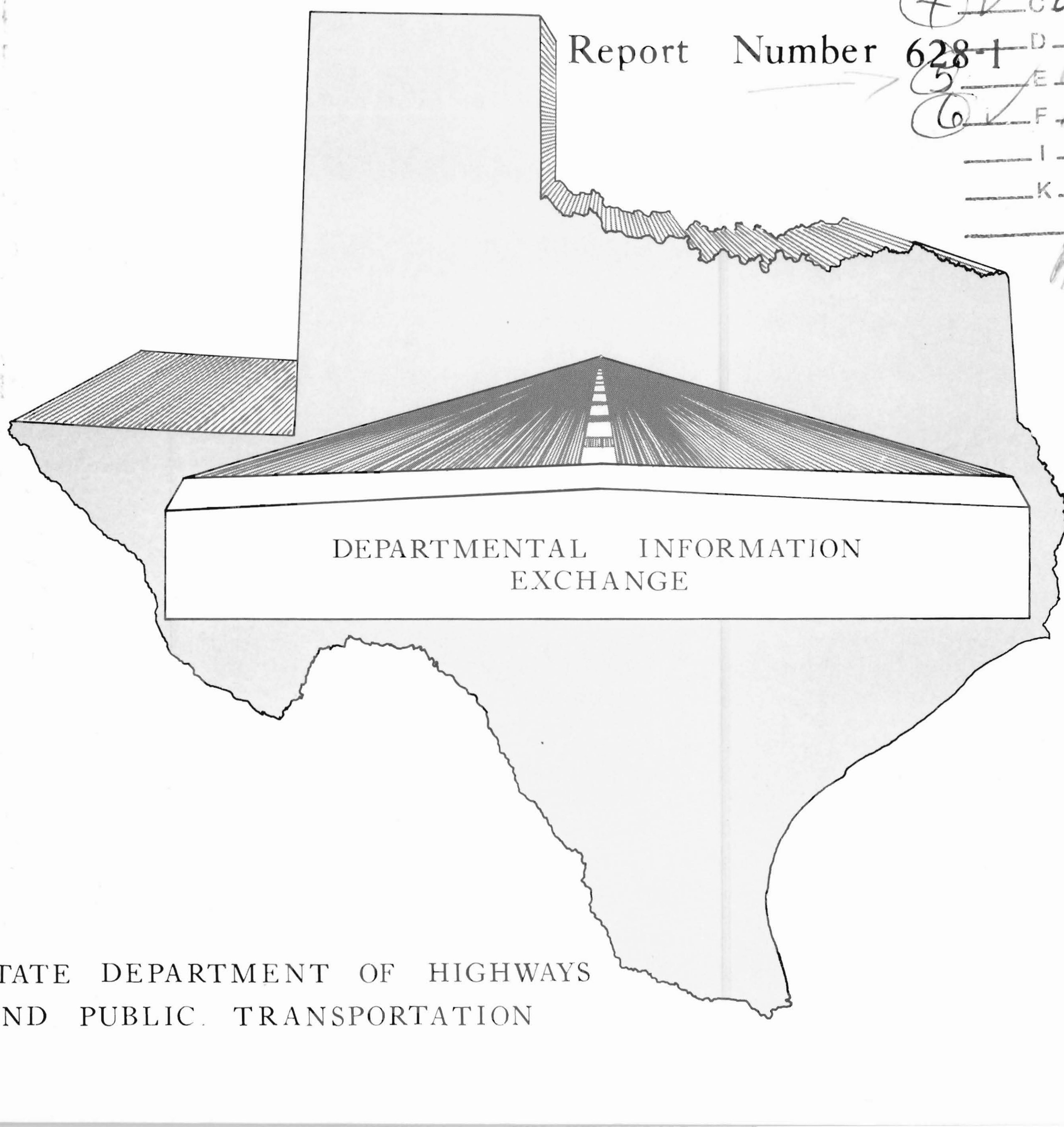
EXPERIMENTAL PROJECTS

FIELD EVALUATION OF BOTTOM ASH IN HOT MIX ASPHALTIC CONCRETE

Report Number 628-1



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AND PUBLIC TRANSPORTATION

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16. Abstract

Aggregate shortages and increased transportation costs have greatly increased prices of related construction items in areas of Texas not blessed with natural aggregates. Some natural aggregates are not performing up to expectations as documented by stripping, rutting and other visual signs of pavement distress noted throughout the Department. Because of these spiraling construction costs and need to field evaluate bottom ash, District 1, supported by the Materials and Tests Division, decided to construct three field test pavements substituting bottom ash for part of the natural aggregates in hot mix asphaltic concrete (HMAC). This report contains design and project control test results on material, pictorial presentation of the sites being constructed, and limited skid and traffic data on the bottom ash-gravel HMAC test sections.

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DISCLAIMER STATEMENT

The material in this report is experimental in nature, and is published for informational purposes only. Any discrepancies with official views or policies of the DHT should be discussed with the appropriate Austin Division prior to the implemenation of the procedures or results.

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

FIELD EVALUATION OF POWER PLANT BOTTOM ASH

IN HOT MIX ASPHALTIC CONCRETE

By

Robert E. Long, Materials & Tests Soils Engineer

&

Richard W. Floyd, Engineering Technician V

Aggregate shortages and increased transportation costs have greatly increased prices of related construction items in areas of Texas not blessed with natural aggregates. Some natural aggregates are not performing up to expectations as documented by stripping, rutting and other visual signs of pavement distress noted throughout the Department. Because of these spiraling construction costs and need to field evaluate bottom ash, District 1, supported by the Materials and Tests Division, decided to construct three field test pavements substituting bottom ash for part of the natural aggregates in hot mix asphaltic concrete (HMAC). This report contains design and project control test results on material, pictorial presentation of the sites being constructed, and limited skid and traffic data on the bottom ash-gravel HMAC test sections.

LABORATORY DESIGN RESULTS

The District 1 Laboratory completed an HMAC design using 45 percent bottom ash from the Monticello source blended with 55 percent siliceous gravel from Frogville, Oklahoma. Gradation results of this design are listed below in Table I.

TABLE I

HOT MIX ASPHALTIC CONCRETE DESIGN DATA

Sieve Size	Monticello Bottom Ash	Frogville Gravel	Design Grading	Item 340 Specifications (Type D)
1/2	0.0	0.0	0.0	0
3/8	1.6	5.0	3.5	0-5
4	7.4	72.7	43.3	20-50
10	13.8	21.8	18.2	10-30
40	31.5	0.3	14.4	0-30
80	23.5	0.1	10.6	4-25
200	16.4	0.1	7.4	3-25
-200	5.8	0.0	2.6	0-6

The Monticello bottom ash is deficient in large sizes, but is a well graded material from the No. 4 mesh sieve through the No. 200 mesh sieve sizes. This pit run gradation blends well with the poorly-graded Frogville gravel to produce a grading that meets the requirements of the Standard Specifications for Item 340, Type D.

Hveem specimens fabricated in the District 1 Laboratory and submitted to the Materials and Tests Division gave the following additional design data shown in Table II and presented graphically in Figure 1.

