Gradation Analysis of Cold Feed And Extracted Bituminous Mix Samples

Final Report for MLR-88-2

June 1988

Highway Division
Iowa Department of Transportation

GRADATION ANALYSIS OF COLD FEED AND EXTRACTED BITUMINOUS MIX SAMPLES

Final Report for
Project MLR-88-2

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TABLE OF CONTENTS

DISCLAIMER

ABSTRACT

Since 1987, the Iowa Department of Transportation has based control of hot asphalt concrete mixes on cold feed gradations.

This report presents results of comparisons between cold feed gradations and gradations of aggregate from the same material after it has been processed through the plant and laydown machine. Results are categorized based on mix type, plant type, and method of dust control, in an effort to quantify and identify the factors contributing to those changes.

Results of the report are:

1. From the 390 sample comparisons made, aggregate degradation due to asphalt plant processing was demonstrated by an average increase of +0.7% passing the #200 sieve and an average increase in surface area of +1.8 sq. ft. per pound of aggregate.

2. Categories with Type A Mix or Recycling as a sorting criteria generally produced greater degradation than categories containing Type B Mixes and/or plants with scrubbers.

3. None of the averages calculated for the categories should be considered unacceptably high, however, it is information that should be considered when making mix changes in the field, selecting asphalt contents for borderline mix designs, or when evaluating potential mix gradation specification or design criteria changes.

INTRODUCTION

Prior to 1987, bituminous mix gradation control was based entirely on extraction gradation results. Beginning with the 1987 construction season, control of asphalt concrete mixes was based on the gradation of cold feed samples in an effort to reduce, if not eliminate, the number of methylene chloride vacuum extractions performed in the District Materials Laboratories. New gradation limits established for cold feed sampling were based on a project records study in which extracted gradations were compared with cold feed gradations to determine the average difference in percent passing for each sieve size. The primary benefit derived from implementing the exclusive use of cold feed control would be the elimination of the labor intensive methylene chloride extraction procedure which requires the use of large quantities of an expensive and hazardous chlorinated solvent.

PROBLEM STATEMENT

The aggregate gradation of a bituminous mix is one of the most critical components in determining mix design and construction characteristics such as % voids, % VMA, density, stability, workability, and recommended asphalt content. Thus, gradation control is essential for assuring that specified gradation requirements are satisfied, and the resulting mix meets or exceeds the design criteria. A detrimental limitation of cold feed gradation control is that cold feeds are used to evaluate mix gradation, while all other tests, such as density and stability, are performed on mix that has been processed through the asphalt plant. Gradation changes, specifically aggregate degradation due to plant processing and handling, must be anticipated and evaluated so mix design criteria and, consequently, pavement quality, is not compromised.

The primary objective of this study is to determine how processing through the asphalt plant affects aggregate gradation of a bituminous mix. Within this primary objective, the study will also examine how other factors, such as plant type, pollution control, or mix type, may be related to any gradation changes that may be identified. Results of the study will be useful in verifying gradation limits established in 1987, and in providing data on which new cold feed gradation limits and filler-bitumen ratios can be founded.

PROCEDURE AND SCOPE

All samples used in this study were obtained from projects constructed during the 1987 construction season. For purposes of this study, District Materials personnel were requested to deliver, to the Central Materials Lab, a series of box samples for each mix design used on a project in their district. Information requested to be provided with each sample included the following:

Material Description (size, type, and class)

Project No.

County

Contractor

Plant Type (drum or batch, baghouse or scrubber)

Mix Design #

Date Sampled

Cold Feed Gradation

Percent Asphalt Intended

Percent Asphalt (tank stick)

Percent Asphalt (district nuclear determination)

The District personnel were requested to coordinate sample procurement such that the material represented by the cold feed gradation was also, as closely as possible, represented by the mix sample gradations. Sampling was to be distributed over the project length as much as possible, and the number of samples submitted per project was based on the following schedule:

Project Mix Design Quantity	No. of Box Samples
< 10,000 tons	3
> 10,000 tons	5

At the conclusion of a project, the box samples were delivered by courier to the Central Materials Laboratory where a 1-1-1 trichloroethane reflux extraction was performed to determine gradation and asphalt content. A nuclear asphalt content determination was also made on those samples for which a nuclear calibration was available.

In 1987, 259 bituminous mix designs were performed by Central Laboratory and District Laboratory personnel. Of these 259 mix designs, 35 failed to meet design criteria, resulting in 224 mix designs released for production. For purposes of this study, samples were requested for all mix designs used on 1987 paving projects. There was no request made for the number or source of samples collected to be based on specific mix types, project location, or any other criteria. Of the 224 mix designs issued, 396 samples representing 110 mix designs, 99 projects, and the following mix types, were received and processed by the Central Materials Bituminous Section.

TABLE I
CATEGORIZATION OF SAMPLES RECEIVED

Mix Size	Type	No. of Samples Processed
3/8	Type A	3
1/2	Type A	51
1/2	Type A Recycled	20
3/4	Type A	67
3/4	Type A Recycled	17
1/2	Type B Class II	3
1/2	Type B Class I	52
1/2	Type B Class I Recycled	6
3/4	Type B Class II	38
3/4	Type B Class I	105
3/4	Type B Class I Recycled	34
	Total	396

The samples were received and stored in the Central Lab throughout the summer and fall of 1987, and processed from November 1987 through January 1988. Reflux extraction gradation and asphalt content from test results were determined and reported. Information from the test reports was stored in a Lotus 123 Version I database, and sorted according to various factors suspected of causing or influencing gradation changes in the bituminous mix. Thirty-five categories were established based on mix type, plant type, and plant pollution control (Table II). The number of sample comparisons in each category varied from 12 to 251. A printed example of format and content of data found in each category can be seen in Appendix A. This example illustrates the data from 81 comparisons that fall within the category "Batch Plants with Baghouse". The data from all 35 categories is too massive for presentation in this report, however, it does remain stored on floppy disks should the information later need to be retrieved. Several samples did not have complete cold feed gradations reported and, therefore, were not included in the final results. Many samples fell within more than one category. For instance, a Type A mix might also fall within the Batch Plant category, the Recycled category, or any one of a number of other categories.

Table II
Extracted vs Cold Feed Gradations:
Sort Categories and No. of Comparisons Analyzed

Criteria Under Which Mixes Were Produced	No. of Comparisons Meeting Criteria
Batch Plant Mixes	107
Drum Plant Mixes	251
Continuous Plant Mixes	32
Recycled Mixes	71
Baghouse Mixes	250
Scrubber	138
Type A Mixes	152
Type B Mixes	241
Type A Mix - Drum Plant	79
Type A Mix - Batch Plant	60
Type A Mix - Recycled	31
Type A Mix - Drum Plant w/Baghouse	61
Type A Mix - Drum Plant w/Scrubber	18
Type A Recycled - Drum Plant	22
Type A Mix - Batch Plant w/Baghouse	46
Type A Mix - Batch Plant w/Scrubber	14
Type B Mix - Drum Plant	171
Type B Mix - Batch Plant	42
Type B Mix - Recycled	40
Type B Mix - Drum Plant w/Baghouse	99
Type B Mix - Drum Plant w/Scrubber	72
Type B Recycled - Drum Plant	32
Type B Mix - Batch Plant w/Baghouse	30
Type B Mix - Batch Plant w/Scrubber	12
Drum Plant w/Baghouse	159
Drum Plant w/Scrubber	90
Recycled Mixes - Drum Plant	54
Batch Plant w/Baghouse	76
Batch Plant w/Scrubber	26
Recycled Mixes - Batch Plant	17
Type B Mix - Class I	191
Type B Mix - Class II	41
Type B Mix - Class I - Drum Plant	134
Type B Mix - Class I - Batch Plant	42
Type B Mix - Class I - Recycled	40
All Mixes	390

After the test results were categorized, the difference in percent passing between the cold feed gradation and the extracted gradation were determined for each sieve size. An average and standard deviation of the percent passing differences associated with each sieve size were calculated for each category and reported in Table III. Also calculated was the surface area per pound of aggregate for each cold feed and extracted gradation. The change in surface area was determined for each set of samples, and again, averages and standard deviations calculated for each of the thirty-five categories. Calculations were done according to the chart "Determination of Surface Area", page 4 of Materials I.M. 511 (Appendix B).

RESULTS

Three hundred ninety gradation comparisons were performed during the course of this study. As expected, aggregate degradation occurred as indicated by an increase in percent passing on all sieve sizes. Referring to Table III, it is observed that the degradation pattern, which is generally consistent through the range of all categories, is well represented by the average for all mixes, which demonstrates a minor change of +.1 on the #3/4", an increase in the range of 1.0% to 1.6% passing for the 1/2" through #8 sieves, a sharp drop to .3% increase on the #16, and the increases for the #30 through #200 leveling out at about .7% passing.

The ranking of the thirty-five categories by amount of degradation based on increase in surface area is shown in Table IV. The increases range from +3.2 sq. ft./lb. for "Type A Mix-Batch Plant with Baghouse", to -0.7 sq. ft./lb. for "Type A Mix-Batch Plant with Scrubber. The increase in minus #200 and the number of comparisons made in each category are also shown. The effect on the

TABLE III:

EXTRACTED VS. COLDFEED GRADATIONS
PERCENT PASSING AVERAGE DIFFERENCES & STANDARD DEVIATIONS

SAMPLE CRITERIA	NO.	3/4 AVG.	3/4 STD	1/2 AVG.	1/2 STD	3/8 AVG.	3/8 STD	NO. 4 AVG.	NO. 4 STD	NO. 8 AVG.	NO. 8 STD	NO. 16 AVG.	NO. 16 STD	NO. 30 AVG.	NO. 30 STD	NO. 50 AVG.	NO. 50 STD	NO. 100 AVG.	NO. 100 STD	NO. 200 AVG.	NO. 200 STD	SURF. AREA AVG.	SURF. AREA STD.
BATCH PLANT	107.0	0.1	0.7	0.7	2.2	1.5	2.7	1.7	3.2	1.1	2.8	0.3	2.3	0.8	1.6	0.6	1.2	0.8	0.9	0.8	0.9	2.2	2.5
DRUM PLANT	251.0	0.1	0.8	1.0	2.4	1.7	3.1	1.6	3.2	1.1	2.8	0.2	2.3	0.7	1.8	0.6	1.2	0.7	1.1	0.7	0.9	1.7	2.6
CONTINUOUS	32.0	-0.1	0.6	1.4	2.3	0.8	2.8	0.6	2.9	0.3	2.7	0.0	2.3	0.3	1.4	0.3	0.8	0.7	0.9	0.6	0.7	1.6	2.0
RECYCLED MIXES	71.0	0.2	0.6	0.4	2.5	0.8	3.2	1.1	3.4	1.3	2.8	0.6	2.3	0.9	1.8	0.9	1.1	0.8	0.7	0.9	0.7	2.3	2.2
BAGHOUSE	250.0	0.1	0.8	0.9	2.3	1.6	2.8	1.6	3.2	1.1	2.8	0.3	2.3	0.7	1.8	0.7	1.2	0.9	1.0	0.8	0.8	2.4	2.5
SCRUBBER	138.0	0.1	0.6	1.1	2.4	1.5	3.2	1.3	3.1	0.9	2.7	-0.1	2.2	0.5	1.7	0.2	1.2	0.4	0.9	0.4	0.8	1.0	2.3
TYPE A MIXES	152.0	0.0	0.6	1.0	2.2	1.8	2.8	2.0	3.3	1.3	2.9	0.4	2.4	0.8	1.8	0.8	1.3	1.0	1.2	0.9	0.9	2.4	2.7
TYPE B MIXES	241.0	0.1	0.8	1.0	2.4	1.5	3.1	1.2	3.1	0.9	2.7	0.1	2.2	0.5	1.7	0.4	1.1	0.6	0.9	0.6	0.8	1.5	2.4
TYPE A DRUM	79.0	0.1	0.4	0.8	2.1	2.0	2.8	2.2	3.1	1.5	2.9	0.4	2.5	0.9	1.9	0.8	1.3	1.0	1.3	0.9	0.9	2.3	2.8
TYPE A BATCH	60.0	0.0	0.7	1.1	2.3	1.6	2.6	1.9	3.5	1.2	2.8	0.3	2.3	0.8	1.7	0.7	1.3	0.9	1.0	0.8	1.0	2.3	2.6
TYPE A RECYCLED	31.0	0.1	0.5	0.7	2.5	1.7	2.5	2.2	3.0	2.1	2.7	1.2	2.4	1.4	1.7	1.3	1.1	1.1	0.6	1.1	0.6	2.9	2.0
A DRUM W/BAGHSE	61.0	0.1	0.4	0.7	1.7	2.2	2.2	2.5	2.8	1.8	2.7	0.7	2.4	0.9	1.7	0.9	1.2	1.1	1.4	0.8	0.9	2.6	2.7
A DRUM W/SCRUB.	18.0	0.0	0.5	0.9	2.8	1.5	3.9	1.5	3.6	0.8	3.4	-0.6	2.7	0.7	2.1	0.5	1.5	0.7	0.9	0.9	0.9	1.6	3.1
A DRUM RECYCLED	22.0	0.2	0.5	0.9	2.4	1.7	2.7	2.1	3.1	2.3	2.7	1.2	2.3	1.4	1.7	1.3	1.0	1.2	0.7	1.2	0.7	3.1	2.2
A BATCH W/BAGH.	46.0	0.0	0.8	1.0	2.3	1.9	2.3	2.1	3.4	1.2	2.7	0.6	2.3	1.2	1.6	1.1	1.2	1.2	0.8	1.1	0.7	3.2	2.0
A BATCH W/SCRUB	14.0	0.0	0.0	1.4	2.3	0.8	3.3	1.3	3.9	1.0	3.1	-0.6	2.4	-0.4	1.5	-0.3	1.0	-0.3	0.8	-0.2	0.9	-0.7	2.2
B DRUM MIXES	171.0	0.1	0.9	1.1	2.5	1.5	3.3	1.3	3.2	0.9	2.7	0.1	2.2	0.5	1.8	0.4	1.2	0.6	0.9	0.6	0.8	1.5	2.5
B BATCH MIXES	42.0	0.2	0.7	0.3	2.0	1.5	2.7	1.4	2.8	1.1	2.8	0.2	2.2	0.7	1.6	0.3	0.9	0.7	0.8	0.7	0.8	2.0	2.1
TYPE B RECYCLED	40.0	0.2	0.7	0.2	2.6	0.0	3.5	0.1	3.5	0.5	2.7	0.1	2.0	0.5	1.8	0.6	1.1	0.7	0.7	0.7	0.8	1.8	2.3
B DRUM W/BAGHSE	99.0	0.1	1.0	1.0	2.4	1.4	3.3	1.2	3.4	0.9	2.8	0.1	2.3	0.6	1.9	0.5	1.2	0.7	0.9	0.7	0.9	1.8	2.5
B DRUM W/SCRUB.	72.0	0.2	0.7	1.3	2.6	1.7	3.3	1.5	3.0	1.0	2.4	0.0	2.0	0.5	1.7	0.4	1.2	0.4	0.9	0.4	0.8	1.1	2.3
B DRUM RECYCLED	32.0	0.1	0.7	0.0	2.3	-0.2	3.5	-0.1	3.5	0.5	2.6	0.0	2.0	0.4	1.8	0.6	1.2	0.7	0.8	0.7	0.8	1.8	2.4
B BATCH W/BAGH.	30.0	0.3	0.7	0.1	2.2	0.9	2.8	1.0	2.9	0.5	2.9	-0.2	2.3	0.4	1.6	0.5	0.9	0.8	0.8	0.8	0.8	2.2	2.3
B BATCH W/SCRB.	12.0	0.1	0.3	0.8	1.0	3.0	1.6	2.5	1.9	2.8	1.9	1.3	1.5	1.5	1.3	-0.1	0.9	0.3	0.6	0.5	0.6	1.5	1.7
DRUM W/BAGHSE.	159.0	0.1	0.9	0.9	2.2	1.7	2.9	1.6	3.2	1.2	2.8	0.4	2.4	0.7	1.8	0.6	1.2	0.8	1.1	0.7	0.9	2.0	2.6
DRUM W/SCRUB.	90.0	0.2	0.6	0.4	2.4	0.7	3.3	1.0	3.5	1.3	2.8	0.5	2.2	0.5	1.8	0.4	1.3	0.5	0.9	0.5	0.8	1.2	2.5
DRUM RECYCLED	54.0	0.2	0.6	0.4	2.4	0.7	3.3	1.0	3.5	1.3	2.8	0.5	2.2	0.9	1.9	0.9	1.2	0.9	0.8	0.9	0.8	2.3	2.4
BATCH W/BAGHSE.	76.0	0.1	0.8	0.6	2.3	1.5	2.6	1.6	3.2	0.9	2.9	0.3	2.3	0.8	1.6	0.8	1.2	1.1	0.8	1.0	0.8	2.8	2.2
BATCH W/SCRUB.	26.0	0.0	0.2	1.1	1.8	1.8	2.9	1.9	3.2	1.8	2.7	0.2	2.2	0.5	1.7	-0.2	0.9	0.0	0.7	0.1	0.9	0.3	2.2
BATCH RECYCLED	17.0	0.1	0.7	0.5	3.0	1.4	2.6	1.8	3.1	1.1	3.1	0.8	2.3	1.0	1.7	0.8	1.0	0.7	0.4	0.8	0.5	2.2	1.6
TYPE B CL I	191.0	0.1	0.7	1.0	2.3	1.4	3.2	1.1	3.2	0.7	2.7	-0.2	2.2	0.4	1.6	0.3	1.1	0.5	0.8	0.5	0.8	1.4	2.2
TYPE B CL II	41.0	0.2	1.2	1.1	2.7	1.6	2.9	1.7	2.4	1.6	2.5	1.1	2.1	1.4	2.0	0.9	1.3	0.9	1.1	0.8	0.9	2.4	2.8
B CL I DRUM	134.0	0.1	0.8	1.1	2.4	1.5	3.3	1.2	3.4	0.8	2.7	-0.2	2.2	0.3	1.7	0.3	1.2	0.5	0.8	0.5	0.8	1.2	2.3
B CL I BATCH	42.0	0.2	0.7	2.0	0.3	1.5	2.7	1.4	2.8	1.1	2.8	0.2	2.2	0.7	1.6	0.3	0.9	0.7	0.8	0.7	0.8	2.0	2.1
B CL I RECYC	40.0	0.2	0.7	0.2	2.6	0.0	3.5	0.1	3.5	0.5	2.7	0.1	2.0	0.5	1.8	0.6	1.1	0.7	0.7	0.7	0.8	1.8	2.3
ALL MIXES	390.0	0.1		1.0		1.6		1.5		1.0		0.2		0.7		0.6		0.7		0.7		1.8	

TABLE IV: CATEGORY RANKING BY SURFACE AREA & MINUS #200 INCREASE

RANKING	CATEGORY	SIZE OF CATEGORY	SURFACE AREA INCREASE	MINUS # 200 INCREASE
1	A MIX-BATCH PLANT W/BAGHOUSE	46.0	3.2	1.1
2	A MIX-RECYCLED DRUM PLANT	22.0	3.1	1.2
3	A MIX-RECYCLED	31.0	2.9	1.1
4	BATCH PLANT W/BAGHOUSE	76.0	2.8	1.0
5	A MIX-DRUM PLANT W/BAGHOUSE	61.0	2.6	0.8
6	PLANTS WITH BAGHOUSE	250.0	2.4	0.8
7	TYPE A MIXES	152.0	2.4	0.9
8	TYPE B CLASS II MIXES	41.0	2.4	0.8
9	ALL RECYCLED MIXES	71.0	2.3	0.9
10	TYPE A MIX-DRUM PLANT	79.0	2.3	0.9
11	TYPE A MIX-BATCH PLANT	60.0	2.3	0.8
12	RECYCLED MIX-DRUM PLANT	54.0	2.3	0.9
13	BATCH PLANT MIXES	107.0	2.2	0.8
14	TYPE B MIX-BATCH PLANT/BAGHSE	30.0	2.2	0.8
15	RECYCLED MIX-BATCH PLANT	17.0	2.2	0.8
16	TYPE B MIX-BATCH PLANT	42.0	2.0	0.7
17	DRUM PLANTS W/BAGHOUSE	159.0	2.0	0.7
18	TYPE B CL I MIX-BATCH PLANT	42.0	2.0	0.7
19	TYPE B RECYCLED MIXES	40.0	1.8	0.7
20	TYPE B MIX-DRUM PLANT W/BAGHSE	99.0	1.8	0.7
21	TYPE B RECYCLED MIX-DRUM PLANT	32.0	1.8	0.7
22	TYPE B CL I RECYCLED MIX	40.0	1.8	0.7
23	DRUM PLANT MIXES	251.0	1.7	0.7
24	CONTINUOUS PLANT MIXES	32.0	1.6	0.6
25	TYPE A MIX-DRUM PLANT W/SCRUB.	18.0	1.6	0.9
26	TYPE B MIXES	241.0	1.5	0.6
27	TYPE B MIX-DRUM PLANT	171.0	1.5	0.6
28	TYPE B MIX-BATCH PLANT W/SCRB.	12.0	1.5	0.5
29	TYPE B CL I MIXES	191.0	1.4	0.5
30	DRUM PLANTS W/SCRUBBER	90.0	1.2	0.5
31	TYPE B CL I MIX-DRUM PLANTS	134.0	1.2	0.5
32	TYPE B MIX-DRUM PLANT W/SCRUB.	72.0	1.1	0.4
33	PLANTS WITH SCRUBBER	138.0	1.0	0.4
34	BATCH PLANTS WITH SCRUBBER	26.0	0.3	0.1
35	TYPE A MIX-BATCH PLNAT W/SCRB.	14.0	-0.7	-0.2

minus #200 material is shown because this portion of the gradation has more effect on mix properties, particularly aggregate surface area, than any other. As seen from the table, the minus #200 increases correlate closely with the surface area increases, with the exception of "Type A Mix-Drum Plant with Scrubber", which had an increase of 0.9% minus #200 but an increase of only 1.6 sq. ft./lb. surface area.

