	100.0	86.1	75.1	52.0	36.9	26.9	18.7	10.4	7.0	5.6
COUNT		28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
AVERAGE		4.773	4.724	2.460	2.356	4.2	14.3	70.7	3017	10.2	95.8	1.09	100.0	89.4	78.9	55.1	39.0	28.3	19.4	10.3	6.7	5.2
Std Dev		0.259	0.248	0.011	0.01	0.75	0.48	4.70	180.83	0.74	12.14	0.16	0.00	1.89	2.70	3.54	2.47	1.56	1.09	0.81	0.73	0.77