TABLE II

HVEEM PROCEDURE AVERAGE DESIGN DATA

Asphalt Content	Cohesiometer Value	Hveem Density	Hveem Stability
6.0	38	87.9	47
7.0	55	88.9	40
8.0	58	91.2	43
9.0	82	92.9	41
10.0	98	95.6	40

This mix produced low Hveem densities which is an indication of high void contents. Because of field experience with moisture-susceptible aggregates, these design Hveem specimens were subjected to wetting by the pressure pycnometer test method. This test method forces water into the Hveem specimen under 1200 psi pressure which is maintained for a minimum of 15 minutes. Results of this laboratory testing are shown in Figure 2. When an asphalt content is selected that holds moisture absorption under 5 percent, current experience indicates the mix will be less susceptible to stripping, shelling and other moisture-related problems causing poor performance.

Relatively high optimum asphalt contents are needed where bottom ash is used as the only aggregate. Because of costly increased asphalt contents and skid resistance of bottom ash blend mixes, the best use of bottom ash in asphaltic concrete pavement will be obtained when blended with natural aggregates.

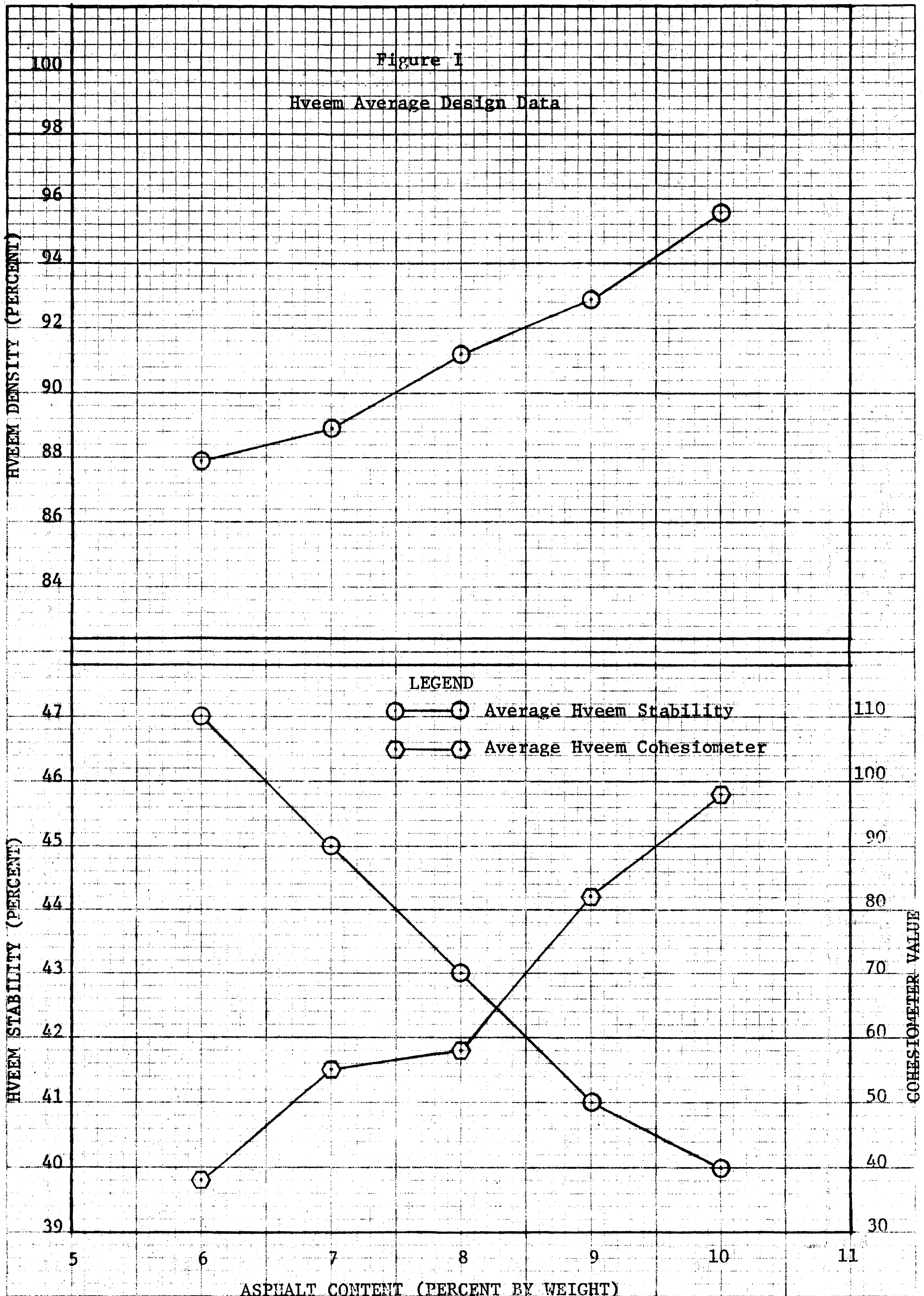


Figure I
Hveem Average Design Data
HVEEM DENSITY (PERCENT)
100
98
96
94
92
90
88
86
84
LEGEND
Average Hveem Stability
Average Hveem Cohesiometer
HVEEM STABILITY (PERCENT)
47
46
45
44
43
42
41
40
39
COHESIOMETER VALUE
110
100
90
80
70
60
50
40
30
5
6
7
8
9
10
11
ASPHALT CONTENT (PERCENT BY WEIGHT)