From Table IV, Type A mix categories have consistently higher degradation than Type B mixes, as demonstrated by 7 of the top 12 categories having Type A Mix as one of the sorting criteria. Correspondingly, categories with B Mix as a sort criteria rank toward the bottom of the list. The average increase in surface area for all Type A Mixes (152) was 2.4 sq. ft./lb. while all Type B Mixes (241) increased by only 1.5 sq. ft./lb.

All mixes produced by plants with baghouses (250) increased surface area by 2.4 sq. ft./lb. and minus #200 by 0.8%. Mixes produced by plants with scrubbers (138) were near the bottom of the rankings with a surface area increase of 1.0 sq. ft./lb. and only a 0.4% increase in material passing the #200 sieve. Batch plant and drum plant mixes had surface area increases of 2.2 and 1.7 sq. ft./lb. respectively, and minus #200 increases of 0.8% and 0.7%. Recycled mixes ranked ninth highest of all 35 categories with a 2.4 sq. ft./lb. surface area increase.

To examine the significance of the reported gradation changes, an example is presented in Appendix C in which actual project, mix design, cold feed, and extraction data is reproduced, and calculations are performed to determine the effect of aggregate breakdown on film thickness and filler bitumen ratio. A sample from Polk Co. FN-613-1(40)--21-77, 3/4" Type A Recycled Binder was selected for illustration because its increases of 0.8% minus #200 and 1.84 sq. ft./lb. approximate the averages of 0.7% and 1.8 sq. ft./lb. obtained for all 390 comparisons. As demonstrated by the calculations, the effective asphalt content for this mix is 4.20%. Calculations were performed according to I.M. 510, "Method of Design of Asphalt Concrete Mixes", found in Appendix B. This produces a Bitumen Index of 0.001486 for the cold feed and 0.001395 for the extracted sample, which further results in film thicknesses of 7.24 microns and 6.79 microns for the cold feed and extracted sample respectively, representing a film thickness decrease of 0.45 microns due to aggregate degradation. Noting that the intended asphalt content was unchanged on this project, the filler bitumen ratio can be expected to increase from 1.09 to 1.26 due to degradation. Since the values in this example were close to the averages for all samples in the study, changes in film thickness and filler bitumen ratio will naturally become more extreme as examinations are made of the categories exhibiting the greatest minus #200 and surface area increase. Although the effect of degradation on mix characteristics such as lab density and % voids in the mineral aggregate (%VMA) cannot be directly calculated in an example such as this, one would normally expect an increase in the minus

#200 to contribute to a lower % VMA, higher lab density, and lower % voids, as the fine particles fill in the voids. The degree to which this occurs depends on the composition and specifications of each individual job mix, and can be accurately determined only through physically testing the material for these properties, an exercise beyond the scope of this study.

A comparison is made in Table V of the data accumulated in 1986 versus the data representing this study. In general, the data from this study demonstrates a greater amount of degradation than the earlier study for the three categories shown. The 1987 reported increase in minus #200, in particular, is approximately greater than the 1986 increase by a factor of 2. A copy of the 1986 cold feed vs extraction data used in Table V can be found in Appendix D. When making this comparison, it should be noted that in the 1986 study, no particular effort was made to assure that samples for extraction also represented the cold feed sample. In the current study, however, a direct effort was made to trace the cold feed material through the asphalt plant and laydown machine prior to retrieving a box sample for extraction gradation analysis. Through this procedure, gradation differences between cold feed and extraction can be primarily attributed to processing and handling, and differences due to sampling error are minimized.

TABLE V: ASPHALT MIX AGGREGATE DEGRADATION DUE TO PROCESSING: COMPARISON OF 1986 VS. 1987 RESULTS

SIEVE SIZE	CHANGE IN PERCENT PASSING					
	DRUM/SCRUBBER		DRUM/BAGHOUSE		BATCH PL./BAGHOUSE	
	1986	1987	1986	1987	1986	1987
3/4 "	0.3	0.2	0.2	0.1	0.0	0.1
1/2 "	0.2	0.4	0.4	0.9	0.6	0.6
3/8 "	1.3	0.7	0.9	1.7	1.9	1.5
# 4	1.3	1.0	0.7	1.6	1.8	1.6
# 8	0.4	1.3	-0.3	1.2	0.9	0.9
# 16	0.1	0.5	0.0	0.4	-0.8	0.3
# 30	0.5	0.5	0.5	0.7	0.6	0.8
# 50	0.3	0.4	0.4	0.6	-0.1	0.8
# 100	0.3	0.5	0.4	0.8	0.3	1.1
# 200	0.2	0.5	0.4	0.7	0.6	1.0

CONCLUSIONS

1. Aggregate degradation occurs, in varying degrees, in nearly every type of mix under all combinations of plant type and dust control. The lone exception to this was "Type A Mix - Batch Plant With Scrubber", which had only 14 items in the data base. Average increases of 0.7% in minus #200 and 1.8 sq. ft./lb. of aggregate were recorded.

2. The average increases of 0.7% minus #200 and 1.8 sq. ft./lb. are not severe enough to warrant any changes in specifications or operation. However, in cases where the acceptance of a mix design is borderline or field changes in the mix design are required, it may be beneficial to refer to the data in this report to anticipate how the mix design gradation will react to a particular set of processing conditions, and whether the changes will be beneficial or detrimental to the performance of the mix. This would be particularly applicable to those categories as shown to be more susceptible to degradation in Table IV, and as long as mix production quality is controlled through cold feed gradations.

3. In reference to Table IV and the comparison of results from the 1986 study with the results from this study, due to the significant differences in results, and regardless of the differences in procedure and scope of the two investigations, any specifi-

cation changes in gradation limits or filler bitumen ratios based on the 1986 study should be reviewed to determine if they are valid, and it should be considered if further changes are now warranted in light of the data presented in this report.

Appendix A
Example of Lotus Database Format Used

Appendix A - Example of Lotus Database Format Used

COLD FEED VS. EXTRACTED GRADATION STUDY - 1987   BATCH PLANTS WITH BAGHOUSE

MIX DESIGN NO.	PROJECT-NUMBER	CONTRACTOR	MATERIAL TYPE SIZE	TYPE	CL	R	PLANT TYPE	DUST CONTRL	SAMPLE DATE	GRADATION SAMPLE	SIEVE # 3/4	DIFF.	SIEVE # 1/2	DIFF.	SIEVE # 3/8	DIFF.	SIEVE # 4	DIFF.	SIEVE # 8	DIFF.	SIEVE # 16	DIFF.	SIEVE # 30	DIFF.	SIEVE # 50	DIFF.	SIEVE # 100	DIFF.	SIEVE # 200	DIFF.	SURF. AREA	DIFF.
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	08-05-87	COLD-FEED	99		83		68		52		43				26						4.4			
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	08-05-87	EXTRACTION	99	0.0	85	2.0	69	1.0	53	1.0	44	1.0	37		26	0.0	11		6.0		4.7	0.3		
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	08-06-87	COLD-FEED	99		84		70		55		45				28						5.4			
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	08-06-87	EXTRACTION	98	-1.0	83	-1.0	72	2.0	54	-1.0	45	0.0	38		27	-1.0	12		6.6		5.2	-0.2		
AB07-28	L-FM-4646(A)	CESSFORD	3/4	B	I	R	BATCH	BAGHOUSE	06-11-87	COLD-FEED	100		84		73		59		46		36		25		13		7.6		5.1		28.02	
AB07-28	L-FM-4646(A)	CESSFORD	3/4	B	I	R	BATCH	BAGHOUSE	06-11-87	EXTRACTION	100	0.0	92	8.0	80	7.0	64	5.0	51	5.0	39	3.0	27	2.0	14	1.0	8.0	0.4	6.9	1.8	32.26	4.24
AB07-28	L-FM-4646(A)	CESSFORD	3/4	B	I	R	BATCH	BAGHOUSE	06-12-87	COLD-FEED	100		88		76		61		48		38		26		13		7.1		5.9		29.42	
AB07-28	L-FM-4646(A)	CESSFORD	3/4	B	I	R	BATCH	BAGHOUSE	06-12-87	EXTRACTION	100	0.0	88	0.0	75	-1.0	61	0.0	47	-1.0	38	0.0	27	1.0	13	0.0	7.9	0.8	7.1	1.2	31.92	2.50
AB07-28	L-FM-4646(A)	CESSFORD	3/4	B	I	R	BATCH	BAGHOUSE	06-15-87	COLD-FEED	99		88		76		60		46		36		24		12		6.6		5.4		27.48	
AB07-28	L-FM-4646(A)	CESSFORD	3/4	B	I	R	BATCH	BAGHOUSE	06-15-87	EXTRACTION	100	1.0	90	2.0	81	5.0	67	7.0	53	7.0	40	4.0	28	4.0	13	1.0	8.0	1.4	7.1	1.7	32.64	5.16
AB07-29	BR-810-0(51)	MANATTS	3/4	B	I		BATCH	BAGHOUSE	06-09-87	COLD-FEED	100		93		84		61		46		38		30		18		9.1		6.2		33.08	
AB07-29	BR-810-0(51)	MANATTS	3/4	B	I		BATCH	BAGHOUSE	06-09-87	EXTRACTION	100	0.0	93	0.0	84	0.0	61	0.0	44	-2.0	36	-2.0	29	-1.0	18	0.0	11.0	1.9	8.5	2.3	37.52	4.44
AB07-29	BR-810-0(51)	MANATTS	3/4	B	I		BATCH	BAGHOUSE	06-12-87	COLD-FEED	99		97		83		57		40		34		26		16		8.1		5.6		29.72	
AB07-29	BR-810-0(51)	MANATTS	3/4	B	I		BATCH	BAGHOUSE	06-12-87	EXTRACTION	99	0.0	92	-5.0	81	-2.0	59	2.0	43	3.0	35	1.0	28	2.0	18	2.0	11.0	2.9	8.2	2.6	36.74	7.02
AB07-29	BR-810-0(51)	MANATTS	3/4	B	I		BATCH	BAGHOUSE	06-16-87	COLD-FEED	99		94		82		59		43		36		27		16		8.3		5.7		30.46	
AB07-29	BR-810-0(51)	MANATTS	3/4	B	I		BATCH	BAGHOUSE	06-16-87	EXTRACTION	100	1.0	95	1.0	84	2.0	61	2.0	45	2.0	36	0.0	28	1.0	18	2.0	10.0	1.7	8.2	2.5	36.34	5.88
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-17-87	COLD-FEED	100		99		90		65		40		30		21		10		6.3		5.5		25.82	
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-17-87	EXTRACTION	100	0.0	99	0.0	94	4.0	71	6.0	47	7.0	35	5.0	25	4.0	12	2.0	7.2	0.9	6.3	0.8	29.60	3.78
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-19-87	COLD-FEED	100		98		88		63		44		33		23		11		6.8		5.9		27.70	
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-19-87	EXTRACTION	100	0.0	96	-2.0	87	-1.0	63	0.0	41	-3.0	31	-2.0	22	-1.0	11	0.0	6.4	-0.4	5.6	-0.3	26.56	-1.14
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-20-87	COLD-FEED	100		99		89		67		46		35		24		11		6.4		5.6		27.44	
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-20-87	EXTRACTION	100	0.0	97	-2.0	85	-4.0	60	-7.0	39	-7.0	29	-6.0	21	-3.0	10	-1.0	6.4	0.0	5.6	0.0	25.82	-1.62
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-23-87	COLD-FEED	100		98		88		64		46		35		24		9.4		4.2		3.3		21.90	
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-23-87	EXTRACTION	100	0.0	97	-1.0	87	-1.0	64	0.0	46	0.0	35	0.0	24	0.0	11	1.6	6.0	1.8	5.1	1.8	26.34	4.44
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-27-87	COLD-FEED	100		98		92		69		47		35		24		11		6.7		5.8		28.02	
AB07-212	SR-7849(7)	NORRIS	1/2	B	I		BATCH	BAGHOUSE	10-27-87	EXTRACTION	100	0.0	99	1.0	92	0.0	69	0.0	48	1.0	36	1.0	25	1.0	12	1.0	6.7	0.0	5.8	0.0	28.58	0.56
AB07-205	SP-687-0(1)	ILLOWA	1/2	B	I		BATCH	BAGHOUSE	10-27-87	COLD-FEED	100		99		87		62		48		38		25		11		4.3		3.4		23.02	
AB07-205	SP-687-0(1)	ILLOWA	1/2	B	I		BATCH	BAGHOUSE	10-27-87	EXTRACTION	100	0.0	99	0.0	89	2.0	64	2.0	48	0.0	37	-1.0	25	0.0	12	1.0	5.5	1.2	4.5	1.1	25.76	2.74
AB07-205	SP-687-0(1)	ILLOWA	1/2	B	I		BATCH	BAGHOUSE	10-29-87	COLD-FEED	100		99		85		59		44		35		24		11		4.5		3.6		22.86	
AB07-205	SP-687-0(1)	ILLOWA	1/2	B	I		BATCH	BAGHOUSE	10-29-87	EXTRACTION	100	0.0	99	0.0	85	0.0	60	1.0	45	1.0	35	0.0	24	0.0	11	0.0	5.4	0.9	4.4	0.8	24.74	1.88
AB07-205	SP-687-0(1)	ILLOWA	1/2	B	I		BATCH	BAGHOUSE	10-30-87	COLD-FEED	100		98		83		58		46		36		24		11		4.5		3.5		22.84	
AB07-205	SP-687-0(1)	ILLOWA	1/2	B	I		BATCH	BAGHOUSE	10-30-87	EXTRACTION	100	0.0	99	1.0	89	6.0	64	6.0	48	2.0	38	2.0	25	1.0	11	0.0	5.3	0.8	4.3	0.8	25.10	2.26
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-01-87	COLD-FEED	99		88		76		60		42		32		24		14		6.5		4.8		26.58	
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-01-87	EXTRACTION	100	1.0	88	0.0	80	4.0	51	-9.0	43	1.0	32	0.0	25	1.0	15	1.0	8.7	2.2	6.1	1.3	30.28	3.70
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-07-87	COLD-FEED	100		87		76		60		43		33		24		10		5.8		4.4		24.44	
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-07-87	EXTRACTION	99	-1.0	85	-2.0	73	-3.0	57	-3.0	42	-1.0	32	-1.0	24	0.0	13	3.0	8.0	2.2	6.5	2.1	29.84	5.40
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-01-87	COLD-FEED	100		92		76		56		38		26		17		9.1		5.9		4.8		23.05	
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-01-87	EXTRACTION	100	0.0	94	2.0	78	2.0	55	-1.0	37	-1.0	26	0.0	18	1.0	10	0.9	7.4	1.5	6.3	1.5	26.70	3.65
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-06-87	COLD-FEED	100		93		78		55		36		25		17		8.8		5.5		4.4		21.90	
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-06-87	EXTRACTION	100	0.0	93	0.0	78	0.0	57	2.0	39	3.0	28	3.0	19	2.0	11	2.2	8.2	2.7	7.1	2.7	29.18	7.28
AB07-201	FN-6-4(85)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	09-23-87	COLD-FEED	99		94		69		52		42		33		22		12		7.6		6.3		28.68	
AB07-201	FN-6-4(85)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	09-23-87	EXTRACTION	98	-1.0	90	-4.0	73	4.0	55	3.0	44	2.0	35	2.0	24	2.0	12	0.0	8.0	0.4	6.4	0.1	29.66	0.98
AB07-201	FN-6-4(85)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	09-23-87	COLD-FEED	99		88		74		54		44		34		22		11		7.1		5.8		27.48	
AB07-201	FN-6-4(85)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	09-23-87	EXTRACTION	100	1.0	87	-1.0	73	-1.0	55	1.0	44	0.0	35	1.0	24	2.0	12	1.0	8.2	0.9	6.6	0.8	30.10	2.62
AB07-201	FN-6-4(85)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	09-25-87	COLD-FEED	99		89		73		54		44		35		24		12		7.5		6.0		28.70	
AB07-201	FN-6-4(85)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	09-25-87	EXTRACTION	99	0.0	87	-2.0	72	-1.0	54	0.0	42	-2.0	33	-2.0	24	0.0	13	1.0	8.2	0.7	6.6	0.6	30.14	1.44
AB07-194	IR-35-4(55)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	09-21-87	COLD-FEED	100		94		75		48		35		28		23		13		6.8		5.7		26.92	
AB07-194	IR-35-4(55)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	09-21-87	EXTRACTION	100	0.0	92	-2.0	71	-4.0	44	-4.0	31	-4.0	25	-3.0	21	-2.0	13	0.0	7.9	1.1	6.7	1.0	28.42	1.50
AB07-194	IR-35-4(55)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	09-22-87	COLD-FEED	99		89		70		41		30		25		20		12		5.5		4.5		22.92	
AB07-194	IR-35-4(55)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	09-22-87	EXTRACTION	100	1.0	95	6.0	75	5.0	46	5.0	30	0.0	24	-1.0	20	0.0	12	0.0	7.2	1.7	6.1	1.6	26.52	3.60
AB07-194	IR-35-4(55)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	09-25-87	COLD-FEED	100		93		70		44		31		24		20		12		6.1		5.0		24.10	
AB07-194	IR-35-4(55)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	09-25-87	EXTRACTION	100	0.0	90	-3.0	71	1.0	43	-1.0	30	-1.0	24	0.0	20	0.0	12	0.0	7.5	1.4	6.4	1.4	27.12	3.02
6B07-6	FN-22-3(31)	L.L. PELLING	1/2	A			BATCH	BAGHOUSE	10-22-87	COLD-FEED	100		93		82		65		51		41		28		11		6.0		4.9		27.28	
6B07-6	FN-22-3(31)	L.L. PELLING	1/2	A			BATCH	BAGHOUSE	10-22-87	EXTRACTION	100	0.0	94	1.0	83	1.0	64	-1.0	50	-1.0	39	-2.0	26	-2.0	11	0.0	6.6	0.6	5.8	0.9	28.58	1.30
6B07-6	FN-22-3(31)	L.L. PELLING	1/2	A			BATCH	BAGHOUSE	09-24-87	COLDFEED	100		93		85		63		49		39		27		11		6.4		5.1		27.42	
6B07-6	FN-22-3(31)	L.L. PELLING	1/2	A			BATCH	BAGHOUSE	09-24-87	EXTRACTION	100	0.0	94	1.0	85	0.0	66	3.0	51	2.0	40	1.0	28	1.0	12	1.0	6.5	0.1	5.4	0.3	28.62	1.20
6B07-6	FN-22-3(31)	L.L. PELLING	1/2	A			BATCH	BAGHOUSE	09-25-87	CPLD-FEED	100		93		86		69		54		42		29		14		8.8		7.1		33.80	
6B07-6	FN-22-3(31)	L.L. PELLING	1/2	A			BATCH	BAGHOUSE	09-25-87	EXTRACTION	100	0.0	94	1.0	89	3.0	73	4.0	57	3.0	44	2.0	30	1.0	14	0.0	8.8	0.0	7.5	0.4	34.94	1.14
AB07-137	IR-35-4(55)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	09-25-87	COLD-FEED	100		100		92		63		46		34		24		13		6.2		4.8		26.48	
AB07-137	IR-35-4(55)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	09-25-87	EXTRACTION	100	0.0	100	0.0	92	0.0	62	-1.0	44	-2.0	33	-1.0	25	1.0	13	0.0	7.0	0.8	5.7	0.9	28.36	1.88
AB07-137	IR-35-4(55)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	10-07-87	COLD-FEED	100		99		88		58		44		34		24		13		6.0		4.7		26.02	
AB07-137	IR-35-4(55)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	10-07-87	EXTRACTION	100	0.0	99	0.0	91	3.0	63	5.0	45	1.0	34	0.0	25	1.0	15	2.0	7.5	1.5	6.1	1.4	30.04	4.02
AB07-137	IR-35-4(55)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	10-08-87	COLD-FEED	100		99		90		63		47		36		26		13		6.6		5.1		27.68	
AB07-137	IR-35-4(55)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	10-08-87	EXTRACTION	100	0.0	100	1.0	91	1.0	64	1.0	45	-2.0	34	-2.0	26	0.0	15	2.0	8.2	1.6	6.7	1.6	31.58	3.90
4M07-1	SR-6302(4)	NORRIS ASPHALT	1/2	B	I		BATCH	BAGHOUSE	05-18-87	COLD-FEED	100		99		87		63		47		36		23		9.4		6.0		5.2		25.98	
4M07-1	SR-6302(4)	NORRIS ASPHALT	1/2	B	I		BATCH	BAGHOUSE	05-18-87	EXTRACTION	100	0.0	99	0.0	88	1.0	66	3.0	48	1.0	36	0.0	23	0.0	9.1	-0.3	5.7	-0.3	5.1	-0.1	25.65	-0.33
4M07-1	SR-6302(4)	NORRIS ASPHALT	1/2	B	I		BATCH	BAGHOUSE	05-19-87	COLD-FEED	100		99		86		63		45		34		23		9.6		6.3		5.6		26.62	
4M07-1	SR-6302(4)	NORRIS ASPHALT	1/2	B	I		BATCH	BAGHOUSE	05-19-87	EXTRACTION	100	0.0	99	0.0	89	3.0	67	4.0	49	4.0	36	2.0	24	1.0	9.2	-0.4	5.7	-0.6	5.1	-0.5	25.88	-0.74
4M07-1	SR-6302(4)	NORRIS ASPHALT	1/2	B	I		BATCH	BAGHOUSE	05-20-87	COLD-FEED	100		100		84		60		45		35		23		9.5		5.4		4.7		24.63	
4M07-1	SR-6302(4)	NORRIS ASPHALT	1/2	B	I		BATCH	BAGHOUSE	05-20-87	EXTRACTION	100	0.0	99	-1.0	89	5.0	66	6.0	50	5.0	38.0	3.0	25	2.0	9.9	0.4	5.7	0.3	5.0	0.3	26.25	1.62
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-09-87	COLD-FEED	99		84		73		58		42		32		24		12		6.4		4.8		25.88	
AB07-198	IR-35-2(199)	CAPCO	3/4	A			BATCH	BAGHOUSE	10-09-87	EXTRACTION	100	1.0	88	4.0	77	4.0	61	3.0	44	2.0	34	2.0	26	2.0	15	3.0	8.8	2.4	7.0	2.2	32.32	6.44
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	07-31-87	COLD-FEED	99		85		71		56		46				28						5.0			
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	07-31-87	EXTRACTION	99	0.0	87	2.0	74	3.0	57	1.0	47	1.0	40		29	1.0	12		6.6		5.1	0.1		
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	08-03-87	COLD-FEED	99		85		72		57		47				29						5.5			
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	08-03-87	EXTRACTION	99	0.0	84	-1.0	70	-2.0	55	-2.0	45	-2.0	37		27	-2.0	12		6.6		5.1	-0.4		
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	08-04-87	COLD-FEED	99		83		69		53		44				27						4.9			
AB07-143	SN-8036(6)	NORRIS	3/4	B	I		BATCH	BAGHOUSE	08-04-87	EXTRACTION	99	0.0	85	2.0	73	4.0	55	2.0	46	2.0	38		28	1.0	12		6.8		5.4	0.5		