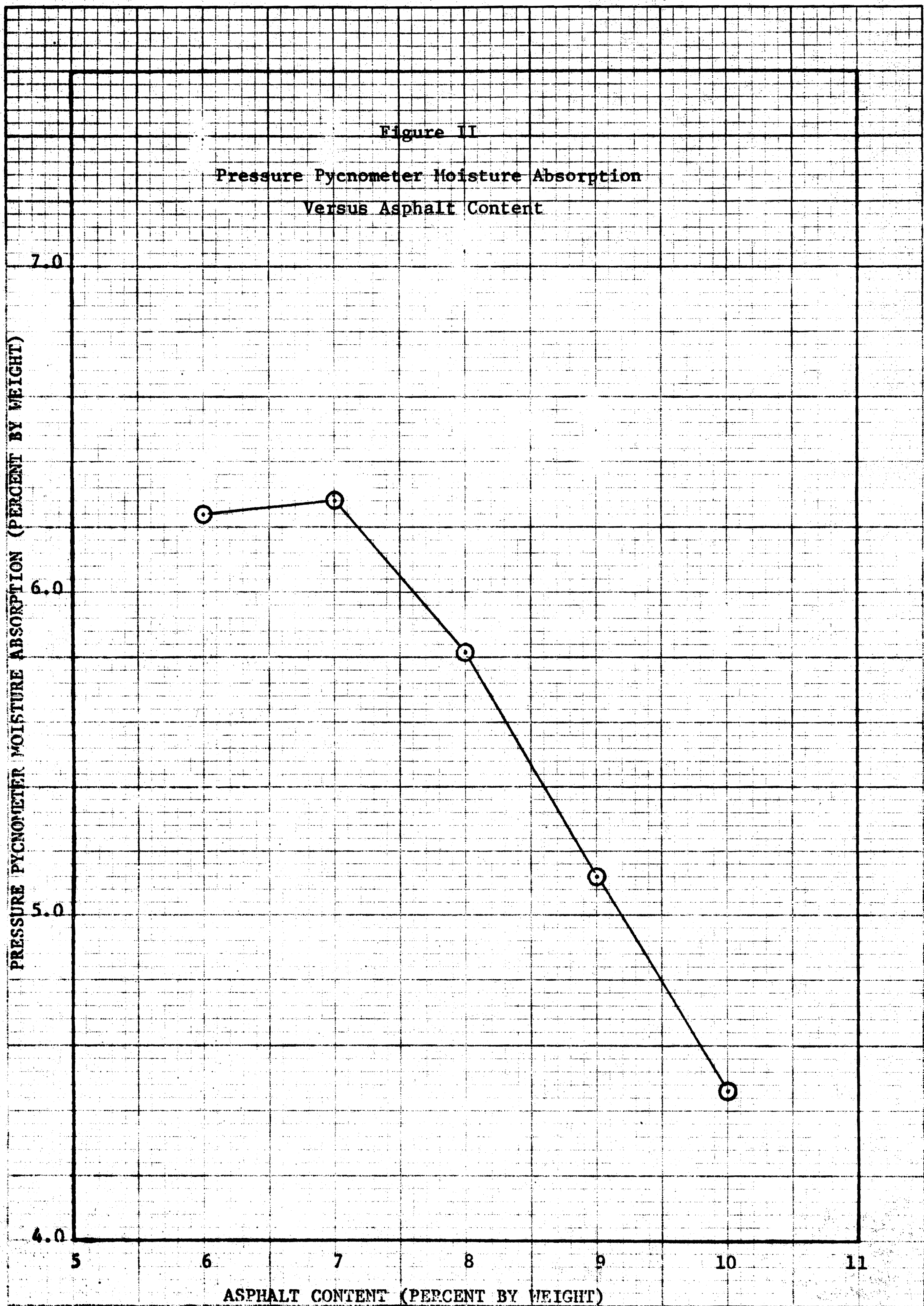


Figure II
Pressure Pycnometer Moisture Absorption
Versus Asphalt Content
PRESSURE PYCNOMETER MOISTURE ABSORPTION (PERCENT BY WEIGHT)
7.0
6.0
5.0
4.0
5
6
7
8
9
10
11
ASPHALT CONTENT (PERCENT BY WEIGHT)

Economic advantages of using bottom ash are reduced aggregate cost and less tonnage for the same depth. Current cost of bottom ash is approximately $3.00 per cubic yard loaded at the source. The above blended bottom ash design produced a Hveem specimen weighing 115 pcf at the optimum asphalt content. A flint gravel mix will normally weigh in excess of 140 pcf which results in a considerable weight advantage for bottom ash blends. Again, these economic advantages of bottom ash mixes are offset by increased cost of higher optimum asphalt content.

CONSIDERATIONS IN SELECTING TEST SITES

The Los Angeles Abrasion, Type A, for the Monticello source is 49 and its polish value is 43 (E79630421). Existing test methods and specifications developed for conventional aggregates often fall short of properly characterizing and evaluating coal-associated wastes (1). District 1 selected three highways for test strips in the Sulphur Springs area that had widely varying traffic. This allowed the bottom ash to be evaluated for wear performance under varying traffic instead of depending on the Los Angeles Abrasion test method, which might not be applicable for bottom ash aggregates. The mechanism of degradation in bottom ash materials by the Los Angeles abrasion machine is primarily a fracturing process rather than wear that produces fine-grained dust associated with natural aggregates.

Based on the above considerations, District 1 selected the following test sites to evaluate asphaltic concrete pavement made with bottom ash:

TABLE III

TEST SITE LOCATIONS

Test Site	County	Highway	Location
1	Hopkins	FM 1870	One mile SE of IH 30
2	Hopkins	SH 11	Four miles W of intersection with SH 19
3	Hopkins	IH 30	At MP 128.5 EBL in Sulphur Springs

CONSTRUCTION NOTES AND TEST DATA

District 1 built the three test sections during June 1980, with its Sulphur Springs Maintenance Forces, under the direction of Mr. Walter B. Darling.

A laydown machine was rented from the Contractor who produced the mix from the Netex Plant loacted at Sulphur Springs. The bottom ash used was pit run material without any prior screening or other preparation. All three test sites were located in the vicinity of Sulphur Springs.

Daily Construction Reports were completed on each test site and these are included in Annex A of this report. The asphalt content was varied to match existing pavement deflection and condition, with traffic also being a consideration.

Construction notes are included under appropriate photographs of each test site in Annex B. The following observations were made during the construction process:

1. Selection of the optimum asphalt content is less critical when using bottom ash blends than when using dense natural aggregates.

2. The voids in the bottom ash will provide an increased safety factor against bleeding and flushing caused by too much asphalt or higher traffic density than expected.

3. There was no lateral displacement of this bottom ash-gravel mix during compaction because of the internal friction of the mix.

4. The mix cools faster than a mix employing natural aggregates, therefore, the rolling should closely follow the laydown operation.

5. The bottom ash mix had a tendency to pickup, requiring diesel coated drums on the flat-wheel roller at the start of the break-down rolling.

POST CONSTRUCTION EVALUATION

Current traffic on the three bottom ash-gravel asphaltic concrete test sections were provided by the Transportation Planning Division and are listed in Table IV.

TABLE IV

CURRENT TRAFFIC ON THE THREE BOTTOM ASH-GRAVEL ASPHALTIC CONCRETE TEST SECTIONS IN DISTRICT 1

Highway	Control-Section	ADT
FM 1870	735-5	3,070
SH 11	83-2	2,820
IH 30	10-2	14,470

District 1 reports excellent service of the bottom ash-gravel asphaltic concrete to date. A short section on SH 11 has been patched, which maintenance personnel indicated would not hold during the construction operation because of an existing soft area.

Skid data taken on September 1, 1981, gave the following results listed in Table V:

TABLE V

SKID VALUES ON BOTTOM ASH-GRAVEL ASPHALTIC CONCRETE TEST SECTIONS IN DISTRICT 1

Highway	Control-Section	Lane Direction	Skid Number
FM 1870	735-5	S.B.	44
			42
		N.B.	51
			43
SH 11	83-2	W.B.	51
			40
		E.B.	42
			43
			41
IH 30	10-2	E.B.O.L.	38
		E.B.I.L.	46

This data indicates this mix will take 5,209,200 repetitions, 80 percent of present traffic being assumed in the eastbound outside lane of IH 30, and still maintain a skid value of 38 even though the second aggregate was a siliceous gravel.

If FM 1870 and SH 11 were subjected to the same type and kind of traffic that now exists on IH 30, it would be 4.7 and 5.1 years respectively, before their skid number would drop to 38 due to the polishing by tire wear.