COLD FEED VS. EXTRACTED GRADATION STUDY - 1987 BATCH PLANTS WITH BAGHOUSE

MIX DESIGN NO.	PROJECT-NUMBER	CONTRACTOR	MATERIAL TYPE SIZE	TYPE	CL	R	PLANT TYPE	DUST CONTRL	SAMPLE DATE	GRADATION SAMPLE	SIEVE # 3/4	DIFF.	SIEVE # 1/2	DIFF.	SIEVE # 3/8	DIFF.	SIEVE # 4	DIFF.	SIEVE # 8	DIFF.	SIEVE # 16	DIFF.	SIEVE # 30	DIFF.	SIEVE # 50	DIFF.	SIEVE # 100	DIFF.	SIEVE # 200	DIFF.	SURF. AREA	DIFF.
ABD7-149	IR-80-3(52)99--12-25	NORRIS	3/4	A			BATCH	BAGHOUSE	09-17-87	COLD-FEED	99		93		81		59		41		29		19		10		6.3		5.1		24.74	
ABD7-149	IR-80-3(52)99--12-25	NORRIS	3/4	A		*	BATCH	BAGHOUSE	09-17-87	EXTRACTION	100	1.0	92	-1.0	80	-1.0	60	1.0	42	1.0	28	-1.0	20	1.0	12	2.0	8.6	2.3	7.2	2.1	30.20	5.46
ABD7-149	IR-80-3(52)99--12-25	NORRIS	3/4	A			BATCH	BAGHOUSE	09-22-87	COLD-FEED	100		91		77		55		38		26		17		10		7.0		5.8		25.56	
ABD7-149	IR-80-3(52)99--12-25	NORRIS	3/4	A		*	BATCH	BAGHOUSE	09-22-87	EXTRACTION	100	0.0	92	1.0	80	3.0	60	5.0	43	5.0	29	3.0	20	3.0	13	3.0	9.2	2.2	7.8	2.0	31.94	6.38
ABD7-149	IR-80-3(52)99--12-25	NORRIS	3/4	A			BATCH	BAGHOUSE	09-23-87	COLD-FEED	100		91		78		55		37		25		17		11		7.1		5.9		25.96	
ABD7-149	IR-80-3(52)99--12-25	NORRIS	3/4	A		*	BATCH	BAGHOUSE	09-23-87	EXTRACTION	100	0.0	94	3.0	81	3.0	60	5.0	42	5.0	29	4.0	20	3.0	13	2.0	9.5	2.4	8.1	2.2	32.56	6.60
ABD7-114	FN-65-4(15)	COMMERCIAL	3/4	A			BATCH	BAGHOUSE	09-02-87	COLD-FEED	100		91		76		59		50		42		30		13		5.5		3.9		26.18	
ABD7-114	FN-65-4(15)	COMMERCIAL	3/4	A			BATCH	BAGHOUSE	09-02-87	EXTRACTION	100	0.0	92	1.0	78	2.0	61	2.0	50	0.0	41	-1.0	30	0.0	14	1.0	7.2	1.7	5.4	1.5	29.86	3.68
ABD7-114	FN-65-4(15)	COMMERCIAL	3/4	A			BATCH	BAGHOUSE	09-03-87	COLD-FEED	100		93		79		62		50		40		26		12		5.8		4.3		26.04	
ABD7-114	FN-65-4(15)	COMMERCIAL	3/4	A			BATCH	BAGHOUSE	09-03-87	EXTRACTION	100	0.0	96	3.0	86	7.0	68	6.0	54	4.0	42	2.0	28	2.0	14	2.0	7.2	1.4	5.5	1.2	30.12	4.08
ABD7-178	FN-415-1(25)	COMMERCIAL	1/2	A			BATCH	BAGHOUSE	09-08-87	COLD-FEED	100		99		86		67		55		43		26		14		5.9		4.6		27.72	
ABD7-178	FN-415-1(25)	COMMERCIAL	1/2	A			BATCH	BAGHOUSE	09-08-87	EXTRACTION	100	0.0	100	1.0	86	0.0	65	-2.0	52	-3.0	40	-3.0	26	0.0	12	-2.0	6.4	0.5	5.2	0.6	27.98	0.26
ABD7-178	FN-415-1(25)	COMMERCIAL	1/2	A			BATCH	BAGHOUSE	09-09-87	COLD-FEED	100		99		80		60		49		38		22		9.5		4.9		4.0		23.47	
ABD7-178	FN-415-1(25)	COMMERCIAL	1/2	A			BATCH	BAGHOUSE	09-09-87	EXTRACTION	100	0.0	100	1.0	86	6.0	66	6.0	52	3.0	39	1.0	25	3.0	10	0.5	6.2	1.3	5.2	1.2	27.06	3.59
ABD7-178	FN-415-1(25)	COMMERCIAL	1/2	A			BATCH	BAGHOUSE	09-10-87	COLD-FEED	100		99		81		60		48		37		22		8.2		4.7		3.2		21.56	
ABD7-178	FN-415-1(25)	COMMERCIAL	1/2	A			BATCH	BAGHOUSE	09-10-87	EXTRACTION	100	0.0	98	-1.0	82	1.0	61	1.0	49	1.0	36	-1.0	22	0.0	9	0.8	5.3	0.6	4.4	1.2	24.06	2.50
ABD7-8	P-83-0(20)	HENNINGSEN	3/4	B	I	R	BATCH	BAGHOUSE	05-25-87	COLD-FEED	99		90		79		59		46		38		29		13		6.8		5.8		29.38	
ABD7-8	P-83-0(20)	HENNINGSEN	3/4	B	I	R	BATCH	BAGHOUSE	05-25-87	EXTRACTION	99	0.0	88	-2.0	78	-1.0	61	2.0	47	1.0	39	1.0	30	1.0	13	0.0	7.1	0.3	5.9	0.1	30.02	0.64
ABD7-8	P-83-0(20)	HENNINGSEN	3/4	B	I	R	BATCH	BAGHOUSE	06-05-87	COLD-FEED	100		91		81		62		48		41		32		14		6.2		5.3		29.32	
ABD7-8	P-83-0(20)	HENNINGSEN	3/4	B	I	R	BATCH	BAGHOUSE	06-05-87	EXTRACTION	100	0.0	90	-1.0	79	-2.0	59	-3.0	45	-3.0	38	-3.0	29	-3.0	13	-1.0	6.1	-0.1	5.2	-0.1	27.96	-1.36
ABD7-8	P-83-0(20)	HENNINGSEN	3/4	B	I	R	BATCH	BAGHOUSE	06-08-87	COLD-FEED	98		86		77		58		44		37		29		12		5.9		5.1		27.24	
ABD7-8	P-83-0(20)	HENNINGSEN	3/4	B	I	R	BATCH	BAGHOUSE	06-08-87	EXTRACTION	100	2.0	90	4.0	78	1.0	58	0.0	44	0.0	37	0.0	29	0.0	13	1.0	6.2	0.3	5.2	0.1	27.88	0.64
ABD7-156	IR-80-3(52)99-12-25	NORRIS	1/2	A			BATCH	BAGHOUSE	09-03-87	COLD-FEED	100		93		80		60		47		34		23		13		8.3		5.6		28.86	
ABD7-156	IR-80-3(52)99-12-25	NORRIS	1/2	A			BATCH	BAGHOUSE	09-03-87	EXTRACTION	100	0.0	97	4.0	85	5.0	69	9.0	53	6.0	37	3.0	26	3.0	16	3.0	10.0	1.7	7.6	2.0	35.06	6.20
ABD7-156	IR-80-3(52)99-12-25	NORRIS	1/2	A			BATCH	BAGHOUSE	09-09-87	COLD-FEED	100		92		75		57		44		31		20		11		6.6		4.6		24.80	
ABD7-156	IR-80-3(52)99-12-25	NORRIS	1/2	A			BATCH	BAGHOUSE	09-09-87	EXTRACTION	100	0.0	91	-1.0	78	3.0	60	3.0	45	1.0	32	1.0	22	2.0	14	3.0	9.7	3.1	7.5	2.9	32.66	7.86
ABD7-156	IR-80-3(52)99-12-25	NORRIS	1/2	A			BATCH	BAGHOUSE	09-14-87	COLD-FEED	100		92		78		57		42		30		20		13		8.4		6.1		28.72	
ABD7-156	IR-80-3(52)99-12-25	NORRIS	1/2	A			BATCH	BAGHOUSE	09-14-87	EXTRACTION	100	0.0	95	3.0	80	2.0	64	7.0	48	6.0	33	3.0	23	3.0	15	2.0	9.8	1.4	7.4	1.3	33.28	4.56
ABD7-95	FN-117-1(16)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	07-30-87	COLDFEED	99		88		72		50		36		27		18		9		6.1		5.0		23.48	
ABD7-95	FN-117-1(16)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	07-30-87	EXTRACTION	99	0.0	90	2.0	72	0.0	52	2.0	39	3.0	31	4.0	21	3.0	10	1.0	6.6	0.5	5.2	0.2	25.30	1.82
ABD7-95	FN-117-1(16)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	08-03-87	COLDFEED	100		90		76		54		41		32		21		9.4		5.6		4.5		23.60	
ABD7-95	FN-117-1(16)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	08-03-87	EXTRACTION	100	0.0	91	1.0	78	2.0	58	4.0	44	3.0	35	3.0	24	3.0	11	1.6	6.9	1.3	5.5	1.0	27.32	3.72
ABD7-95	FN-117-1(16)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	08-04-87	COLDFEED	99		86		74		55		43		33		22		9.4		5.2		4.0		22.88	
ABD7-95	FN-117-1(16)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	08-04-87	EXTRACTION	100	1.0	92	6.0	80	6.0	59	4.0	45	2.0	35	2.0	24	2.0	11	1.6	6.4	1.2	5.1	1.1	26.44	3.56
ABD7-136	IR-29-4(33)72	HENNINGSEN	3/4	B		R	BATCH	BAGHOUSE	08-06-76	COLDFEED	100		91		78		61		49		35		24		13		6.7		5.0		27.26	
ABD7-136	IR-29-4(33)72	HENNINGSEN	3/4	B		R	BATCH	BAGHOUSE	08-06-76	EXTRACTION	100	0.0	89	-2.0	77	-1.0	60	-1.0	48	-1.0	35	0.0	24	0.0	13	0.0	7.4	0.7	5.7	0.7	28.74	1.48
ABD7-136	IR-29-4(33)72	HENNINGSEN	3/4	B		R	BATCH	BAGHOUSE	08-07-87	COLDFEED	100		91		79		63		51		37		25		13		7.1		5.3		28.40	
ABD7-136	IR-29-4(33)72	HENNINGSEN	3/4	B		R	BATCH	BAGHOUSE	08-07-87	EXTRACTION	100	0.0	90	-1.0	78	-1.0	61	-2.0	49	-2.0	36	-1.0	25	0.0	14	1.0	7.9	0.8	6.1	0.8	30.26	1.86
ABD7-104	FN-117-1(16)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	08-10-87	COLDFEED	100		93		79		55		43		34		23		11		6.0		4.6		25.02	
ABD7-104	FN-117-1(16)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	08-10-87	EXTRACTION	100	0.0	95	2.0	79	0.0	57	2.0	44	1.0	34	0.0	24	1.0	11	0.0	6.2	0.2	4.9	0.3	25.84	0.82
ABD7-104	FN-117-1(16)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	08-11-87	COLDFEED	100		93		79		59		47		38		25		12		5.7		4.3		25.50	
ABD7-104	FN-117-1(16)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	08-11-87	EXTRACTION	100	0.0	95	2.0	81	2.0	59	0.0	45	-2.0	35	-3.0	24	-1.0	11	-1.0	7.0	1.3	5.6	1.3	27.60	2.10
ABD7-104	FN-117-1(16)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	08-14-87	COLDFEED	100		93		81		62		48		38		26		11		6.3		4.9		26.76	
ABD7-104	FN-117-1(16)	DES MOINES ASPHALT	1/2	A			BATCH	BAGHOUSE	08-14-87	EXTRACTION	100	0.0	94	1.0	81	0.0	59	-3.0	44	-4.0	34	-4.0	24	-2.0	11	0.0	6.8	0.5	5.5	0.6	27.20	0.44
ABD7-79	FN-415-1(27)	DES MOINES ASPHALT	3/4	B	I		BATCH	BAGHOUSE	06-23-87	COLDFEED	98		80		70		52		43		35		22		10		5.0		3.8		22.72	
ABD7-79	FN-415-1(27)	DES MOINES ASPHALT	3/4	B	I		BATCH	BAGHOUSE	06-23-87	EXTRACTION	98	0.0	82	2.0	69	-1.0	51	-1.0	41	-2.0	33	-2.0	23	1.0	11	1.0	6.1	1.1	4.8	1.0	25.16	2.44
ABD7-79	FN-415-1(27)	DES MOINES ASPHALT	3/4	B	I		BATCH	BAGHOUSE	06-24-87	COLDFEED	95		82		69		53		43		35		24		10		5.6		4.3		24.18	
ABD7-79	FN-415-1(27)	DES MOINES ASPHALT	3/4	B	I		BATCH	BAGHOUSE	06-24-87	EXTRACTION	98	3.0	81	-1.0	65	-4.0	51	-2.0	42	-1.0	34	-1.0	23	-1.0	10	0.0	5.9	0.3	4.7	0.4	24.70	0.52
ABD7-79	FN-415-1(27)	DES MOINES ASPHALT	3/4	B	I		BATCH	BAGHOUSE	08-27-87	COLDFEED	98		86		70		55		45		37		24		11		5.5		4.1		24.38	
ABD7-79	FN-415-1(27)	DES MOINES ASPHALT	3/4	B	I		BATCH	BAGHOUSE	08-27-87	EXTRACTION	100	2.0	86	0.0	76	6.0	59	4.0	48	3.0	39	2.0	27	3.0	13	2.0	7.9	2.4	6.0	1.9	30.24	5.86
ABD7-200	FN-6-4(85)	DES MOINES ASPHALT	1/2	A		R	BATCH	BAGHOUSE	09-30-87	COLDFEED	100		97		84		58		41		32		23		12		7.0		5.6		27.34	
ABD7-200	FN-6-4(85)	DES MOINES ASPHALT	1/2	A		R	BATCH	BAGHOUSE	09-30-87	EXTRACTION	99	-1.0	96	-1.0	85	1.0	61	3.0	44	3.0	35	3.0	25	2.0	12	0.0	7.5	0.5	6.0	0.4	28.98	1.64
ABD7-200	FN-6-4(85)	DES MOINES ASPHALT	1/2	A		R	BATCH	BAGHOUSE	10-01-87	COLDFEED	100		97		85		59		43		32		21		10		6.4		5.2		25.56	
ABD7-200	FN-6-4(85)	DES MOINES ASPHALT	1/2	A		R	BATCH	BAGHOUSE	10-01-87	EXTRACTION	100	0.0	99	2.0	87	2.0	61	2.0	44	1.0	34	2.0	23	2.0	12	2.0	8.0	1.6	6.5	1.3	29.72	4.16
ABD7-200	FN-6-4(85)	DES MOINES ASPHALT	1/2	A		R	BATCH	BAGHOUSE	10-02-87	COLDFEED	100		97		84		57		40		30		21		10		6.6		5.3		25.52	
ABD7-200	FN-6-4(85)	DES MOINES ASPHALT	1/2	A		R	BATCH	BAGHOUSE	10-02-87	EXTRACTION	100	0.0	99	2.0	87	3.0	62	5.0	44	4.0	33	3.0	23	2.0	11	1.0	7.4	0.8	6.1	0.8	28.36	2.84
ABD7-125	FN-67-1(70)	CENTRAL VALLEY	3/4	A			BATCH	BAGHOUSE	07-29-87	COLDFEED	100		94		84		61		47		38		29		14		6.7		4.7		27.94	
ABD7-125	FN-67-1(70)	CENTRAL VALLEY	3/4	A			BATCH	BAGHOUSE	07-29-87	EXTRACTION	99	-1.0	96	2.0	86	2.0	63	2.0	48	1.0	38	0.0	29	0.0	15	1.0	8.0	1.3	5.5	0.8	30.38	2.44
ABD7-125	FN-67-1(70)	CENTRAL VALLEY	3/4	A			BATCH	BAGHOUSE	07-31-87	COLDFEED	98		94		83		60		46		37		28		14		6.0		4.4		26.76	
ABD7-125	FN-67-1(70)	CENTRAL VALLEY	3/4	A			BATCH	BAGHOUSE	07-31-87	EXTRACTION	100	2.0	93	-1.0	87	4.0	66	6.0	48	2.0	38	1.0	28	0.0	12	-2.0	5.3	-0.7	3.9	-0.5	25.22	-1.54
ABD7-125	FN-67-1(70)	CENTRAL VALLEY	3/4	A			BATCH	BAGHOUSE	08-05-87	COLDFEED	100		94		84		64		49		40		30		14		5.9		4.1		26.94	
ABD7-125	FN-67-1(70)	CENTRAL VALLEY	3/4	A			BATCH	BAGHOUSE	08-05-87	EXTRACTION	97	-3.0	92	-2.0	84	0.0	65	1.0	49	0.0	38	-2.0	30	0.0	14	0.0	6.1	0.2	4.3	0.2	27.24	0.30
ABD7-131	FN-163-1(40)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	07-23-87	COLDFEED	96		83		71		57		44		36		27		15		7.6		4.6		27.98	
ABD7-131	FN-163-1(40)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	07-23-87	EXTRACTION	98	2.0	88	5.0	76	5.0	62	5.0	50	6.0	41	5.0	31	4.0	16	1.0	7.9	0.3	4.8	0.2	30.08	2.10
ABD7-131	FN-163-1(40)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	07-24-87	COLDFEED	99		85		76		62		49		39		28		16		7.3		4.6		28.78	
ABD7-131	FN-163-1(40)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	07-24-87	EXTRACTION	97	-2.0	88	3.0	77	1.0	65	3.0	51	2.0	41	2.0	31	3.0	17	1.0	9.4	2.1	6.2	1.6	33.62	4.84
ABD7-131	FN-163-1(40)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	07-24-87	COLDFEED	99		86		77		62		50		40		28		15		7.0		4.4		28.10	
ABD7-131	FN-163-1(40)	DES MOINES ASPHALT	3/4	A			BATCH	BAGHOUSE	07-24-87	EXTRACTION	98	-1.0	87	1.0	76	-1.0	63	1.0	50	0.0	40	0.0	31	3.0	16	1.0	9.1	2.1	6.0	1.6	32.66	4.56
ABD7-106	FN-163-1(40)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	07-20-87	COLDFEED	100		84		71		50		41		34		24		10		6.8		5.2		26.12	
ABD7-106	FN-163-1(40)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	07-20-87	EXTRACTION	100	0.0	90	6.0	76	5.0	59	9.0	48	7.0	39	5.0	28	4.0	14	4.0	8.0	1.2	6.1	0.9	30.90	4.78
ABD7-106	FN-163-1(40)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	07-22-87	COLDFEED	100		89		76		62		51		41		27		12		6.9		5.2		28.40	
ABD7-106	FN-163-1(40)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	07-22-87	EXTRACTION	100	0.0	88	-1.0	77	1.0	62	0.0	49	-2.0	39	-2.0	26	-1.0	13	1.0	7.6	0.7	5.9	0.7	29.86	1.46
ABD7-106	FN-163-1(40)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	07-22-87	COLDFEED	100		91		75		62		51		41		28		12		6.7		5.1		28.26	
ABD7-106	FN-163-1(40)	DES MOINES ASPHALT	3/4	A		R	BATCH	BAGHOUSE	07-22-87	EXTRACTION	100	0.0	91	0.0	77	2.0	62	0.0	50	-1.0	39	-2.0	27	-1.0	13	1.0	7.7	1.0	5.9	0.8	30.10	1.84