These highways are subjected to much lighter wheel loads and it is anticipated that the reduction in skid number due to tire wear would be much slower. It can be concluded from this data, that bottom ash-gravel blends will perform on substantial mileage of the Department's highway system until the next surface course is required for reasons other than skid resistance.

BOTTOM ASH HOT MIX ASPHALTIC CONCRETE INVESTIGATIONS BY OTHER DISTRICTS

District 17 has vast experience with using the bottom ash produced by the Aluminum Company (ALCOA) near Rockdale in Milam County. This is a small, dense, dark bottom ash and District 17 has ceased using it in recent years because of poor surface drainage and night visibility. Other uses were also developed for this aggregate which made the supply questionable. Districts 10 and 15 have made laboratory investigations using bottom ash in hot mix asphaltic concrete designs.

CONCLUSIONS

1. That bottom ash blend mixes will require more asphalt than natural aggregates.

2. That bottom ash blend mixes will produce lower compacted density, pounds per cubic foot, than natural aggregates.

3. That bottom ash blend mixes have a wider range of optimum asphalt contents which increased the chance of obtaining a successful performing pavement course.

4. That bottom ash blend mixes will cool fast, requiring adequate rollers working closely behind the laying operation.

5. That bottom ash blend mixes exhibit high internal friction with no lateral displacement during compaction.

6. That bottom ash blend mixes tend to pickup and drums on breakdown rollers must be coated with diesel until the roller drum temperature increases.

7. That bottom ash blend mixes tend to increase skid values and this mix has maintained acceptable skid values after 14 months of interstate traffic.

8. That the Los Angeles machine wear is not a good indicator of performance of bottom ash when used in bituminous mixes.

9. That the cost of bottom ash blend mixes will be somewhat higher based on additional asphalt used and aggregate transportation costs.

SELECTED CONCLUSIONS DRAWN IN REFERENCE 1

1. That bottom ash-aggregate-asphalt mixtures of sufficient stability can be designed to meet current requirements for road construction.

2. That increasing the conventional aggregate content of a bottom ash mixture will not necessarily promote higher stability, although it does help reduce optimum asphalt content.

3. The experimental results of immersion-compression tests indicate that the moisture damage potential is not critical in these mixtures and that, in fact, there was an apparent increase in mixture stability due to the immersion process. The apparent bonding of the bottom ash aggregate particles and possible physico-chemical changes in the presence of moisture may be responsible for the improvement due to moisture. It was therefore concluded that bottom ash mixtures exhibit a high degree of resistance to moisture damage.

4. It has been concluded that the properties of most wet and dry bottom ashes can meet performance specifications for conventional aggregates and that these materials could be used successfully in one form or another.

RECOMMENDATIONS

1. That Districts with bottom ash production nearby, follow the District 1 procedure and use their District Laboratory to design a bottom ash blend and their Maintenance Forces to build test sections using this design. This will give the Department experience to fully evaluate the advantages and disadvantages of using such materials as a substitute aggregate.

2. That the Department continue to investigate new sources of bottom ash as lignite power plants come on line for highway construction aggregates by processing the new sources through the Aggregate Quality Monitoring Program.

REFERENCES

1. Mumtay Usmen, David A. Anderson and Lyle K. Moulton, "Applicability of Conventional Test Methods and Material Specifications to Coal-Associated Waste Aggregates." Transportation Research Board 691, page 50.

2. Report No. FHWA-RD-78-146, "Power Plant Bottom Ash in Black Base and Bituminous Surfacing," State of the Art Report.

3. Report No. FHWA-RD-78-147, "Power Plant Bottom Ash in Black Base and Bituminous Surfacing." Volume 1, Laboratory Investigation Results.

4. Report No. FHWA-RD-78-148, "Power Plant Bottom Ash in Black Base and Bituminous Surfacing," Volume 2, User's Manual.

ANNEX A

DAILY ROAD REPORTS ON
THREE BOTTOM ASH TEST SITES

Texas Highway Department
Construction Form No. 404 Rev. (2)

TEXAS HIGHWAY DEPARTMENT
DAILY CONSTRUCTION REPORT—ASPHALTIC CONCRETE PAVEMENT

County Hopkins Highway FM-1870 Project Req. 01-0-710L(1) Control 11953
Location of Plant Sulphur Springs Type of Plant Weigh batch Contractor Netex Plant
Date 6-4-80 Specification Item 340... Type D Plant Started ____ M. Plant Stopped ____ M.

Location No.							
1	Main Lane	3	Decel. Lane	5	Entr. Ramp	7	
2	Fr. Rd. Lane	4	Accel. Lane	6	Exit Ramp	8	

Sieve Size	Combined Bin Analysis: Design No. 1	1	2	3	4	5	6	7	8	Extractions: 1	2	3
1¾" - ⅞"												
⅞" - ⅝"												
1/2	0	0	0	0						0		
½" - ⅜"	5.2	5.1	5.8	5.5						4.3		
⅜" - 4	29.4	33.6	26.2	25.1						32.6		
¼" - 10												
4 - 10	19.6	21.6	22.2	21.9						12.9		
+ 10	54.2	60.3	54.2	52.5						49.8		
10 - 40	12.0	10.7	13.9	13.9						10.0		
40 - 80	8.7	6.1	8.4	8.4						12.1		
80 - 200	9.8	8.0	8.8	8.8						13.9		
Pass 200	5.3	4.9	4.7	4.7						6.7		
Asphalt	10.0	10.0	10.0	11.7						7.5		
Total	100.0	100.0	100.0	100.0						100.0		

Bin Analy. No.	Extr. No.	Time	Location No.	Course	of Courses	Station No.	Mix Temp. °F. Plant	Road	Specimen Nos.	Lab Dens.	% Stab.
1		1:40					325°				
2		2:10									
3		3:40									
	1	4:00							1-80-493	95.0	38

Materials Used	Asphalt (Tons)	Aggregate (Tons)
Previous Report	0.00	
This Report	48.29	
Total To Date	48.29	

Percent Complete-Asphaltic Concrete Pavement	
Percent Complete—This Type	%
Percent Complete—All Types	%

Days Run

Location No.	Course	of Courses	Station to Station	Width (Feet)	Rate of Application: Inches Lbs/Sq. Yd. Sq. Yds.	Tons	Inches Lbs/Sq. Yd. Sq. Yds.	Tons	Inches Lbs/Sq. Yd. Sq. Yds.	Tons
1			Test section located approximately one mile S. E. of IH-30 on FM-1870 in Hopkins Co.							
					Pea Gravel - Buster Matls., Frogville, Okla.					
					Bottom Ash - Monticello Plant, Mt. Pleasant, Texas					
					AC-20 Asph. - Dorchester, Mt. Pleasant, Texas					
Total Today										
Previous Report										
Total To Date										
Avg. Rate To Date						Lbs/Sq. Yd.		Lbs/Sq. Yd.		Lbs/Sq. Yd.

Weather Clear
Warm
Min. Temp. ____ °F.
Max. Temp. ____ °F.

Remarks Material composed of approximately 60% pea gravel and 40% bottom ash by weight.