COLD FEED VS. EXTRACTED GRADATION STUDY - 1987   BATCH PLANTS WITH BAGHOUSE

MIX DESIGN NO.	PROJECT-NUMBER	CONTRACTOR	MATERIAL TYPE SIZE	TYPE	CL	R	PLANT TYPE	DUST CONTRL	SAMPLE DATE	GRADATION SAMPLE	SIEVE # 3/4	DIFF.	SIEVE # 1/2	DIFF.	SIEVE # 3/8	DIFF.	SIEVE # 4	DIFF.	SIEVE # 8	DIFF.	SIEVE # 16	DIFF.	SIEVE # 30	DIFF.	SIEVE # 50	DIFF.	SIEVE # 100	DIFF.	SIEVE # 200	DIFF.	SURF. AREA	DIFF.
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	09-22-87	COLDFEED	100		92		81		61		48		37		25		14		8.6		6.3		31.04	
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	09-22-87	EXTRACTION	100	0.0	92	0.0	80	-1.0	61	0.0	47	-1.0	35	-2.0	25	0.0	13	-1.0	8.7	0.1	6.6	0.3	31.08	0.04
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	09-24-87	COLDFEED	100		92		77		60		47		37		24		12		6.5		4.7		26.42	
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	09-24-87	EXTRACTION	100	0.0	91	-1.0	77	0.0	59	-1.0	45	-2.0	34	-3.0	24	0.0	12	0.0	7.9	1.4	6.0	1.3	29.00	2.58
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	09-25-87	COLDFEED	99		92		80		61		48		38		25		12		7.5		5.4		28.42	
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	09-25-87	EXTRACTION	100	1.0	95	3.0	79	-1.0	59	-2.0	46	-2.0	35	-3.0	24	-1.0	12	0.0	8.2	0.7	6.3	0.9	29.78	1.36
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	09-29-87	COLDFEED	100		92		81		64		51		40		26		12		6.8		5.0		27.84	
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	09-29-87	EXTRACTION	100	0.0	90	-2.0	81	0.0	64	0.0	50	-1.0	37	-3.0	25	-1.0	12	0.0	7.6	0.8	5.9	0.9	29.34	1.50
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	10-01-87	COLDFEED	100		93		80		65		51		39		26		11		6.4		4.6		26.60	
1807-9	FM-94(11)	FT. DODGE ASPHALT	3/4	B	I		BATCH	BAGHOUSE	10-01-87	EXTRACTION	100	0.0	93	0.0	84	4.0	67	2.0	52	1.0	39	0.0	27	1.0	13	2.0	8.3	1.9	6.3	1.7	31.28	4.68
										NO. OF SAMPLES		81.0		81.0		81.0		81.0		82.0		76.0		81.0		76.0		76.0		81.0		76.0
										AVG. DIFF.		0.11		0.63		1.46		1.60		0.88		0.29		0.83		0.84		1.06		0.98		2.78
										STD. DEV.		0.8		2.3		2.6		3.2		2.8		2.3		1.6		1.2		0.8		0.8		2.2

Appendix B
Materials Instructional Memorandum 510 and 511

METHOD OF DESIGN OF ASPHALTIC CONCRETE MIXES

GENERAL

The design of asphaltic concrete mixes involves determining an economical blend of aggregates that provides a combined gradation within the limits of the specifications and a determination of the percent asphalt to mix with the aggregate blend. Trial mixes prepared with different asphalt contents are tested for mix properties and the results analyzed to select the asphalt content that is judged to be most satisfactory for the intended use of the mix.

RAW MATERIALS

The aggregate sources, proposed aggregate blend proportions, and the source of asphalt are selected by the contractor. This information is submitted to the District Materials Engineer on Form 955 for approval. Material source approval, gradations, crushed particle amount and type, asphalt grade, and other specific requirements are checked prior to submitting materials and Form 955 to the laboratory.

TRIAL MIXES

A. Preparation of Aggregates

Aggregates must be air dried to a surface dried condition prior to further preparation. The individual aggregates are combined in the proportions proposed on the Form 955 in accordance with Test Method Iowa 504. About 100 lbs. of this combined aggregate is required for the design work. 130 lbs. of this combined aggregate is required if the asphalt nuclear gauge is to be calibrated to the mix.

B. Asphalt Cement

The asphalt cement used for trial mixes shall be of the same grade as indicated on the Form 955 and shall also be from the same source when possible.

C. Selecting Trial Asphalt Contents

Three trial mixes of different asphalt contents are made to assure close bracketing of the final recommended design asphalt content. Two trial mixes may be adequate for this purpose if recent results have been obtained with aggregate of the same or slightly adjusted composition.

The trial mix asphalt contents are best guess estimations that are one percent apart. They may be based on past experience, analysis of the aggregate gradation, calculated surface area of the aggregate, or trial and error.

The gradation plotted on the 0.45 power gradation chart indicates the void space available for asphalt. Gradations that closely follow the maximum density line indicate low void space.

The surface area of the aggregate is related to the film thickness of asphalt obtained by a given asphalt content. A higher surface area will almost always require a higher asphalt content.

D. Mix Preparation

Preparation of trial mixes is in accordance with Test Method Iowa 504.

E. Nuclear Calibration

The asphalt nuclear gauge is calibrated to the mix in accordance with I.M. 335.

TESTING RAW MATERIALS

Test procedures for the asphalt and combined aggregate are as follows:

Test	Cent. Lab Test No.	I.M. No.
Specific Gravity of Asphalt*	617	369
Bulk Sp.G. of Combined Aggregate	203	---
Water Absorption of Combined Aggregate	203	308**

*The sp.g. of the asphalt may be obtained from certifying documents or a lab test report.
**Procedure "C"

TESTING TRIAL MIXES

Test procedures for A.C. mixes are as follows:

	Cent. Lab Test No.	I.M. No.
Maximum Specific Gravity*	507	340 or 363
Compacting Marshall Specimens	502	325
Density of Compacted Mixes (Lab Density)	503	321
Marshall Stability and Flow	506	---

*The Rice sp.g. procedure, Test Method Iowa 507 or I.M. 340, is the referee method. The high pressure air meter procedure, I.M. 363, should only be used if results have previously been shown to correlate with Rice results.)

Four Marshall specimens are made from each trial mix. An extra specimen of the first mix compacted is usually made to determine the amount of mix necessary to produce the proper specimen thickness. The four specimens of each A.C. content are checked for lab density and on the following day (after the required cooling period) the three specimens with the closest densities are tested for stability and flow.

If a District Lab is not equipped for Marshall Stability, the selected three specimens are shipped to the Central Lab for testing. The specimens must be fully identified and packaged to prevent damage.

DESIGN CALCULATIONS

A. Calculation Basis and Nomenclature

The derivation of the formulas used for calculations is based on an assumed 100 grams of mix so that mix percentages are numerically equal to weights. Following is a list of nomenclature symbols used and their definitions:

%AC = % of asphalt cement in the trial mix
%Ag = % of combined aggregate in the trial mix = 100 - %AC
%Abs = % water absorption of the combined aggregate
Abs = fraction of water absorption of the combined aggregate = %Abs/100. This quantity is always used in the calculations rather than %Abs.
Gag = bulk specific gravity of the combined aggregate. This quantity may be by test or by calculation.
Gac = specific gravity of the asphalt
Gmx = maximum specific gravity of trial mix by test. This quantity may be referred to as the solid sp.g. or solid density. A calculated max. sp.g. should be designated as Gmx (calc.).
Gcm = density of compacted mix or lab density
%V = calculated % air voids in the compacted mix
%VMA = calculated % voids in the mineral aggregate

B. Calculated Maximum Specific Gravity

A theoretical maximum specific gravity may be calculated when the bulk sp.g. and water absorption of the aggregate is known. This calculated maximum specific gravity is used to check the results determined by test and is not intended for calculating other design quantities. A Rice specific gravity should not be considered suspect unless the calculated specific gravity differs by more than 0.030. Calculate the maximum sp.g. using the following steps and report the results to three decimal places.

1. Wt. of AC absorbed = 0.5 x Abs x %Ag
2. Wt. of effective AC = %AC - line 1
3. Volume of Aggregate = %Ag/Gag
4. Volume of effective AC = line 2/Gac
5. Gmx (calc.) = 100/(line 3 + line 4)

C. Calculated Bulk Specific Gravity of the Combined Aggregate

The bulk sp.g. of the combined aggregate (Gag) may be calculated from the maximum specific gravity of the mix determined by test. It is calculated with the following line steps and reported to three decimal places:

1. Gmx x %Ag x Gac
2. Gac x 100
3. 0.5 x Abs x %Ag x Gmx
4. Gmx x %AC
5. line 2 + line 3 - line 4
6. Gag (calc.) = line 1/line 5

D. Void Calculations

Quantities used to calculate void results shall be determined by test except Gag(calc.) may be used to calculate %VMA. The following formulas are used to calculate the indicated quantities that are reported to one decimal place.

$$\%V\text{, air voids in the compacted mix} = 100 - \frac{100 \times Gcm}{Gmx}$$

$$\%VMA\text{, voids in the aggregate} = 100 - \frac{Gcm \times \%Ag}{Gag}$$

$$\%VMA\text{ filled with asphalt} = \frac{\%VMA - \%V}{\%VMA} \times 100$$

E. Filler/Bitumen Ratio

Calculate the ratio as follows and report to two decimal places:

$$\text{Filler/Bitumen Ratio} = \frac{\%\text{Passing \#200}}{\%AC}$$

F. Asphalt Film Thickness

Calculations of asphalt film thickness are described in I.M. 511. It is reported to two decimal places.

EXAMPLE CALCULATIONS

Given data:

%AC = 5.75
%Ag = 100 - 5.75 = 94.25
%Abs = 0.30
Abs = 0.30/100 = 0.003

Gag (test) = 2.667
Gac = 1.031
Gmx (test) = 2.438
Gcm (lab dens.) = 2.347

A. Calculated Maximum Sp.G.

1. Wt. of AC absorbed = 0.003 x 94.25 x 0.5 = 0.141
2. Wt. of effective AC = 5.75 - 0.141 = 5.609
3. Volume of aggregate = 94.25/2.667 = 35.339
4. Volume of effective AC = 5.609/1.031 = 5.440
5. Gmx (calc.) - 100/(35.339 + 5.440) = 2.452

This calculated sp.g. compares favorably with the 2.438 obtained by test.

B. Calculated Bulk Sp.G. of Combined Aggregate

1. 2.438 x 94.25 x 1.031 = 236.905
2. 1.031 x 100 = 103.1
3. 0.5 x 0.003 x 94.25 x 2.438 = 0.345
4. 2.438 x 5.75 = 14.019
5. 103.1 + 0.345 - 14.019 = 89.426
6. Gag (calc.) = 236.905/89.426 = 2.649

C. Void Calculations

$$\%V = 100 - \frac{100 \times 2.347}{2.438} = 100 - 96.3 = 3.7$$

$$\%VMA \text{ using Gag (test)} = 100 - \frac{2.347 \times 94.25}{2.667} = 17.0$$

$$\%VMA \text{ using Gag (calc.)} = 100 - \frac{2.347 \times 94.25}{2.649} = 16.5$$

$$\%VMA \text{ filled with asphalt} = \frac{17.0 - 3.7}{17.0} \times 100 = 78.2$$

EVALUATING RESULTS

The test data and calculated results are compared to the criteria given in the appropriate table shown in I.M. 511 corresponding to the type and use of the mix. An asphalt content is selected that will produce a percent air voids in the compacted mix that is near or slightly above the minimum void values in Table F of I.M. 511 for the course and traffic count involved with the intended use of the mix. Interpolation may be necessary.

REPORTING RESULTS

The test and calculated results along with the % asphalt recommended to start the project is reported on Form 820956. Distribution of the report:

District Engineer
Resident or County Engineer
Bituminous Engineer (R. Monroe)
Asphalt Construction Engineer (J. Smythe)
Asphalt Mix Engineer (D. Heins)
Contractor
Bituminous Lab (W. Oppedal)
Asphalt Mix Design file

CONTROL OF ASPHALTIC CONCRETE MIXTURES

A. General

The job mix formulas are established on the basis of the results of tests performed on samples obtained during the initial stages of material production. Since these samples may not be truly representative of the material produced, and since materials do change with time and through handling, the plant produced mixtures may not develop test characteristics that meet design criteria. Therefore, each mixture shall be reevaluated after paving operations have begun. Because material and mixture characteristics may change at any time, they must be monitored continuously throughout the course of the work. The reevaluation procedures outlined herein are to be carefully followed so that all mix characteristics will conform with the appropriate requirements contained in tables A, B, C, D, E and F.

B. Job Mix Formula Definition

The specifications define the job mix formula as the percentage passing each specified sieve (target gradation), and the percentage of each material including asphalt, (aggregate and asphalt proportions). The original job mix formula and subsequent adjustments are set after consultation with the contractor on the basis of gradation, stability, skid resistance, film thickness, asphalt and void analysis. Design criteria for setting the original formula and subsequent adjustments are provided by the attached tables for the various mix types and service requirements.