Richard W. Floyd
Inspector

Type D Date 6-4-80 Report No. 1

Texas Highway Department
Construction Form No. 404 Rev. (2)

TEXAS HIGHWAY DEPARTMENT
DAILY CONSTRUCTION REPORT—ASPHALTIC CONCRETE PAVEMENT

County: Hopkins Highway: SH-11 Project: Req. 01-0-710L(1) Control: 11953
Location of Plant: Sulphur Springs Type of Plant: Weigh batch Contractor: Netex plant
Date: 6-5-80 Specification Item: 340... Type: D Plant Started: ____ M. Plant Stopped: ____ M.

Location No.							
1	Main Lane	3	Decel. Lane	5	Entr. Ramp	7	
2	Fr. Rd. Lane	4	Accel. Lane	6	Exit Ramp	8	

Sieve Size	Combined Bin Analysis: Design No. 2	1	2	3	4	5	6	7	8	Extractions: 1	2	3
1¾" - ⅞"												
⅞" - ⅝"												
1/2	0	0	0							0		
½" - ⅜"	5.2	3.9	6.0							3.5		
⅜" - 4	29.4	31.1	31.8							29.3		
¼" - 10												
4 - 10	19.6	22.5	22.0							16.3		
+ 10	54.2	57.5	59.8							49.1		
10 - 40	11.1	18.4	10.2							11.8		
40 - 80	8.6	6.1	6.9							12.7		
80 - 200	9.8	4.4	7.2							13.1		
Pass 200	4.3	1.6	3.9							5.0		
Asphalt	12.0	12.0	12.0							8.3		
Total	100.0	100.0	100.0							100.0		

Bin Analy. No.	Extr. No.	Time	Location No.	Course	of Courses	Station No.	Mix Temp. °F. Plant	Road	Specimen Nos.	Lab Dens.	% Stab.
1							300°				
2											
	1								1-80-501	99.0	35

Materials Used

	Asphalt (Tons)	Aggregate (Tons)
Previous Report	48.29	
This Report	102.46	
Total To Date	150.75	

Percent Complete-Asphaltic Concrete Pavement	
Percent Complete—This Type	%
Percent Complete—All Types	%

Days Run

Location No.	Course	of Courses	Station to Station	Width (Feet)	Rate of Application: Inches Lbs/Sq. Yd. Sq. Yds.	Tons	Inches Lbs/Sq. Yd. Sq. Yds.	Tons	Inches Lbs/Sq. Yd. Sq. Yds.	Tons
2			Test section located approximately four miles from the intersection of SH-19 and SH-11 on SH-11 in Hopkins County.							
					Pea Gravel - Buster Matls., Frogville, Okla.					
					Bottom Ash - Monticello Plant, Mt. Pleasant, Texas					
					AC-20 Asph. - Dorchester, Mt. Pleasant, Texas					

Weather: Clear Warm
Min. Temp. ____ °F.
Max. Temp. ____ °F.

	Sq. Yds.	Tons	Sq. Yds.	Tons	Sq. Yds.	Tons
Total Today						
Previous Report						
Total To Date						
Avg. Rate To Date		Lbs/Sq. Yd.		Lbs/Sq. Yd.		Lbs/Sq. Yd.

Remarks: Material composed of approximately 60% pea gravel and 40% bottom ash by weight.

Richard W. Floyd
Inspector

Type: D Date: 6-5-80 Report No. 2

Texas Highway Department
Construction Form No. 404 Rev. (2)

TEXAS HIGHWAY DEPARTMENT
DAILY CONSTRUCTION REPORT—ASPHALTIC CONCRETE PAVEMENT

County Hopkins Highway IH-30 Project Req. 01-0-710L(1) Control 11953
Location of Plant Sulphur Springs Type of Plant Weigh batch Contractor Netex plant
Date 6-6-80 Specification Item 340... Type D Plant Started ____ M. Plant Stopped ____ M.

Location No.								
	1	Main Lane	3	Decel. Lane	5	Entr. Ramp	7	
	2	Fr. Rd. Lane	4	Accel. Lane	6	Exit Ramp	8	

Sieve Size	Combined Bin Analysis: Design No. 3	1	2	3	4	5	6	7	8	Extractions: 1	2	3
1¾" - ⅞"												
⅞" - ⅝"												
1/2	0	0								0		
½" - ⅜"	5.2	3.7								1.8		
⅜" - 4	29.4	27.8								25.9		
¼" - 10												
4 - 10	19.6	23.1								20.0		
+ 10	54.2	54.6								47.7		
10 - 40	12.1	15.6								12.6		
40 - 80	8.6	7.6								12.9		
80 - 200	9.8	7.5								13.4		
Pass 200	4.3	3.7								5.3		
Asphalt	11.0	11.0								8.1		
Total	100.0	100.0								100.0		

Bin Analy. No.	Extr. No.	Time	Location No.	Course of Courses	Station No.	Mix Temp. °F. Plant	Road	Specimen Nos.	Lab Dens.	% Stab.
1						280°				
	1							1-80-503	91.7	44

Materials Used	Asphalt (Tons)	Aggregate (Tons)
Previous Report	150.75	
This Report	51.61	
Total To Date	202.36	

Percent Complete-Asphaltic Concrete Pavement	
Percent Complete—This Type	%
Percent Complete—All Types	%

Days Run

Location No.	Course of Courses	Station	to	Station	Width (Feet)	Rate of Application: ____ Inches Lbs/Sq. Yd. Sq. Yds.	Tons	____ Inches Lbs/Sq. Yd. Sq. Yds.	Tons	____ Inches Lbs/Sq. Yd. Sq. Yds.	Tons
3		Test section located mileage marker 128.5 E.B.L. on IH-30 in Hopkins Co.									
						Pea Gravel - Buster Matls., Frogville, Okla.					
						Bottom Ash - Monticello Plant, Mt. Pleasant, Texas					
						AC-20 Asph. - Dorchester, Mt. Pleasant, Texas					
					Total Today						
					Previous Report						
					Total To Date						
					Avg. Rate To Date	Lbs/Sq. Yd.		Lbs/Sq. Yd.		Lbs/Sq. Yd.	

Weather Clear
Warm
Min. Temp. ____ °F.
Max. Temp. ____ °F.

Remarks Material composed of approximately 60% pea gravel and 40% bottom ash by weight.

Richard W. Floyd
Inspector

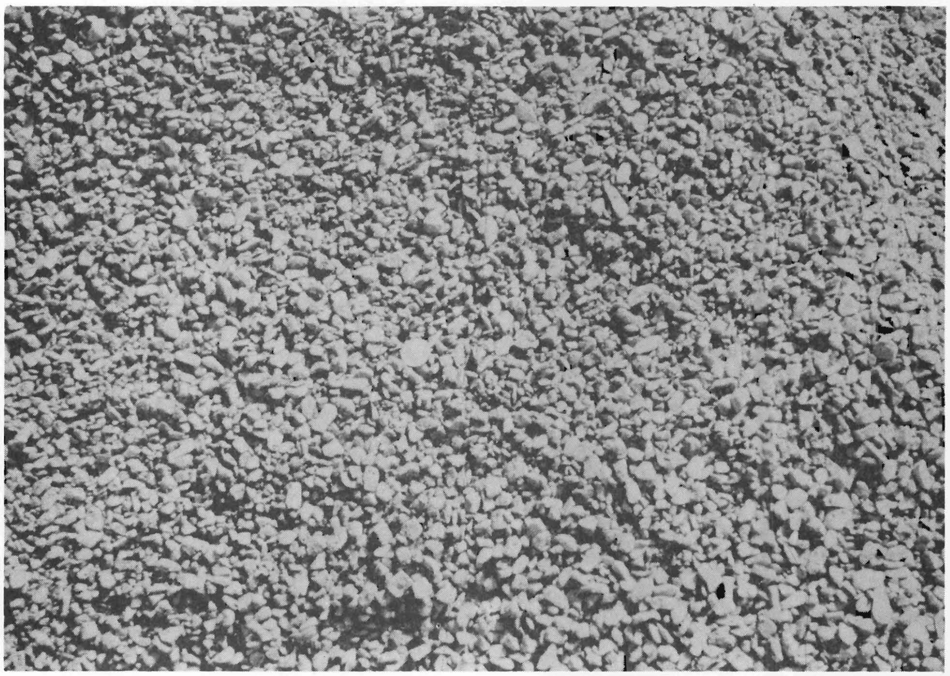
Type D Date 6-6-80 Report No. 3

ANNEX B

PICTORIAL PRESENTATION

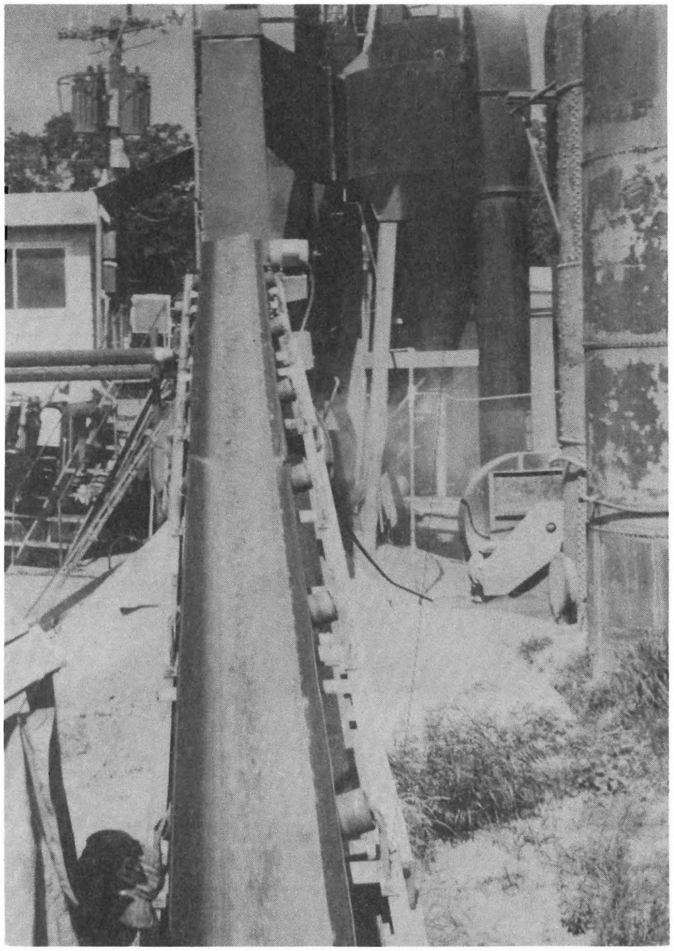
CONSTRUCTION OF THREE

BOTTOM ASH-GRAVEL HMAC TEST SITES

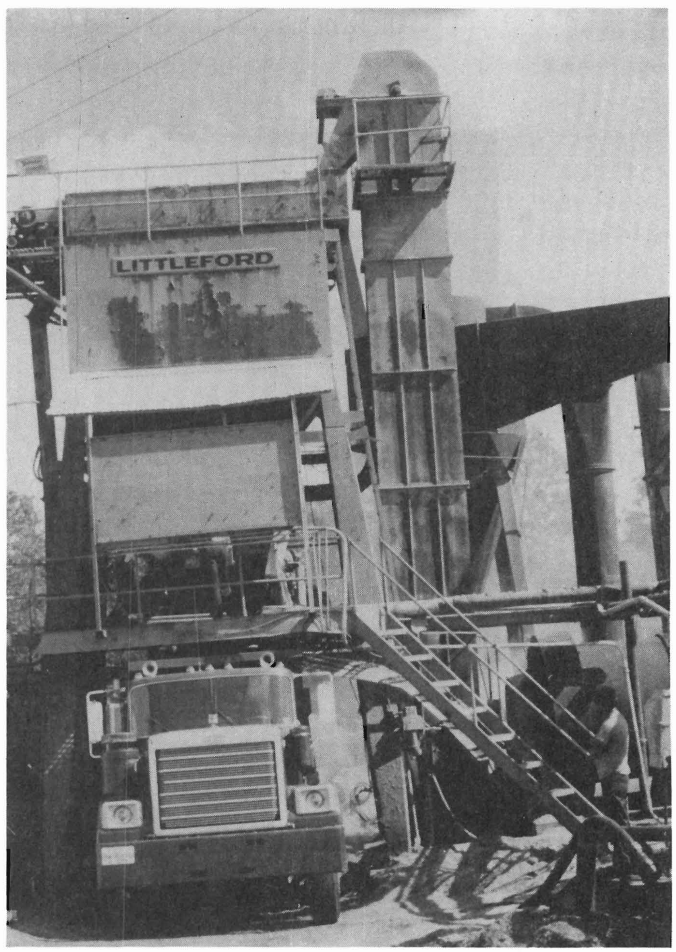


Photograph 1. Siliceous gravel from Frogville, Oklahoma, stockpiled at the HMAC plant.

Photograph 2. Pit run bottom ash from the Monticello Power Plant, stockpiled at the HMAC plant.



Photograph 3. Cold Feed belt moving the two aggregates to the dryer.