C Sampling and Testing

The initial plant calibrations will, in virtually all cases, be based on the formula established by the Central Laboratory. Samples of the combined aggregate and plant produced mixture should be obtained and analyzed as soon as the operations of the plant stabilize. The first samples can normally be obtained after the plant has operated an hour or so. Sampling and testing should be performed promptly so that production and proportion changes, if required, can be effected before large quantities of mix are produced. If adjustments are made in the proportions, the entire procedure must be repeated.

Laboratory density per I.M. 325 shall be furnished to each project as set out in the sampling and testing guides contained in I.M. 204.

For interstate and high traffic urban projects the 75 blow Marshall density values are to be used for density-void control as outlined in this Instructional Memorandum and for determining the density of compacted pavements as required by the specifications (high traffic urban situations shall be those exceeding 10,000 vehicles per day).

The 50 blow Marshall values shall be used for all other projects. Sand Mix Surface Courses. (Pen. or Visc. Graded Binder, and Emulsion Residue Binder). Density-void control is to be based on the special one (1) inch Marshall specimens compacted with 75 blows on one (1) specimen face.

D. Job Mix Formula Changes

1. Changes in Mix Characteristics.

As soon as the test data are available they should be compared with ranges of values found in the attached tables and with the original job mix data. In the event that the plant produced mixtures do not exhibit test characteristics which fall within the ranges found in the tables, the District Materials Engineer will order appropriate changes in the Job Mix Formula.

The District Materials Engineer may order changes even though the test results are within the ranges given providing that the quality of the mix will be improved with respect to durability or friction properties.

When changes are ordered for the foregoing reasons, the magnitude of the changes are to be limited such that adjusted mixtures will continue to exhibit test characteristics which fall within the ranges found in the tables. In each case, the properties of the aggregate and asphalt, projected traffic loadings and volumes, layer thickness, and service conditions shall be taken into account.

The tables contain two sets of design void ranges, one based on the Job Mix calculated solid specific gravity, and one based on the measured solid specific gravity using the procedure outlines in I.M. 340. Since the latter procedure utilizes tests on the actual plant mix rather than tests on preliminary aggregate samples, adjustments can be made on a rational basis. This approach should also be utilized when changes are noted in aggregate characteristics resulting from production adjustments or variation.

Each days percent of road density is determined daily comparing the densities of the road cores to the laboratory density of the first uncompacted mix box sample taken for the day's production from which the cores were taken.

Variations in compacted laboratory density and/or measured solid specific gravity of more than 0.020 shall be investigated promptly since these tests reflect changes in asphalt content, and aggregate properties and gradation. In some cases variations may be attributed to segregation, thoroughness of mixing, sampling procedure, and changes in aggregate production.

If the density variation for a given mix proportion exceeds ± 0.020 from the average of the previous day's tests without apparent reason, the investigation shall include the testing of the back up samples for that particular day's run. The average density of all samples tested for that day shall be used in determining roadway density compliance. If no backup sample is available, the density determination shall be averaged with the density of the previous day's run to determine density compliance.

If the second day's density variation for any particular mix exceeds ± 0.020 from the first day's test without apparent reason, then the backup samples shall be tested for the first day also, and averaged for each day.

2. Proportion Changes

The contractor must occasionally adjust aggregate proportions in order to consistently comply with the job mix formula target gradation tolerances and to correct for calibration errors. Proportion changes of 10 percent or less, for each material, may be approved without delaying operations for qualifying tests. Adjustments or interchanges exceeding 10 percent shall be evaluated before they are approved. Changes will be subject to the crushed particle and sand limitations, and mix design criteria.

3. Aggregate Changes

(a) The addition of new materials to job mix formula may be approved without central laboratory tests providing the materials are produced from geologically comparable sources, do not constitute more than 15 percent of the aggregate, meet quality requirements, and produce mixes that meet design criteria and specifications.

(b) When aggregates are introduced from sources that are not geologically comparable or otherwise differ significantly, complete laboratory testing is required.

4. Target Gradation Changes

Unusual aggregate gradation variation or degradation may cause the contractor to request that a new job mix formula target gradation be set using materials already on hand. Target gradation changes shall not be considered or approved until options under 2 and 3 above have been evaluated.

Resetting the target may also involve proportion interchanges and the introduction of a new aggregate. New target gradations together with proportion changes may be approved for future production when all design criteria and specifications limitations can be satisfied. Except for stability and A.C. film thickness, mixture characteristics can be predicted from tests on previous production; changes that may adversely affect stability should not be approved without central laboratory consultation. Compliance with film thickness criteria shall be determined by the following procedure:

Determination of Surface Area
(Refer to Form 955)

PROPOSED TARGET	1½	1	SIEVE ANALYSIS % PASSING									
			3/4	½	3/8	4	8	16	30	50	100	200
COMBINED GRADING			100	93	81	65	48	38	27	13	8.1	6.8
SURFACE AREA C.						.02	.04	.08	.14	.30	.60	1.60 TOTAL
S.A. SQ.FT./LB.					+2.0	1.30	1.92	3.04	3.78	3.90	4.86	10.88 31.68

Effective A.C. Content - Aggregate Basis

$$\text{Effective A.C. \%} = (\text{A.C. \% Mix}) - \frac{1/2\ (\text{\% Water Absorption*})(\text{\% Aggr in Mix})}{100}$$

*Refer to Job Mix Report.

Bitumen Index

$$\text{Bitumen Index} = \frac{(\text{Effective A.C. \%})}{100\ (\text{Surface Area})}$$

Film Thickness

$$\text{Film Thickness (Microns)} = (\text{Bitumen Index})\ (4870)$$

When significant aggregate characteristics change, e.g. Specific Gravity, and Absorption, or other variations are encountered, complete central laboratory tests are required. Field adjustments in job mix formulas must be supported by complete district laboratory testing. Modification of job mix formulas that exhibit borderline test characteristics, e.g. stability, voids, and film thickness, shall be approached with caution because some types of adjustments may result in unsatisfactory mixes.

TYPE A ASPHALTIC CONCRETE
LEVELING, BINDER, AND SURFACE COURSES
TABLE A

Test Value Guides for Plant Produced Mixtures

Mix Size	1"Mix	3/4" Mix	1/2" Mix	3/8" Mix
Mix Compacted in Laboratory			Average Values	
%Lab Air Voids (Min)		See Table F		
(Max)	6	6	6	6
(1) (2) (Calculated) Per I.M. 510				
%Lab Air Voids (Min)		See Table F		
(Max)	6	6	6	6
(1) (2) (Rice) Per I.M. 510				
%Voids in Mineral Aggr.(50 blow)	14	14.5	15	15.5
VMA (Min) (1) (75 blow)	13	13.5	14	14.5
A.C. Film Thickness (Min) (3)	7.0M	7.0M	7.0M	7.0M
A.C. Film Thickness (Min) (4)	6.5M	6.5M	6.5M	6.5M
Marshall Stability (lbs.) (Min)	1750	1750	1750	1750
Filler/Bitumen (5) Ratio (Max) Cold feed	1.20	1.20	1.20	1.20
Extraction (7)	1.30	1.30	1.30	1.30
Mix Compacted on Roadway				
%Lab Density (Min)			As Specified	
%Voids (Min-Max) (1) (2) avg. (6)	4-8	4-8	4-8	4-8

(1) Except when otherwise specified, mix proportions should be adjusted to exhibit test values in the ranges given. When conflicts develop, void criteria based on Rice Procedure shall govern (50 blow and 75 blow marshall mix design).
(2) Extreme caution should be exercised when mixtures exhibited average values near the lower limits and ADT exceeds 3000 VPD. (See Table F)
(3) Applies to wearing courses only, refer to job mix report for data. M=Microns)
(4) Applies to binder courses only, refer to job mix report for data. (M=Microns)
(5) Filler bitumen is the ratio of material passing the 200 mesh screen divided by percent of asphalt in the mix.
(6) Target lab voids prevail. Density may have to be increased to be within maximum field voids. General Specifications 2303.14 and Table "G." If conflicts develop between lab and field voids, see Table F.
(7) Only on projects where F/B is based on extractions.

TYPE B ASPHALTIC CONCRETE
LEVELING, BINDER, AND SURFACE COURSES
TABLE B

Test value Guides for Plant Produced Mixtures

Mix Size	1"Mix	3/4"Mix	1/2"Mix	3/8"Mix
Mix Compacted in Laboratory			Average Values	
%Lab Air Voids (Min)		See Table F		
(Max)	6	6	6	6
(1) (2) (Calculated) Per I.M. 510				
%Lab Air Voids (Min)		See Table F		
(Max)	6	6	6	6
(1) (2) (Rice) Per I.M. 510				
%Voids in Mineral Aggr. VMA (Min) (1)	14	14.5	15	15.5
A.C. Film Thickness (Min) (3)	7.0M	7.0M	7.0M	7.0M
A.C. Film Thickness (Min) (4) 6.5M	6.5M	6.5M	6.5M	
Marshall Stability (lbs.)	1500	1500	1500	1500
Filler/Bitumen (5) Ratio (max) Cold feed	1.20	1.20	1.20	1.20
Extraction (7)	1.30	1.30	1.30	1.30
Mix Compacted on Roadway				
%Lab Density (Min)			As Specified	
%Voids (Min-Max) (1) (2) Avg. (6)	3-8	3-8	3-8	3-8

(1) Except when otherwise specified, mix proportions should be adjusted to exhibit test values in the ranges given. When conflicts develop, void criteria based on Rice Procedure shall govern.
(2) Extreme caution should be exercised when mixtures exhibit average values near the lower limits and ADT exceeds 2000 VPD. (See Table F.)
(3) Applies to wearing courses only, refer to job mix report for date, (M=Microns)
(4) Applies to binder courses only, refer to lab mix report data. M=Microns.
(5) Filler/bitumen is the ratio of material passing the 200 mesh screen divided by percent of asphalt in the mix.
(6) Target lab voids prevail. Density may have to be increased to be within maximum field voids. General Specifications 2303.14 and Table "G." If conflicts develop between lab and field voids, see Table F.
(7) Any projects where F/B is based on extractions.

TYPE B ASPHALTIC CONCRETE
CLASS I AND II BASE COURSES
TABLE C

Test Value Guides for Plant Produced Mixtures

Class of Mixture		I	II
		Mix Compacted in Laboratory	Average Values
%Lab Air Voids (1) (2) (Min)		See Table F	
(Max)		6	6
(Calculated) Per I.M. 510			
%Lab Air Voids (1) (2) (Min)		See Table F	
(Max)		6	6
(Rice) Per I.M. 510			
%Voids in Miner Aggregate VMA (Min) (1)		14.5	14.5
A.C. Film Thickness (Min) (3)		7.0M	7.0M
A.C. Film Thickness (Min) (4)		6.5M	6.5M
Marshall Stability (Lbs.) (Min)		1500	1000
Filler/Bitumen Ratio (5) (Max.)	Cold feed	1.20	1.20
	Extraction (7)	1.30	1.30
Mix Compacted on Roadway			
%Lab Density (Min)		As Specified	
%Voids (Min-Max) (1) (2) Avg. (6)		3-8	3-8

(1) Except when otherwise specified, mix proportions should be adjusted to exhibit test values in the ranges given. When conflicts develop, void criteria based on Rice Procedure should be given prime consideration.
(2) Extreme cautions should be exercised when mixtures exhibit average values near the lower limits and ADT exceeds 500 VPD (see Table F).
(3) Applies to wearing courses only, refer to job mix report for data. (M=Microns)
(4) Applies to lower courses only, refer to job mix report for data. (M=Microns)
(5) Filler bitumen is the ratio of material passing the 200 mesh screen divided by percent of asphalt in the mix.
(6) Target lab voids prevail. Density may have to be increased to be within maximum field voids. General Specifications 2303.14 and Table "G." If conflicts develop between lab and field voids, see Table F.
(7) Only on projects where F/B is based on extractions.

ASPHALT - SAND SURFACE COURSES
Table D

Test Value Guides for Plant Produced Mixtures Mix compacted in laboratory Average Values	
%Lab Air Voids (Min-Max) (1), (2) (Calculated) Per I.M. 510	6.5 - 9.5
%Lab Air Voids (Min-Max) (1) (2) (Rice) Per I.M. 510	6.5 - 9.5
Marshall Stability (lbs.) Min.	200

(1) Except when otherwise specified, mix proportions should be adjusted to exhibit test values in the ranges given. When conflicts develop, void criteria based on Rice Procedure shall govern.

(2) Extreme caution should be exercised when mixtures exhibited average values near the lower limits and ADT exceeds 2000 VPD.

ASPHALT TREATED BASE
Table E

Test Value Guides for Plant Produced Mixtures

Class of Mixture (2)	1	2
Filler/Bitumen Ratio (1) (Max.)		
Cold Feed	1.3	1.3
Extraction	1.5	1.5
A.C. Film Thickness (min.)	6.0M	6.0M

(1) The filler/bitumen ratio is the ratio of material passing the 200 mesh screen divided by percent of asphalt in the mix.

(2) Class I compaction max. field voids 8.0%

Iowa Department of Transportation
Office of Materials
Table F

Laboratory voids shall be controlled on the basis of traffic volumes. The following minimums are specified for field control and shall prevail unless a conflict develops between laboratory voids, pavement voids and the specified density. If conflicts do develop, a test strip shall be constructed to determine whether or not the compactive effort required is within reason. Any relief granted in the laboratory voids will be subject to a review of the test strip results and characteristics of the mix by the central office. The minimum voids, as determined by the laboratory job mix, will be targeted at 0.50% higher.

After October 1, except for Interstate mainline paving, the District Materials Engineer may adjust the minimum Laboratory Void Limit downward by as much as 0.25%. This authorization is contingent upon a thorough review of all mix characteristics and placement and compaction efforts. Any such change shall be documented and a copy of such documentation shall be copied to the Materials Engineer immediately.

	Traffic Volumes				
Course Position	75 Blow	50 Blow Marshall			
	≥10,000	5000-10,000	2000-5000	1000-2000	≤1000
Surface Course	3.5%	3.5%	3.5%	3.0%	2.5%
Binder Course	3.5%	3.5%	3.0%	3.0%	2.5%
Base Course (Upper 1/2±)	3.5%	3.5%	3.0%	3.0%	2.5%
Base Course (Lower 1/2±)	3.5%	3.5%	3.0%	3.0%	2.5%

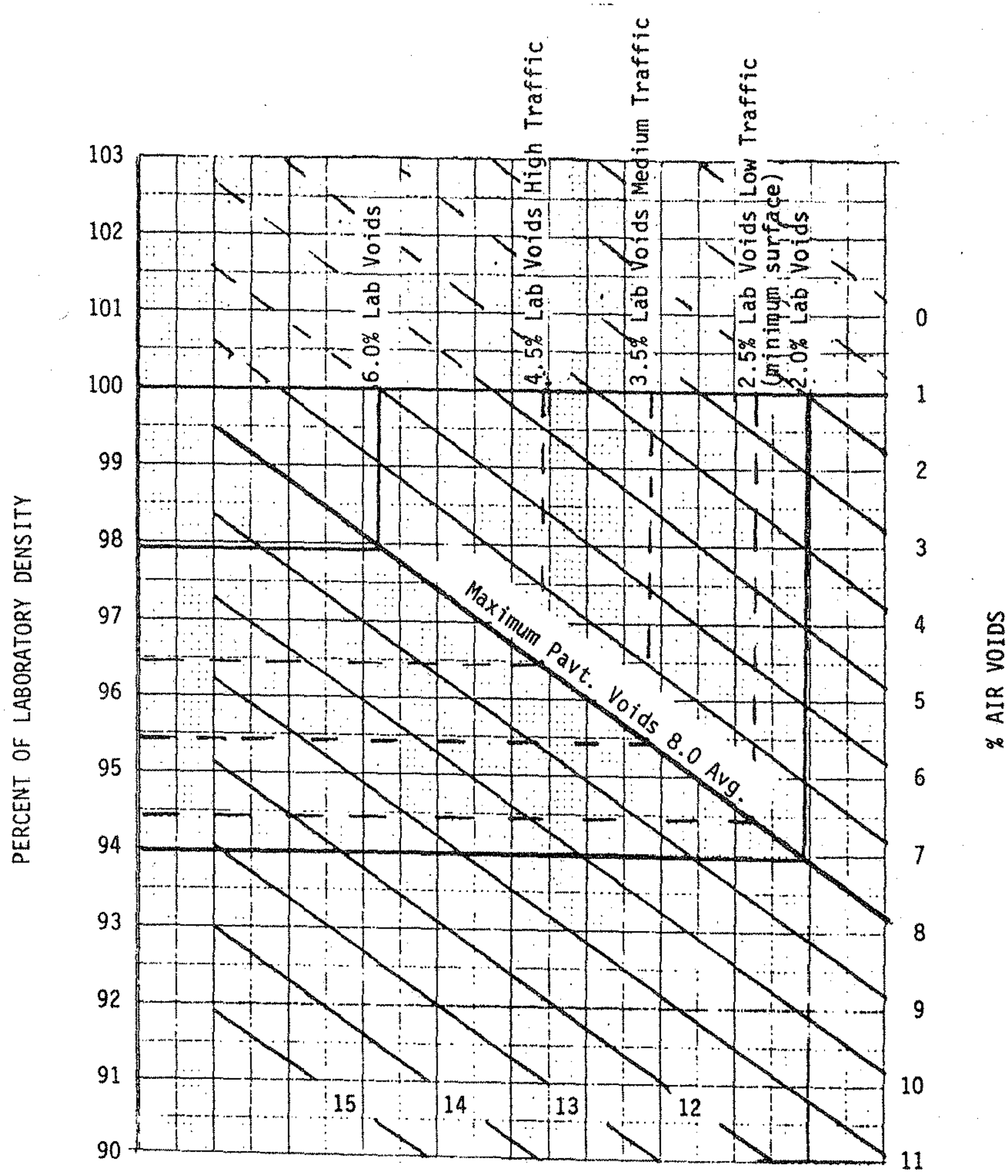
DENSITY VOID GRAPH
TABLE G

The Density Void Graph (Table G) can be used to demonstrate the relationship between laboratory voids, pavement voids and the required density. As an example, the minimum laboratory voids for a surface course with traffic volumes ranging from 2000-5000 VPD can be 3.5% (Table F). By referring to Table G., it can be shown what with laboratory voids of 3.5% at 100% density, it will be necessary to compact to a minimum of about 95.4% of laboratory density in order to assure a maximum of 8% pavement voids. Similarly, at 4.5% laboratory voids, the minimum density would be about 96.4%.

January 1988
Supersedes January 1987

Iowa Department of Transportation
Office of Materials

DENSITY-VOIDS GRAPH
TABLE G



Appendix C
Example of Effects on Aggregate Degradation on Mix properties

APPENDIX C
Effect of Average Aggregate Degradation on Mix Properties

This sample experienced a gradation increase of +0.8 on the No. 200 sieve and an increase in surface area of 1.84 ft^2. These numbers approximate the averages calculated for all 390 sample comparisons. This example demonstrates the effect of the average degradation on several of the mix properties.