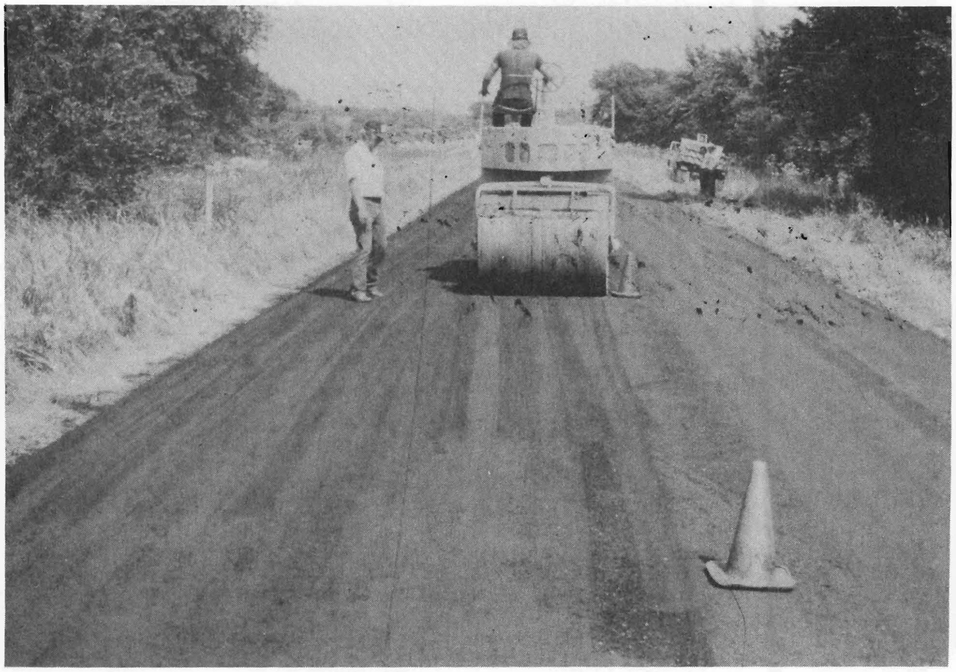
Photograph 4. The Netex HMAC Batch Plant located at Sulphur Springs.

Photograph 5. The first test site constructed was located approximately one mile SE of IH 30 on FM 1870.

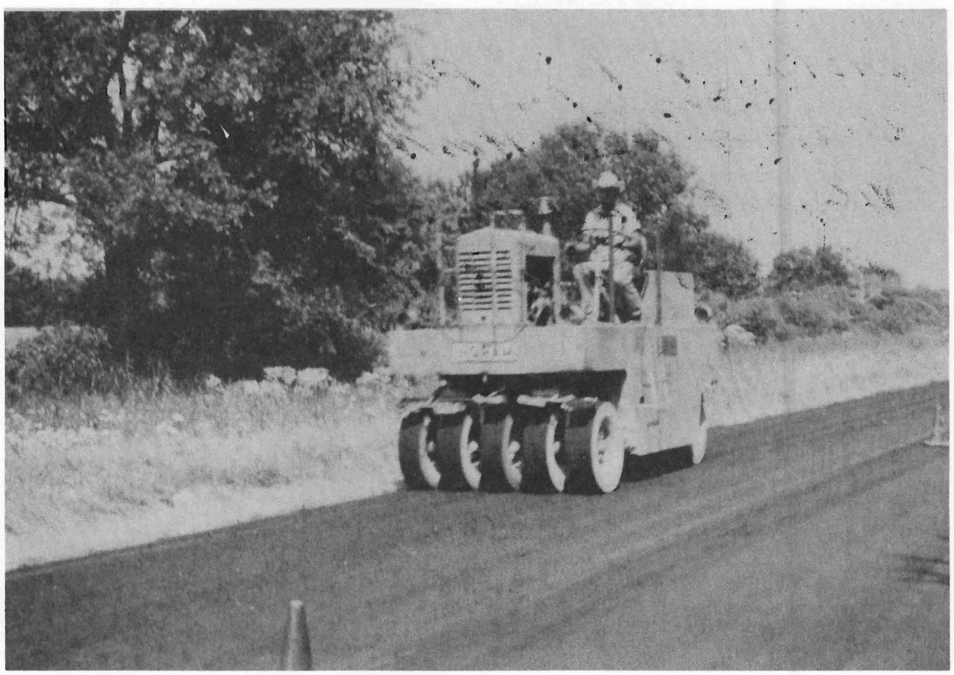
Photograph 6. An RC-2 tack coat was applied by the Sulphur Springs' Maintenance Forces, who are under the immediate supervision of Mr. Walter B. Darling.

Photograph 7. A heavy tack coat was applied to insure bonding between the existing seal coat and the new bottom ash HMAC. Optimum asphalt content was 10 percent but there was no apprehension about the tack flushing up through the asphalt.

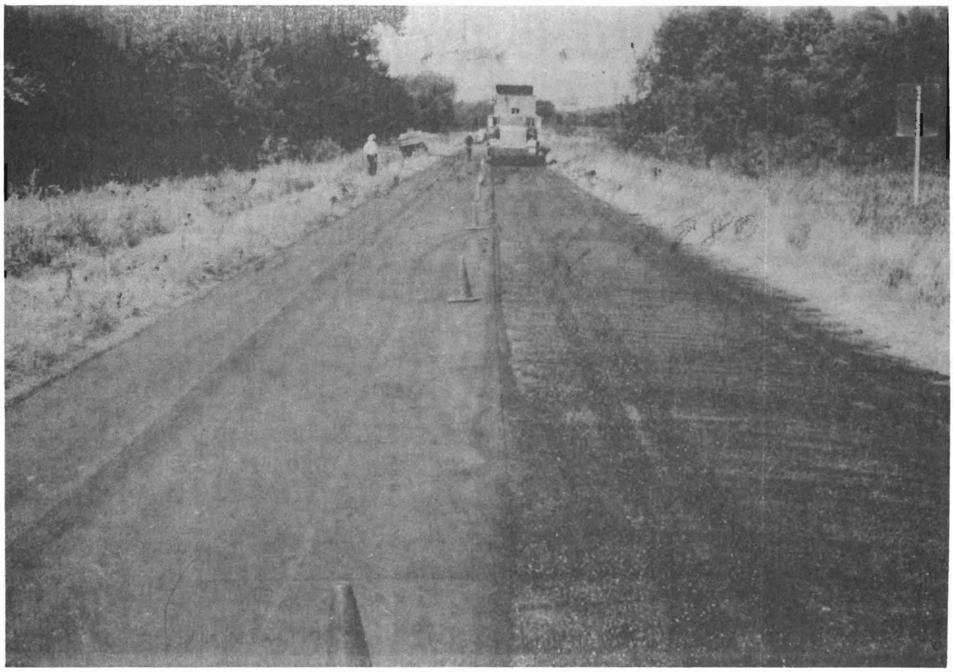
Photograph 8. The uncompacted bottom ash mix displayed a tendency to stick and pull apart when placed in contact with cold, dry objects. A flat wheel roller was used for breakdown rolling. A light coat of diesel prevented the asphaltic concrete pavement from sticking to the roller drum.