Example: Polk Co. FN-163-1(40)--21-77

3/4" Type A Recycled Binder

Mix Design #ABD7-106

Contractor - Des Moines Asphalt

Sample Date 7-22-87

Bulk Sp. Gr. Comb. Dry Agg. 2.661

A.C. content - 4.70% intended

Water Absorption - 1.04%

SIEVE ANALYSIS - SURFACE AREA CALCULATION

	Percent Passing			Surface Area (sq.ft./lb.)			
	Cold Feed	Extraction	Diff.	Factor	Cold Feed	Extr.	Diff.
3/4"	100	100	0				
1/2"	91	91	0	+2.0	+2.0	+2.0	0
3/8"	75	77	2.0				
No. 4	62	62	0	.02	1.24	1.24	0
No. 8	51	50	-1.0	.04	2.04	2.00	-.04
No. 16	41	39	-2.0	.08	3.28	3.12	-.16
No. 30	28	27	-1.0	.14	3.92	3.78	-.14
No. 50	12	13	+1.0	.30	3.60	3.90	+.30
No. 100	6.7	7.7	+1.0	.60	4.02	4.62	+.60
No. 200	5.1	5.9	+0.8	1.60	8.16	9.44	+1.28
		Total Surf. Area ($ft.^2$/lb)			28.26	30.10	1.84

Effective A.C. Content - Aggregate Basis

$$\text{Effective A.C.\%} = (\text{A.C. \% Mix}) - \frac{1/2\ (\%\ \text{Water Absorption})(\%\text{Aggr. in Mix})}{100}$$

$$\text{Effective A.C. \%} = 4.7 - \frac{1/2\ (1.04)(95.3)}{100} = 4.20\%$$

Bitumen Index

$$\text{Bitumen Index} = \frac{(\text{Effective A.C.\%})}{100\ (\text{Surface Area})}$$

$$\text{Bitumen Index (Cold Feed)} = \frac{4.20}{100(28.26)} = 0.001486$$

$$\text{Bitumen Index (Extraction Grad.)} = \frac{4.20}{100(30.10)} = 0.001395$$

Film Thickness

Film Thickness (microns) = (Bitumen Index) (4870)

Film Thickness (Cold Feed) = (.001486)(4870) = 7.24 microns
Film Thickness (Extraction) = (.001395)(4870) = 6.79 microns

$\therefore$ Film Thickness decreases by 0.45 microns due to aggregate degradation.

Filler - Bitumen Ratio

Filler Bitumen (Cold Feed) $= \frac{5.1}{4.7} = 1.09$

Filler Bitumen (Extracted) $= \frac{5.9}{4.7} = 1.26$

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
ASPHALT CONCRETE MIX DESIGN
LAB LOCATION AMES

MIX, TYPE AND CLASS: TYPE A RECYCLED LAB NO. ABD7-106

INTENDED USE: BINDER

SIZE 3/4" SPEC. NO. 1030, 1036 DATE REPORTED 7/7/87

COUNTY POLK PROJECT FN-163-1(40)--21-77

CONTRACTOR DES MOINES ASPHALT

PROJ. LOCATION FROM U.S. 65 TO HUBBEL & FROM E. 33RD CT. TO 4 MILE CREEK

AGG. SOURCES CR. LST. - MARTIN MARIETTA, AMES MINE, STORY, CO.; CHIPS MARTIN MARIETTA, FERGUSON, MARSHALL CO.; SAND - HALLETT, E.D.M.; POLK CO.; MILLINGS @ 5.46% - PROJECT

JOB MIX FORMULA AGGREGATE PROPORTIONS: 25% AAT7-611; 25% AAT7-612; 30% AAT7-613 20% ABC7-121

JOB MIX FORMULA - COMBINED GRADATION

1-1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.200
	100	88	74	59	49	40	27	12	7.1	5.3	
TOLERANCE:	98/100	7	7	7	5		4				2*

% ASPHALT ADDED	3.41	4.41	5.41
ASPHALT SOURCE AND APPROXIMATE VISCOSITY	KOCH - 1100 POISES		
PLASTICITY INDEX			
ASPH. IN MIX	4.5	5.5	6.5
NUMBER OF MARSHALL BLOWS	75	75	75
MARSHALL STABILITY - LBS.	3347	2503	1837
FLOW - 0.01 IN.	7	9	13
SP.GR. BY DISPLACEMENT(LAB DENS.)	2.384	2.398	2.396
BULK SP. GR. COMB. DRY AGG.	2.659	2.659	2.659
SP. GR. ASPH. @ 77 F.	1.032	1.032	1.032
CALC. SOLID SP.GR.	2.513	2.476	2.440
% VOIDS - CALC.	5.13	3.14	1.79
RICE SP. GR.	2.496	2.456	2.420
% VOIDS - RICE	4.49	2.36	0.99
% WATER ABSORPTION - AGGREGATE	1.04	1.04	1.04
% VOIDS IN THE MINERAL AGGREGATE	14.38	14.78	15.75
% V.M.A. FILLED WITH ASPHALT	64.33	78.76	88.66
CALCULATED ASPH.FILM THICKNESS(MICRONS)	7.13	9.02	10.94
FILLER/BITUMEN RATIO		1.13	

A CONTENT OF 4.7% ASPHALT IS RECOMMENDED TO START THE JOB. THIS IS AN ADD. 3.61% AC10. *ALSO CONTROLLED BY FILLER/BITUMEN RATIO.
NUC. CAL.: TEMP = 205; WT - 7300; SLOPE = 4.59; I'CEPT = (-4.71)

COPIES:
ASPHALT MIX DESIGN
FN-163-1(40)--21-77, POLK
R. MUMM
P. MCGUFFIN
R. MONROE
J. SMYTHE
D. HEINS
DES MOINES ASPHALT
W. OPPEDAL

SIGNED: ORRIS J. LANE, JR.
TESTING ENGINEER

D. Heaw

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

COUNTY: POLK PROJECT NO.: FN-163-1(40)--21-77 DATE: 06-30-1987

PROJECT LOCATION: SEE PROPOSAL

TYPE OF MIX: A CLASS OF MIX: COURSE: BINDER (Recycled) MIX SIZE: 3/4"

CONTRACTOR: DES MOINES ASPHALT TRAFFIC: 15100 A.D.T.

MATERIAL	IDENT #	% IN MIX	PRODUCER & LOCATION
3/4" CR. LMST	1MT7-231	25	MART. MARIETTA AMES SW-24-84-24 STORY
3/4"CLEAN LMST	1MT7-232	25	MART. MAR. FERGUSON SW-5-82-17 MARSHALL
SAND	1MT7-233	30	HALLETT EDM SE-18-78-23 POLK
ACC MILLINGS	1MT7-183	20	HWY 163 MILLINGS

TYPE AND SOURCE OF ASPHALT CEMENT: BITUMINOUS MATERIALS TAMA

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
3/4" CR. LMST	100	100	100	89	71	46	33	25	22	15	11	8.0
3/4"CLEAN LMST	100	100	100	65	30	8.0	1.5	1.0	0.9	0.8	0.8	0.6
SAND	100	100	100	100	100	99	92	76	44	9.5	1.1	0.5
ACC MILLINGS	100	100	100	98	95	80	65	52	39	25	19	15

PRELIMINARY JOB MIX FORMULA TARGET GRADATION

TOLERANCE			98/100	7	7	7	5		4			2
COMB GRADING	100	100	100	88	74	59	49	40	27	12	7.1	5.3
SURFACE AREA C.	TOTAL					0.02	0.04	0.08	0.14	0.30	0.60	1.60
S.A. SQ. FT./LB.	28.34				+2.0	1.2	2.0	3.2	3.7	3.5	4.2	8.5

PRODUCTION LIMITS FOR AGGREGATES APPROVED BY THE CONTRACTOR/PRODUCER

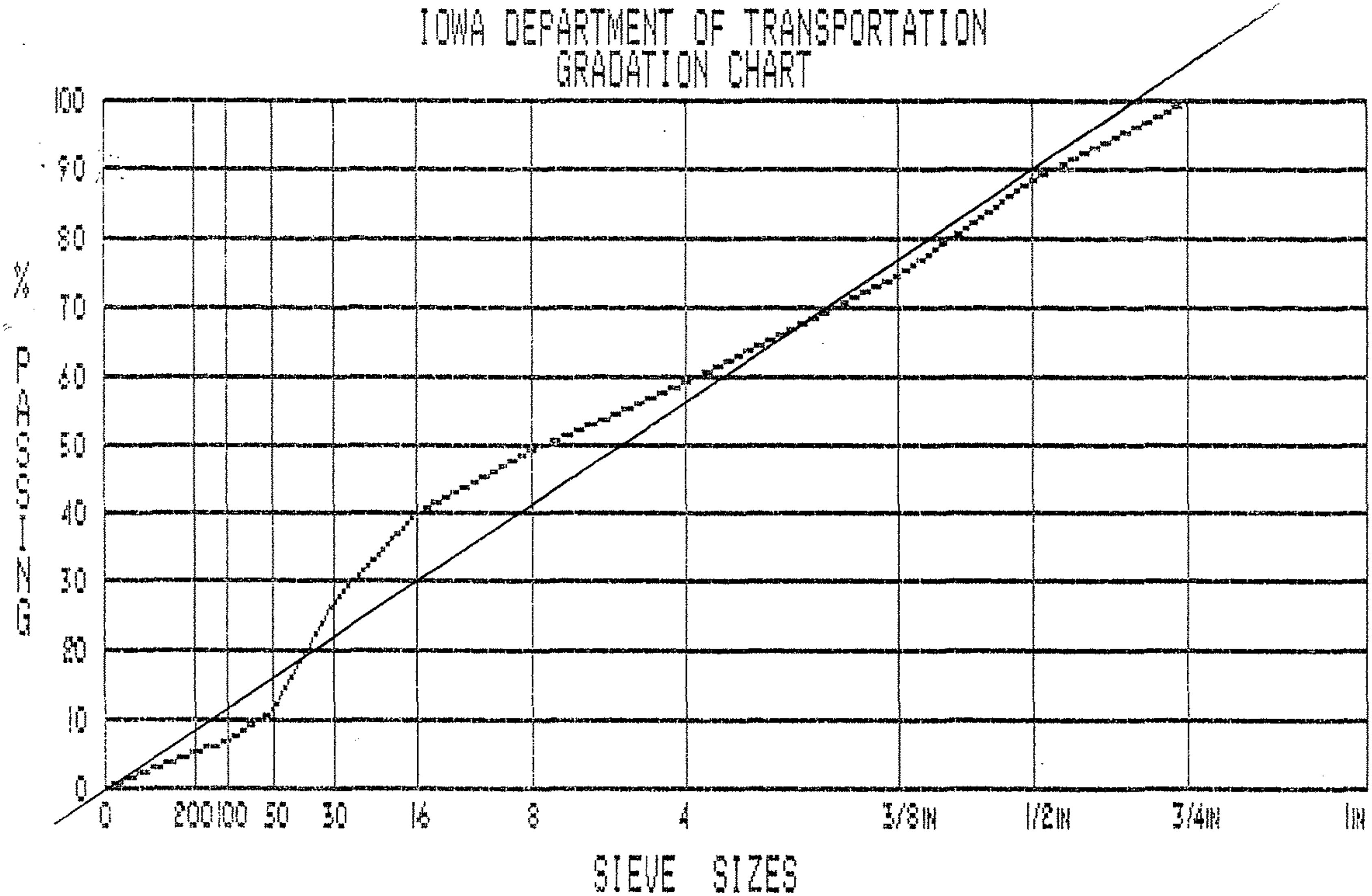
SIEVE SIZE	25.0% 3/4" CR. LMST MIN	MAX	25.0% 3/4"CLEAN LMST MIN	MAX	30.0% SAND MIN	MAX	20.0% ACC MILLINGS MIN	MAX	MIN	MAX
1"	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
3/4"	98.0	100.0	98.0	100.0	100.0	100.0	100.0	100.0		
1/2"	82.0	94.0	58.0	70.0	100.0	100.0	91.0	100.0		
3/8"	64.0	76.0	23.0	35.0	100.0	100.0	88.0	100.0		
#4	39.0	51.0	1.0	13.0	92.0	100.0	73.0	87.0		
#8	28.0	37.0	0.0	6.0	87.0	97.0	60.0	70.0		
#30	19.0	25.0	0.0	4.0	40.0	48.0	35.0	43.0		
#200	6.0	9.5	0.0	2.0	0.0	2.0	13.0	17.0		

COMMENTS: SPECS 1030 AND 1036. ON 163 IN DES MOINES. APPROX 3000 TONS
SECOND MIX DESIGN. AMES LMST IS 23-26.

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

Signed Bob Goodhue
Contractor/Producer

Signed Richard F. Munn
Dist. Mat'ls. Engr.



PROJECT NO.: FN-163-1(40)--21-77
TYPE OF MIX: A

MIX SIZE: 3/4"
CLASS OF MIX:

Asph. Conc.
R. Mumm
R. Monroe
D. Heins

Form 820257
6-83

FORM 257
20M 4-71

Iowa Department of Transportation

Materials Department

AMES LABORATORY

TEST REPORT — BITUMINOUS MATERIALS

Material 3/4" Type A Recycled Binder **Laboratory No.** ABC8-24

Intended Use Cold Feed Research

Project No. Dept. INfo. **County** Polk

Contractor Des Moines Asphalt

Producer

Plant Cedar Rapids Batch W/Baghouse

Unit of Material FN-1 3-1(40)--21-77 ABD7-106

Sampled by Jensen **Sender's No.** 3 of 3

Date Sampled 7-22-87 **Date Rec'd** 1-6-88 **Date Reported** 1-14-88

SIEVE ANALYSIS — PER CENT PASSING

	1½"	1"	3/4"	1/2"	3/8"	No. 4	No.8	No. 16	No. 30	No. 50	No. 100	No. 200
			100	91	77	62	50	39	27	13	7.7	5.9
Cold Feed			100	91	75	62	51	41	28	12	6.7	5.1

% Aggregate - By Extraction 94.96
% Bitumen - By Extraction 5.04
% Water
% Volatile

Specimens molded & tested @ 77° F.
Marshall Stability, lbs.
Flow, 0.01 Inches
Specific Gravity
After 8 cycles of F&T Specimens molded @ 40° F. & tested @ 77° F.
Marshall Stability, lbs.
Flow, 0.01 Inches
Specific Gravity

Percent Asphalt Intended 4.70 (Add 3.61)
Percent Asphalt Tank Stick 3.80
Percent Asphalt Dist 1 Nuclear 4.95
Percent Asphalt Cent. Lab Nuclear 4.89

DISPOSITION:

By Chris J. Lane Jr.
Testing Engineer

Appendix D
Results of 1986 Cold Feed vs Extraction Study

Appendix D – Results of 1986 Cold Feed vs Extraction Study

Project Number	Yr. Let	Contractor	Mixer &	Dust Control	Mix Size	Gradation Type	Sieve No 3/4	Diff.	Sieve No 1/2	Diff.	Sieve No 3/8	Diff.	Sieve No 4	Diff.	Sieve No 8	Diff.	Sieve No 16	Diff.	Sieve No 30	Diff.	Sieve No 50	Diff.	Sieve No 100	Diff.	Sieve No 200	Diff.	Number of Samples
															Gradation Data												
FN-410-1-/1/-21-22	84	MATHY CONSTR	Drum	Scrubber	1/2	Comb.			99.6		91.3		69.5		55.0		44.5		32.2		18.2		11.8		8.0		6
FN-410-1-/1/-21-22	84	MATHY CONSTR	Drum	Scrubber		Ext.			99.4	-0.2	91.2	-0.1	70.0	0.5	55.6	0.6	45.0	0.5	32.2	0.0	17.8	-0.4	11.8	0.0	7.7	-0.3	5
FN-410-1-/1/-21-22	84	MATHY CONSTR	Drum	Scrubber	3/4	Comb.	99.8		87.6		76.5		59.2		48.3		40.0		28.7		16.0		10.2		6.7		6
FN-410-1-/1/-21-22	84	MATHY CONSTR	Drum	Scrubber		Ext.	99.8	0.0	88.2	0.6	77.6	1.1	60.4	1.2	49.6	1.3	41.1	1.1	29.4	0.7	16.3	0.3	10.4	0.2	6.9	0.2	5
FN-9-4-/31/-21-32	84	ROHLIN	Drum	Scrubber	1/2	Comb.			94.4		79.2		56.9		47.7		36.1		26.1		15.3		5.3		4.0		19
FN-9-4-/31/-21-32	84	ROHLIN	Drum	Scrubber		Ext.			95.3	1.5	83.7	4.5	64.3	7.4	53.5	5.8	40.1	4.0	28.8	2.7	17.0	1.7	8.8	3.5	6.8	2.8	24
FN-9-4-/31/-21-32 Emmett	84	ROHLIN	Drum	Scrubber	3/4	Comb.	99.9		93.3		77.9		55.6		46.1		32.6		20.4		9.8		4.7		3.9		37
FN-9-4-/31/-21-32	84	ROHLIN	Drum	Scrubber		Ext.	99.9	0.0	95.6	2.3	83.1	5.2	64.3	8.7	52.7	6.6	38.6	6.0	25.5	5.1	14.7	4.9	8.6	3.9	6.9	3.0	39 Recycle.
FN-18-6-/21/-21-34	83	CARLSON	Drum	Scrubber	1/2	Comb.			100.0		93.3		72.0		55.0		42.0		30.0		17.0		9.7		6.6		3
FN-18-6-/21/-21-34	83	CARLSON	Drum	Scrubber		Ext.			100.0	0.0	93.9	0.6	73.9	1.9	55.6	0.6	42.4	0.4	30.3	0.3	16.7	-0.3	9.6	-0.1	6.1	-0.5	4
FN-64-2-/20/-21-49	82	CESSFORD	Drum	Scrubber	1/2	Comb.			99.4		87.6		61.2		46.8		37.0		26.6		14.4		7.9		5.4		5
FN-64-2-/20/-21-49	82	CESSFORD	Drum	Scrubber		Ext.			99.5	0.1	89.0	1.4	63.0	1.8	48.0	1.2	38.0	1.0	28.0	1.4	16.0	1.6	9.0	1.1	6.3	0.9	2
FN-64-2-/20/-21-49	82	CESSFORD	Drum	Scrubber	1/2	Comb.			99.2		88.5		63.8		50.2		40.4		29.3		15.6		8.2		5.5		19
FN-64-2-/20/-21-49	82	CESSFORD	Drum	Scrubber		Ext.			99.2	0.0	89.3	0.8	65.2	1.4	50.9	0.7	41.1	0.7	30.4	1.1	16.7	1.1	8.9	0.7	6.2	0.7	8
FN-64-2-/20/-21-49 Jackson	82	CESSFORD	Drum	Scrubber	3/4	Comb.	98.8		85.3		68.8		44.9		33.4		27.1		20.9		13.8		8.6		5.8		16
FN-64-2-/20/-21-49	82	CESSFORD	Drum	Scrubber		Ext.	100.0	1.2	87.8	2.5	71.9	3.1	48.1	3.2	34.9	1.5	28.3	1.2	22.4	1.5	15.1	1.3	9.7	1.1	6.9	1.1	15
FN-64-2-/20/-21-49	82	CESSFORD	Drum	Scrubber	3/4	Comb.	99.4		86.3		69.9		45.6		33.3		26.5		20.1		12.6		7.7		5.3		40
FN-64-2-/20/-21-49	82	CESSFORD	Drum	Scrubber		Ext.	100.0	0.6	89.5	3.2	74.0	4.1	50.3	4.7	36.9	3.6	29.5	3.0	23.0	2.9	15.1	2.5	9.5	1.8	6.7	1.4	22
FN-169-8-/24/-21-55	82	H.HODGMAN & SON	Drum	Scrubber	3/8	Comb.					99.7		87.2		69.8		49.1		31.2		17.5		10.6		7.8		20
FN-169-8-/24/-21-55	82	H.HODGMAN & SON	Drum	Scrubber		Ext.					99.7	0.0	85.6	-1.6	67.3	-2.5	47.7	-1.4	30.2	-1.0	15.2	-2.3	8.5	-2.1	6.1	-1.7	12
FN-9-2-/10/-21-72	83	W. HODGMAN &SON	Drum	Scrubber	1/2	Comb.			99.2		90.8		71.4		55.2		40.5		26.8		14.4		9.2		7.7		19
FN-9-2-/10/-21-72	83	W. HODGMAN &SON	Drum	Scrubber		Ext.			99.3	0.1	90.7	-0.1	72.1	0.7	56.7	1.5	40.7	0.2	26.5	-0.3	13.5	-0.9	8.3	-0.9	6.8	-0.9	16
P-363-0-/3/-30-06	83	B.L.ANDERSON	Drum	Scrubber	1/2	Comb.			100.0		95.0		69.7		49.7		40.3		25.3		13.0		8.8		7.6		3
P-363-0-/3/-30-06	83	B.L.ANDERSON	Drum	Scrubber		Ext.			100.0	0.0	95.6	0.6	71.7	2.0	51.9	2.2	40.7	0.4	26.5	1.2	11.2	-1.8	6.7	-2.1	5.7	-1.9	3
P-363-0-/3/-30-06 Benton	83	B.L.ANDERSON	Drum	Scrubber	1/2	Comb.			100.0		95.6		74.0		54.7		44.0		26.7		13.3		9.4		8.4		3
P-363-0-/3/-30-06	83	B.L.ANDERSON	Drum	Scrubber		Ext.			100.0	0.0	96.5	0.9	74.3	0.3	53.5	-1.2	41.5	-2.5	26.3	-0.4	9.9	-3.4	6.2	-3.2	5.3	-3.1	4
SP-637-0-/2/-7C-61	82	HENNINGSEN	Drum	Scrubber	3/4	Comb.	100.0		98.5		89.5		70.0		55.5		43.0		30.0		12.8		7.7		6.8		2
SP-637-0-/2/-7C-61	82	HENNINGSEN	Drum	Scrubber		Ext.	100.0	0.0	98.5	0.0	91.0	1.5	71.2	1.2	55.4	-0.1	43.2	0.2	27.6	-2.4	11.6	-0.4	7.4	-0.3	6.2	-0.6	5
SP-637-0-/2/-7C-61	82	HENNINGSEN	Drum	Scrubber	3/4	Comb.	100.0		98.3		88.3		67.7		53.3		41.7		28.0		10.3		6.7		5.4		3
SP-637-0-/2/-7C-61	82	HENNINGSEN	Drum	Scrubber		Ext.	100.0	0.0	97.9	-0.4	90.4	2.1	70.5	2.8	54.9	1.6	41.6	-0.1	28.1	0.1	11.1	0.8	6.9	0.2	5.8	0.4	3
FR-218-8/14/-26-09	83	CARLSON	Drum	Scrubber	1/2	Comb.			100.0		90.4		64.1		46.0		35.1		22.3		9.9		7.0		6.1		7 Recycled
FR-218-8/14/-26-09	83	CARLSON	Drum	Scrubber		Ext.			100.0	0.0	90.7	0.3	64.1	0.0	45.4	-0.6	34.7	-0.4	22.3	0.0	10.6	0.7	7.5	0.5	6.7	0.6	6
FR-218-8/14/-26-09	83	CARLSON	Drum	Scrubber	1/2	Comb.			100.0		89.3		62.6		46.6		36.1		22.8		10.1		7.1		5.8		10
FR-218-8/14/-26-09	83	CARLSON	Drum	Scrubber		Ext.			100.0	0.0	90.2	0.9	62.6	0.0	44.3	-2.3	34.1	-2.0	22.4	-0.4	10.8	0.7	7.7	0.6	6.5	0.7	8
FR-218-8/14/-26-09	83	CARLSON	Drum	Scrubber	1/2	Comb.			100.0		92.8		66.4		49.2		38.4		26.4		12.8		7.3		5.8		5
FR-218-8/14/-26-09	83	CARLSON	Drum	Scrubber		Ext.			100.0	0.0	94.7	1.9	67.2	0.8	47.5	-1.7	36.9	-1.5	25.4	-1.0	12.9	0.1	7.8	0.5	6.3	0.5	6
FR-218-8/14/-26-09	83	CARLSON	Drum	Scrubber	3/4	Comb.	100.0		89.0		72.6		53.3		41.4		32.8		22.5		11.7		6.8		5.9		8
FR-218-8/14/-26-09	83	CARLSON	Drum	Scrubber		Ext.	100.0	0.0	91.3	2.3	76.1	3.5	55.0	1.7	40.9	-0.5	31.8	-1.0	22.1	-0.4	11.6	-0.1	6.8	0.0	5.8	-0.1	13
FR-30-8-/12/-26-16	84	RIVER CITY PAV.	Drum	Scrubber	1/2	Comb.			99.3		87.0		58.9		45.2		37.9		28.7		15.8		7.6		5.8		21
FR-30-8-/12/-26-16	84	RIVER CITY PAV.	Drum	Scrubber		Ext.			99.8	0.5	86.7	-0.3	59.3	0.4	44.6	-0.6	37.6	-0.3	28.4	-0.3	14.8	-1.0	6.9	-0.7	5.2	-0.6	21
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber	1/2	Comb.			100.0		92.5		71.0		51.5		37.0		23.5		12.0		7.2		6.3		2
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber		Ext.			100.0	0.0	94.0	1.5	71.0	0.0	50.5	-1.0	35.5	-1.5	23.0	-0.5	11.5	-0.5	6.7	-0.5	5.4	-0.9	2
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber	1/2	Comb.			92.7		80.3		57.2		40.3		30.3		21.7		13.2		8.5		6.8		6
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber		Ext.			91.8	-0.9	78.2	-2.1	53.8	-3.4	37.3	-3.0	28.7	-1.6	20.9	-0.8	13.0	-0.2	8.6	0.1	7.1	0.3	6
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber	1/2	Comb.			100.0		92.4		68.4		49.6		35.8		22.6		11.5		6.9		5.5		5
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber		Ext.			92.3	-7.7	82.5	-9.9	58.0	-10.4	42.5	-7.1	30.0	-5.8	21.0	-1.6	11.5	0.0	7.8	0.9	6.4	0.9	4
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber	3/4	Comb.	99.2		87.8		73.0		48.8		33.2		25.2		19.2		13.1		9.0		7.3		13
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber		Ext.	100.0	0.8	90.8	3.0	76.8	3.8	52.4	3.6	34.9	1.7	26.2	1.0	19.9	0.7	12.9	-0.2	8.7	-0.3	7.1	-0.2	17
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber	3/4	Comb.	100.0		87.0		73.8		54.6		40.8		32.4		23.8		15.8		10.6		8.5		5
FR-9-7-/22/-26-45	83	CARLSON	Drum	Scrubber		Ext.	100.0	0.0	89.0	1.0	74.8	1.0	54.8	0.2	40.0	-0.8	30.8	-1.6	23.3	-0.5	14.5	-1.3	9.3	-1.3	7.4	-1.1	4
FR-30-7-/69/-26-57	84	RIVER CITY PAV.	Drum	Scrubber	1/2	Comb.			99.4		86.6		57.9		44.1		37.1		28.3		15.8		7.6		5.9		16
FR-30-7-/69/-26-57	84	RIVER CITY PAV.	Drum	Scrubber		Ext.			99.7	0.3	86.8	0.2	58.8	0.9	43.7	-0.4	36.9	-0.2	28.1	-0.2	14.1	-1.7	6.6	-1.0	4.9	-1.0	17
FR-9-6-/25/-26-98	82	ROHLIN CONSTR.	Drum	Scrubber	1/2	Comb.			99.8		90.1		70.1		55.3		42.2		26.2		13.3		8.8		6.5		28
FR-9-6-/25/-26-98	82	ROHLIN CONSTR.	Drum	Scrubber		Ext.			99.9	0.1	91.7	1.6	70.3	0.2	54.1	-1.2	40.6	-1.6	25.4	-0.8	12.1	-1.2	7.5	-1.3	5.3	-1.2	25
FR-9-6-/25/-26-98	82	ROHLIN CONSTR.	Drum	Scrubber	3/4	Comb.	99.0		89.2		77.3		61.4		49.2		38.1		24.8		13.4		8.8		6.5		20
FR-9-6-/25/-26-98	82	ROHLIN CONSTR.	Drum	Scrubber		Ext.	100.0	1.0	90.7	1.5	79.4	2.1	63.5	2.1	49.6	0.4	37.6	-0.5	24.7	-0.1	12.8	-0.6	8.1	-0.7	5.8	-0.7	17
HES-4-3-/9/-2H-13	84	ROHLIN CONSTR.	Drum	Scrubber	1/2	Comb.			99.8		89.8		69.0		51.4		36.8		22.8		11.0		7.0		4.9		5
HES-4-3-/9/-2H-13 Calhoun	84	ROHLIN CONSTR.	Drum	Scrubber		Ext.			100.0	0.2	90.1	0.3	68.7	-0.3	52.5	1.1	38.1	1.3	24.1	1.3	12.5	1.5	8.6	1.6	6.4	1.5	3
HES-4-3-/9/-2H-13	84	ROHLIN CONSTR.	Drum	Scrubber	3/4	Comb.	100.0		95.0		85.7		70.5		55.0		40.0		23.5		9.5		5.0		4.1		4
HES-4-3-/9/-2H-13	84	ROHLIN CONSTR.	Drum	Scrubber		Ext.	100.0	0.0	98.0	3.0	89.1	3.4	73.5	3.0	58.2	3.2	43.6	3.6	27.2	3.7	14.0	4.5	9.4	3.6	7.2	3.1	1
HES-4-3-/9/-2H-13	84	ROHLIN CONSTR.	Drum	Scrubber	3/4	Comb.	99.5		94.4		87.5		74.4		61.2		46.0		27.6		11.7		6.8		5.0		16
HES-4-3-/9/-2H-13	84	ROHLIN CONSTR.	Drum	Scrubber		Ext.	99.5	0.0	94.7	0.3	87.1	-0.4	72.6	-1.8	59.3	-1.9	44.8	-1.2	27.8	0.2	13.4	1.7	8.4	1.6	6.3	1.3	16
HES-18-3-/39/-2H-74	82	ROHLIN CONSTR.	Drum	Scrubber	1/2	Comb.			100.0		89.7		72.9		61.1		44.4		26.4		12.3		7.0		5.3		7
HES-18-3-/39/-2H-74	82	ROHLIN CONSTR.	Drum	Scrubber		Ext.			99.7	-0.3	88.4	-1.3	65.1	-7.8	53.7	-7.4	39.3	-5.1	25.1	-1.3	12.3	0.0	7.6	0.6	6.0	0.7	6
F-18-2-/39/-20-21	82	ROHLIN CONSTR.	Drum	Scrubber	1/2	Comb.			100.0		90.4		68.3		51.4		37.9		25.7		14.8		8.9		7.1		16
F-18-2-/39/-20-21	82	ROHLIN CONSTR.	Drum	Scrubber		Ext.			98.6	-1.4	90.2	-0.2	69.8	1.5	54.3	2.9	39.7	1.8	27.0	1.3	16.3	1.5	9.9	1.0	7.7	0.6	23
F-60-2-/9/-20-84	82	ROHLIN CONSTR.	Drum	Scrubber	1/2	Comb.			100.0		90.6		71.5		56.5				27.7						7.5		15
F-60-2-/9/-20-84	82	ROHLIN CONSTR.	Drum	Scrubber		Ext.			99.9	-0.1	93.0	2.4	75.3	3.8	60.6	4.1			29.7	2.0					8.5	1.0	19
FN-188-1-/5/-21-12	84	RIVERCITY PAV.	Drum	Scrubber	3/4	Comb.	100.0		100.0		91.0		69.4		56.0		43.6		27.0		11.6		8.2		7.4		5
FN-188-1-/5/-21-12	84	RIVERCITY PAV.	Drum	Scrubber		Ext.	100.0	0.0	98.8	-1.2	91.2	0.2	70.3	0.9	55.1	-0.9	42.5	-1.1	25.3	-1.7	10.8	-0.8	6.5	-1.7	5.6	-1.8	7
FN-188-1-/5/-21-12	84	RIVERCITY PAV.	Drum	Scrubber	3/4	Comb.	99.8		92.2		80.6		63.9		50.1		38.2		23.3		9.8		6.9		5.8		16
FN-188-1-/5/-21-12	84	RIVERCITY PAV.	Drum	Scrubber		Ext.	99.8	0.0	93.2	1.0	82.6	2.0	64.6	0.7	49.5	-0.6	37.3	-0.9	22.4	-0.9	9.8	0.0	6.6	-0.3	5.5	-0.3	13
FN-71-8-/10/-21-21	83	ROHLIN	Drum	Scrubber	1/2	Comb.			93.5		83.1		59.8		45.2		35.6		25.4		14.8		8.3		5.1		5
FN-71-8-/10/-21-21 Clay	83	ROHLIN	Drum	Scrubber		Ext.			95.8	2.3	86.8	3.7	65.3	5.5	50.0	4.8	38.1	2.5	28.0	2.6	16.6	1.8	9.3	1.0	6.6	1.5	9
FN-71-8-/10/-21-21	83	ROHLIN	Drum	Scrubber	1/2	Comb.			99.4		87.1		50.1		38.6		31.6		23.4		12.8		5.3		3.1		17
FN-71-8-/10/-21-21	83	ROHLIN	Drum	Scrubber		Ext.			98.9	-0.5	87.6	0.5	58.0	7.9	45.0	6.4	35.6	4.0	26.4	3.0	16.2	3.4	8.9	3.6	6.2	3.1	13 Recycle.
FN-13-3-/30/-21-22	84	MATHY CONTR.	Drum	Scrubber	1/2	Comb.			100.0		89.0		68.0		54.5		44.5		30.5		16.0		9.9		6.9		2
FN-13-3-/30/-21-22	84	MATHY CONTR.	Drum	Scrubber		Ext.			100.0	0.0	92.0	3.0	71.9	3.9	57.3	2.8	46.9	2.4	32.6	2.1	16.8	0.8	10.7	0.8	7.2	0.3	3
FN-13-3-/30/-21-22	84	MATHY CONTR.	Drum	Scrubber	3/4	Comb.	99.0		98.2		77.2		62.5		52.8		43.5		29.8		15.3		9.5		6.6		4
FN-13-3-/30/-21-22	84	MATHY CONTR.	Drum	Scrubber		Ext.	99.2	0.2	91.5	-6.7	80.4	3.2	64.0	1.5	52.6	-0.2	43.4	-0.1	30.0	0.2	16.2	0.9	10.6	1.1	7.1	0.5	8
FN-128-1-/5/-21-22	84	MATHY	Drum	Scrubber	1/2	Comb.			99.1		89.8		69.0		56.1		46.0		31.9		16.8		10.8		7.5		8
FN-128-1-/5/-21-22	84	MATHY	Drum	Scrubber		Ext.			99.1	0.0	91.6	1.8	70.2	1.2	55.4	-0.7	45.2	-0.8	31.3	-0.6	16.2	-0.6	10.0	-0.8	7.0	-0.5	8
FN-128-1-/5/-21-22	84	MATHY	Drum	Scrubber	3/4	Comb.	99.6				77.3		61.1		50.1		41.1		28.5		14.9		9.5		6.6		28
FN-128-1-/5/-21-22	84	MATHY	Drum	Scrubber		Ext.	99.5	-0.1			80.6	3.3	63.3	2.2	50.8	0.7	41.7	0.6	29.2	0.7	16.0	1.1	10.3	0.8	6.8	0.2	33
FN-52-1-/38/-21-49	85	Cessford	Drum	Scrubber	3/4	Comb.	99.4		91.0		81.0		62.5		49.8		38.5		27.7		14.7		9.4		6.2		6
FN-52-1-/38/-21-49	85	Cessford	Drum	Scrubber		Ext.	100.0	0.6	92.0	1.0	82.2	1.2	64.3	1.8	48.3	-0.7	38.3	-0.2	27.5	-0.2	14.3	-0.4	8.8	-0.6	5.8	-0.4	6
FN-18-6-/19/-21-34	85	River City	Drum	Scrubber	1/2	Comb.			99.5		90.2		63.8		46.8		33.5		21.5		12.8		9.2		7.4		4
FN-18-6-/19/-21-34	85	River City	Drum	Scrubber		Ext.			100.0	0.5	93.2	3.0	64.5	0.7	45.5	-0.5	32.5	-1.0	21.8	0.3	12.0	-0.8	9.1	-0.1	7.4	0.0	4
				Mean of Differences --				0.25		0.19		1.28		1.30		0.44		0.08		0.45		0.33		0.30		0.22	Drum scrubber
				Std. Dev. of Differences --				0.40		1.99		2.33		3.26		2.82		2.18		1.52		1.61		1.50		1.31	

1986 work

Project Number	Yr. Let	Contractor	Mixer	Dust Control	Mix Size	Gradation Type	Sieve No 3/4	Diff.	Sieve No 1/2	Diff.	Sieve No 3/8	Diff.	Sieve No 4	Diff.	Sieve No 8	Diff.	Sieve No 16	Diff.	Sieve No 30	Diff.	Sieve No 50	Diff.	Sieve No 100	Diff.	Sieve No 200	Diff.	Number of Samples	
EACIR-80-1-/139/-27-0C7	83	HENNINGSEN	Drum	Baghouse	1/2	Comb.			98.4		81.8		54.3		39.5		30.5		23.0		9.6		6.5		6.0		17	
EACIR-80-1-/139/-27-0C7	83	HENNINGSEN	Drum	Baghouse		Ext.			98.9	0.5	82.7	0.9	56.3	2.0	40.4	0.9	30.4	-0.1	22.6	-0.4	10.6	1.0	7.6	1.1	6.7	0.7	24	
IR-80-1-/149/-27-12-78	84	HENNINGSEN	Drum	Baghouse	1/2	Comb.			99.5		88.5		66.0		49.8		37.5		26.0		12.8		7.5		6.2		4	
IR-80-1-/149/-27-12-78	84	HENNINGSEN	Drum	Baghouse		Ext.			99.2	-0.3	88.3	-0.2	64.7	-1.3	48.8	-1.0	36.7	-0.8	25.7	-0.3	12.5	-0.3	6.9	-0.6	5.5	-0.7	10	
IN-80-1-/143/-27-15-78	83	HENNINGSEN CONT	Drum	Baghouse	3/4	Comb.	97.7		97.2		77.2		57.5		44.0		35.0		27.3		11.5		7.7		7.0		4	
IN-80-1-/143/-27-15-78	83	HENNINGSEN CONT	Drum	Baghouse		Ext.	99.7	2.0	92.0	4.8	81.5	4.3	62.0	4.5	47.8	3.8	38.3	3.3	29.5	2.2	12.3	0.8	8.4	0.7	7.3	0.3	4	
IN-80-1-/143/-27-15-78	83	HENNINGSEN CONT	Drum	Baghouse	3/4	Comb.	98.6		93.3		80.3		58.0		44.7		36.0		27.7		10.8		7.0		6.4		3	
IN-80-1-/143/-27-15-78	83	HENNINGSEN CONT	Drum	Baghouse		Ext.	100.0	1.4	96.5	3.2	83.5	3.2	60.5	2.5	46.0	1.3	36.0	0.0	27.5	-0.2	12.5	1.7	8.3	1.3	7.2	0.8	2	
FR-4-3-/?/-26-13	83	FORT DODGE ASPH	Drum	Baghouse	3/4	Comb.	99.9		95.3		87.0		72.1		57.4		42.6		24.9		9.5		5.4		3.9		12	
FR-4-3-/?/-26-13	83	FORT DODGE ASPH	Drum	Baghouse		Ext.	100.0	0.1	95.1	-0.2	86.1	-0.9	69.2	-2.9	55.0	-2.4	40.7	-1.9	24.4	-0.5	11.2	1.7	7.2	1.8	5.3	1.4	21	
FR-4-3-/?/-26-13	83	FORT DODGE ASPH	Drum	Baghouse	3/4	Comb.	99.8		94.3		87.3		72.5		57.5		43.3		27.3		12.9		8.3		6.2		4	
FR-4-3-/?/-26-13	83	FORT DODGE ASPH	Drum	Baghouse		Ext.	100.0	0.2	94.9	0.6	85.1	-2.2	68.4	-4.1	54.6	-2.9	40.4	-2.9	24.7	-2.6	11.3	-1.6	7.2	-1.1	5.3	-0.9	18	
FR-18-7-/31/-26-19	83	CESSFORD	Drum	Baghouse	1/2	Comb.			100.0		95.6		68.5		48.0		37.2		25.3		12.8		8.1		6.8		12	
FR-18-7-/31/-26-19	83	CESSFORD	Drum	Baghouse		Ext.			100.0	0.0	94.9	-0.7	68.7	0.2	48.1	0.1	37.0	-0.2	26.0	0.7	13.1	0.3	8.2	0.1	6.5	-0.3	9	
EACF-34-1-/49/-2K-65	83	HENNINGSEN	Drum	Baghouse	1/2	Comb.			98.1		88.9		64.7		44.8		35.8		27.0		12.4		6.9		5.8		19	
EACF-34-1-/49/-2K-65	83	HENNINGSEN	Drum	Baghouse		Ext.			98.1	0.0	89.8	0.9	66.0	1.3	45.4	0.6	36.4	0.6	27.2	0.2	12.9	0.5	7.4	0.5	6.4	0.6	43	
FN-107-2-/6/-21-17	84	MATHY CONSTR.	Drum	Baghouse	1/2	Comb.			99.5		90.5		72.3		57.2		44.0		29.8		15.3		8.5		6.5		6	
FN-107-2-/6/-21-17	84	MATHY CONSTR.	Drum	Baghouse		Ext.			99.5	0.0	91.1	0.6	72.2	-0.1	56.2	-1.0	43.3	-0.7	30.0	0.2	15.5	0.2	8.7	0.2	6.5	0.0	9	
FN-18-7-/36/-21-19	83	CESSFORD	Drum	Baghouse	1/2	Comb.			100.0		90.6		69.1		50.8		37.9		25.9		13.1		7.7		6.3		12	
FN-18-7-/36/-21-19	83	CESSFORD	Drum	Baghouse		Ext.			99.8	-0.2	92.5	1.9	70.1	1.0	51.4	0.6	39.3	1.4	27.4	1.5	13.9	0.8	8.5	0.8	7.0	0.7	10	
FN-18-7-/36/-21-19	83	CESSFORD	Drum	Baghouse	3/4	Comb.	100.0		92.0		80.5		65.4		52.0		41.2		28.0		13.5		7.5		6.0		11	
FN-18-7-/36/-21-19	83	CESSFORD	Drum	Baghouse		Ext.	100.0	0.0	93.9	1.9	83.5	3.0	67.2	1.8	54.0	2.0	43.0	1.8	29.4	1.4	13.7	0.2	7.3	-0.2	6.1	0.1	15	
FN-52-2-/43/-21-31	84	MATHY CONSTR.	Drum	Baghouse	1/2	Comb.			99.3		88.6		58.7		43.7		35.0		27.7		19.3		12.0		7.2		3	
FN-52-2-/43/-21-31	84	MATHY CONSTR.	Drum	Baghouse		Ext.			99.4	0.1	87.4	-1.2	58.5	-0.2	43.6	-0.1	35.1	0.1	27.8	0.1	19.4	0.1	12.1	0.1	7.4	0.2	8	
FN-52-2-/43/-21-31	84	MATHY CONSTR.	Drum	Baghouse	3/4	Comb.	100.0		96.9		87.3		60.5		45.1		36.1		28.2		18.7		10.8		6.3		12	
FN-52-2-/43/-21-31	84	MATHY CONSTR.	Drum	Baghouse		Ext.	99.9	-0.1	96.4	-0.5	86.3	-1.0	60.5	0.0	45.4	0.3	36.4	0.3	28.5	0.3	18.8	0.1	10.9	0.1	6.5	0.2	17	
FN-52-2-/43/-21-31	84	MATHY CONSTR.	Drum	Baghouse	3/4	Comb.	99.7		91.5		77.5		60.3		47.8		38.5		30.3		19.0		10.7		5.9		4	
FN-52-2-/43/-21-31	84	MATHY CONSTR.	Drum	Baghouse		Ext.	100.0	0.3	93.0	1.5	78.5	1.0	60.9	0.6	48.5	0.7	39.4	0.9	30.8	0.5	19.9	0.9	11.3	0.6	6.6	0.7	3	
FN-275-1-/14/-21-36	84	HENNINGSEN	Drum	Baghouse	1/2	Comb.			99.8		88.8		65.1		48.8		37.5		26.3		13.4		7.6		6.1		8	
FN-275-1-/14/-21-36	84	HENNINGSEN	Drum	Baghouse		Ext.			100.0	0.2	88.2	-0.6	63.6	-1.5	46.4	-2.4	35.7	-1.8	26.0	-0.3	13.3	-0.1	7.9	0.3	6.6	0.5	9	
FN-275-1-/14/-21-36	84	HENNINGSEN	Drum	Baghouse	3/4	Comb.	100.0		100.0		88.5		64.7		48.9		37.6		25.7		13.3		7.5		6.0		7	
FN-275-1-/14/-21-36	84	HENNINGSEN	Drum	Baghouse		Ext.	100.0	0.0	99.8	-0.2	88.8	0.3	64.0	-0.7	46.8	-2.1	36.2	-1.4	26.0	0.3	13.5	0.2	7.8	0.3	6.5	0.5	10	
FN-3-3/23/-21-46	83	MANATTS INC.	Drum	Baghouse	1/2	Comb.			100.0		89.8		66.0		49.0		35.3		22.0		10.8		6.1		4.3		7	
FN-3-3/23/-21-46	83	MANATTS INC.	Drum	Baghouse		Ext.			99.2	-0.8	90.9	1.1	67.5	1.5	49.1	0.1	35.3	0.0	23.0	1.0	12.5	1.7	7.7	1.6	5.9	1.6	8	
FN-3-3/23/-21-46	83	MANATTS INC.	Drum	Baghouse	3/4	Comb.	100.0				85.6		65.7		52.0		41.3		26.7		13.0		7.9		6.2		3	
FN-3-3/23/-21-46	83	MANATTS INC.	Drum	Baghouse		Ext.	100.0	0.0			90.3	4.7	72.7	7.0	57.7	5.7	45.8	4.5	29.3	2.6	13.3	0.3	7.9	0.0	6.1	-0.1	6	
FN-3-3/23/-21-46	83	MANATTS INC.	Drum	Baghouse	3/4	Comb.	100.0		94.2		84.4		65.3		52.0		40.9		26.7		11.3		6.6		5.0		7	
FN-3-3/23/-21-46	83	MANATTS INC.	Drum	Baghouse		Ext.	100.0	0.0	94.8	0.6	84.3	-0.1	65.7	0.4	51.5	-0.5	40.8	-0.1	27.7	1.0	12.6	1.3	7.9	1.3	6.2	1.2	5	
FN-150-1-/26/-21-57	84	CESSFORD CONSTR	Drum	Baghouse	1/2	Comb.			99.2		93.3		69.9		52.0		41.4		29.1		13.8		7.6		5.6		9	
FN-150-1-/26/-21-57	84	CESSFORD CONSTR	Drum	Baghouse		Ext.			99.1	-0.1	92.8	-0.5	69.6	-0.3	52.1	0.1	41.7	0.3	29.8	0.7	15.0	1.2	8.6	1.0	6.5	0.9	10	
FN-150-1-/26/-21-57	84	CESSFORD CONSTR	Drum	Baghouse	3/4	Comb.	100.0				93.3		70.1		51.9		41.3		28.6		13.3		7.1		5.1		8	
FN-150-1-/26/-21-57	84	CESSFORD CONSTR	Drum	Baghouse		Ext.	100.0	0.0			93.2	-0.1	70.3	0.2	52.1	0.2	41.5	0.2	28.9	0.3	13.6	0.3	7.4	0.3	5.4	0.3	8	
FN-63-3-/35/-21-62	84	MANATTS	Drum	Baghouse	1/2	Comb.			100.0		88.6		62.0		49.7				29.3						5.7		3	
FN-63-3-/35/-21-62	84	MANATTS	Drum	Baghouse		Ext.			98.7	-1.3	84.9	-3.7	63.0	1.0	51.0	1.3			29.9	0.6					5.7	0.0	5	
FN-63-3-/35/-21-62	84	MANATTS	Drum	Baghouse	1/2	Comb.			100.0		88.7		63.0		51.3				29.5						4.6		4	
FN-63-3-/35/-21-62	84	MANATTS	Drum	Baghouse		Ext.			99.8	-0.2	86.2	-2.5	65.4	2.4	51.0	-0.3			29.3	-0.2					5.3	0.7	7	
FN-63-3-/35/-21-62	84	MANATTS	Drum	Baghouse	3/4	Comb.	100.0				79.8		65.8		56.0				32.2						4.6		5	
FN-63-3-/35/-21-62	84	MANATTS	Drum	Baghouse		Ext.	100.0	0.0			79.2	-0.6	63.8	-2.0	54.0	-2.0			31.0	-1.2					4.7	0.1	4	
FN-34-4-/19/-21-88	83	CESSFORD CONSF.	Drum	Baghouse	3/4	Comb.	100.0		99.0		87.0		65.0		49.0		35.7		22.0		9.8		5.9		4.8		3	
FN-34-4-/19/-21-88	83	CESSFORD CONST.	Drum	Baghouse	3/4	Ext.	100.0	0.0	99.7	0.7	88.4	1.4	66.1	1.1	49.4	0.4	36.2	0.5	23.6	1.6	10.5	0.7	7.2	1.3	6.2	1.4	6	
FN-148-1-/5/-21-87	84	HENNINGSEN	Drum	Baghouse	1/2	Comb.			99.8		89.5		69.3		52.7				31.5						5.5		6	
FN-148-1-/5/-21-87	84	HENNINGSEN	Drum	Baghouse		Ext.			99.8	0.0	90.8	1.3	68.2	-1.1	52.2	-0.5			31.6	0.1					6.1	0.6	10	
FN-148-1-/5/-21-87	84	HENNINGSEN	Drum	Baghouse	3/4	Comb.	99.8				82.4		66.3		53.0				32.5						5.8		25	
FN-148-1-/5/-21-87	84	HENNINGSEN	Drum	Baghouse		Ext.	99.9	0.1			83.7	1.3	66.4	0.1	52.9	-0.1			32.4	-0.1					5.8	0.0	21	
FN-186-0-/1/-21-88	84	HENNINGSEN	Drum	Baghouse	3/4	Comb.	100.0				91.3		68.8		53.0		43.0		31.7		16.5		8.9		7.4		6	
FN-186-0-/1/-21-88	84	HENNINGSEN	Drum	Baghouse		Ext.	100.0	0.0			92.1	0.8	69.0	0.2	51.1	-1.9	40.4	-2.6	29.8	-1.9	15.0	-1.5	7.6	-1.3	6.2	-1.2	7	
FN-5-4-/14/-21-91	83	BROWER	Drum	Baghouse	1/2	Comb.			99.4		88.4		72.7		58.3				29.4						5.0		7	
FN-5-4-/14/-21-91	83	BROWER	Drum	Baghouse		Ext.			99.3	-0.1	88.8	0.4	72.0	-0.7	57.3	-1.0			32.5	3.1					7.2	2.2	5	
FN-92-9-/38/-21-92	84	NORRIS	Drum	Baghouse	3/4	Comb.	100.0				78.0		58.7		46.7				25.7						5.8		3	
FN-92-9-/38/-21-92	84	NORRIS	Drum	Baghouse		Ext.	100.0	0.0			89.6	11.6	62.4	3.7	46.3	-0.4			27.4	1.7					6.3	0.5	11	
FN-14-1-/6/-21-93	84	NORRIS CONSTR	Drum	Baghouse	1/2	Comb.			99.3		87.6		66.2		51.4				25.9						5.3		10	
FN-14-1-/6/-21-93	84	NORRIS CONSTR	Drum	Baghouse		Ext.			98.5	-0.8	87.9	0.3	65.9	-0.3	50.2	-1.2			26.1	0.2					6.2	0.9	13	
FN-14-1-/6/-21-93	84	NORRIS CONSTR	Drum	Baghouse	3/4	Comb.	99.0				76.5		58.9		46.3				23.9						5.3		8	
FN-14-1-/6/-21-93	84	NORRIS CONSTR	Drum	Baghouse		Ext.	99.0	0.0			77.5	1.0	59.6	0.7	46.2	-0.1			24.6	0.7					5.9	0.6	6	
SP-624-0-/2/-7C-08	83	DESMOINES ASPH.	Drum	Baghouse	3/4	Comb.	93.4		87.7		75.2		56.1		43.8		33.4		22.3		9.6		5.0		3.8		9	
SP-624-0-/2/-7C-08	83	DESMOINES ASPH.	Drum	Baghouse		Ext.	100.0	0.6	90.0	2.3	78.6	3.4	59.2	1.1	43.6	-0.2	33.1	-0.3	24.6	2.3	13.0	3.4	7.9	2.9	6.1	2.3	17	Boyle
SP-624-0-/2/-7C-08	83	DESMOINES ASPH.	Drum	Baghouse	3/4	Comb.	98.9		86.6		74.8		57.0		42.6		31.8		21.1		10.6		6.3		5.4		9	
SP-624-0-/2/-7C-08	83	DESMOINES ASPH.	Drum	Baghouse		Ext.	100.0	1.1	88.5	1.9	76.6	1.8	59.3	2.3	44.5	1.9	33.8	2.0	22.3	1.2	11.2	0.6	6.9	0.6	6.0	0.6	8	
FN-186-0-/1/-21-88	85	Henningson	Drum	Baghouse	1/2	Comb.			100.0		91.3		68.8		53.0		43.0		31.7		16.5		8.9		7.4		6	
FN-186-0-/1/-21-88	85	Henningson	Drum	Baghouse		Ext.			100.0	0.0	92.3	1.0	69.4	0.6	51.4	-1.6	40.6	-2.4	30.0	-1.7	14.8	-1.7	7.2	-1.7	5.8	-1.6	5	
FR-169-2-/16/-26-88	85	Henningson	Drum	Baghouse	3/4	Comb.	98.8		89.9		79.6		64.6		50.6		32.1		18.0		9.3		5.9		5.0		7	
FR-169-2-/16/-26-88	85	Henningson	Drum	Baghouse		Ext.	99.7	0.9	91.4	1.5	81.3	1.7	65.1	0.5	50.0	-0.6	37.3	5.2	22.0	4.0	9.6	0.3	6.3	0.4	5.5	0.5	7	
FR-169-2-/16/-26-88	85	Henningson	Drum	Baghouse	1/2	Comb.			93.0		90.6		70.2		52.2		37.2		20.6		9.3		5.9		5.0		5	
FR-169-2-/16/-26-88	85	Henningson	Drum	Baghouse		Ext.			93.2	0.2	91.8	1.2	71.2	1.0	51.8	-0.4	36.6	-0.6	21.0	0.4	9.0	-0.3	6.7	0.8	5.8	0.8	5	
FR-34-4-/21/-26-88	85	Henningson	Drum	Baghouse	1/2	Comb.			99.0		88.8		64.9		51.4		36.6		20.4		8.7		6.0		4.7		7	
FR-34-4-/21/-26-88	85	Henningson	Drum	Baghouse		Ext.			99.8	0.8	89.3	0.5	67.8	2.9	48.8	-2.6	35.0	-1.6	20.5	0.1	8.7	0.0	5.8	-0.2	5.0	0.3	6	
FR-34-4-/21/-26-88	85	Henningson	Drum	Baghouse	3/4	Comb.	99.6		91.0		82.2		67.0		51.8		38.2		21.4		9.5		6.0		4.7		8	
FR-34-4-/21/-26-88	85	Henningson	Drum	Baghouse		Ext.	99.5	-0.1	91.4	0.4	80.5	-1.7	63.2	-3.8	47.6	-4.2	35.4	-2.8	21.0	-0.4	8.8	-0.7	5.8	-0.2	5.0	0.3	8	
FN-144-3-/9/-21-37	85	Cessford	Drum	Baghouse	3/4	Comb.	99.4		95.4		88.4		70.0		54.7		42.1		30.3		17.2		9.4		6.6		10	Sizes 4 -
FN-144-3-/9/-21-37	85	Cessford	Drum	Baghouse		Ext.	99.2	-0.2	95.3	-0.1	88.1	-0.3	69.4	-0.6	54.5	-0.2	42.1	0.0	30.1	-0.2	17.9	0.7	9.1	-0.3	6.6	0.0	9	50, Combi
FN-144-3-/9/-21-37	85	Cessford	Drum	Baghouse	1/2	Comb.			100.0		95.2												9.4		6.6		10	
FN-144-3-/9/-21-37	85	Cessford	Drum	Baghouse		Ext.			100.0	0.0	95.5	0.3											9.1	-0.3	6.6	0.0	9	
FR-14-2-/15/-26-59	85	Des Moines Asphalt	Drum	Baghouse	1/2	Comb.			99.5		89.0		68.0		49.5				22.5						6.7		2	
FR-14-2-/15/-26-59	85	Des Moines Asphalt	Drum	Baghouse		Ext.			100.0	0.5	90.0	1.0	69.0	1.0	48.5	-1.0			23.0	0.5					5.8	-0.9	2	
FR-103-1-/6/-26-56	85	Cessford	Drum	Baghouse	3/4	Comb.	99.4				71.1		52.7		49.0				26.0						6.0		9	
FR-103-1-/6/-26-56	85	Cessford	Drum	Baghouse		Ext.	99.7	0.3			73.2	2.1	55.2	2.5	44.6	-4.4			26.8	0.8					6.6	0.6	8	
FR-103-1-/6/-26-56	85	Cessford	Drum	Baghouse	1/2	Comb.			98.5		85.5		54.5		43.8				24.5						7.6		4	
FR-103-1-/6/-26-56	85	Cessford	Drum	Baghouse		Ext.			99.3	0.8	89.2	3.7	60.8	6.3	47.5	3.7			27.0	2.5					5.7	-1.9	4	
						Mean of Differences --		0.17		0.41		0.92		0.72		-0.27		0.03		0.53		0.41		0.38		0.35		Drum Baghouse
						Std. Dev. of Differences --		0.44		1.00		2.36		2.17		1.90		1.89		1.27		1.01		0.91		0.83		