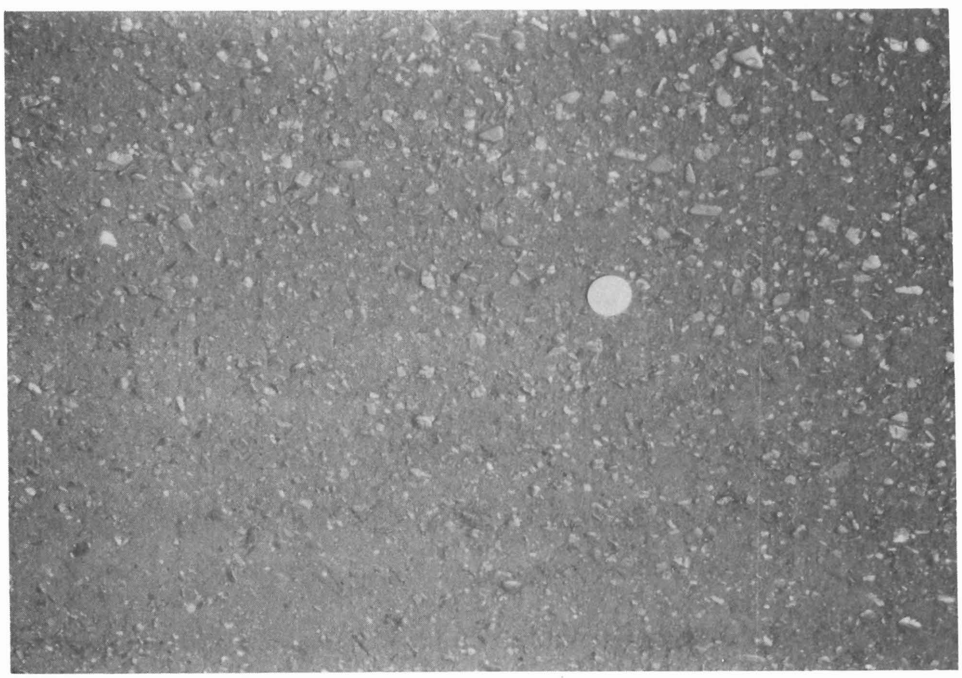
Photograph 9. The bottom ash mix cooled fast and required immediate rolling for proper densification. There was no lateral displacement normally associated with smooth gravel mixes. Mr. Charles Wingfield is monitoring the breakdown rolling for mix pickup.



Photograph 10. The breakdown rolling was followed by compaction from a pneumatic tire roller. This roller gave a uniform appearance to the completed pavement.

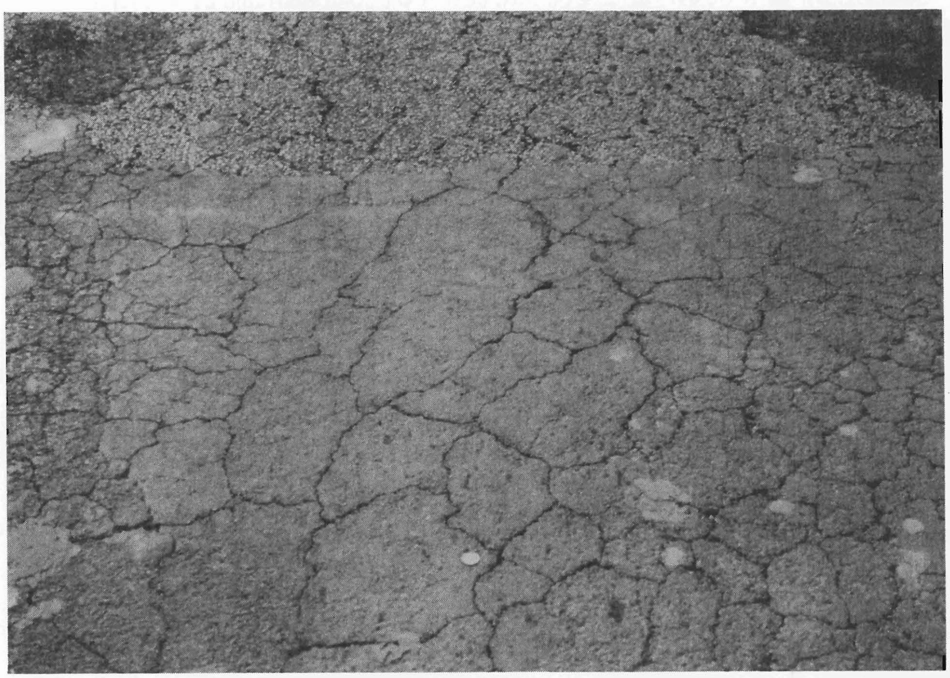


Photograph 11. Overall view of the test site on FM 1870 with SE lane paved. The paving operation is progressing toward IH 30. Again note the heavy tack coat.



Photograph 12. A close-up view of the completed mix. Note the predominance of uncrushed siliceous gravel in the completed surface.

Photograph 13. Overall view of the test section site on SH 11 before overlaying with the bottom ash mix.



Photograph 14. Close-up view of a patched area at the west end of the test site. This road has considerable deflection and considerable cracking was observed throughout the test section.

Photograph 15. A heavy hand-sprayed RC-2 tack was used in the EBL of SH 11. Since an optimum asphalt content of 12 percent was selected to hedge against deflection cracking, there was some apprehension about this tack flushing through the compacted bottom ash mat. This has not occurred to date.

Photograph 16. Depicts the ability of the bottom ash mix to be placed in neat lines.

Photograph 17. There was some concern about being able to rake this high-friction bottom ash mixture. This tapered start was hand-constructed without difficulty.

Photograph 18. Flat-wheel breakdown rolling of the bottom ash mix on SH 11.

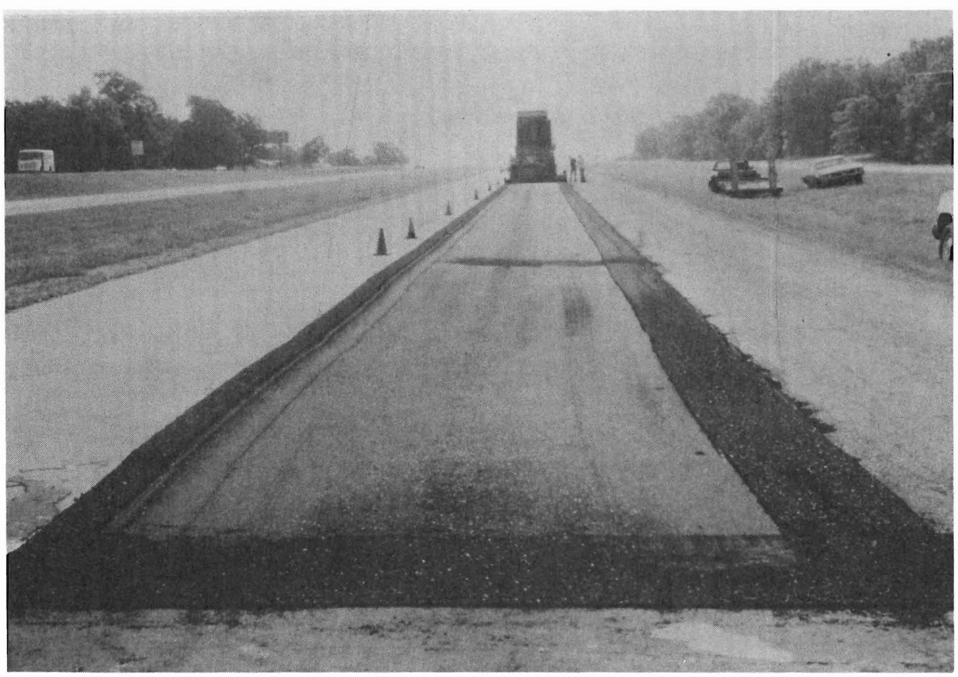
Photograph 19. Mr. Charles Wingfield, Sulphur Springs' Maintenance Forces, operating the pneumatic-tired roller to complete the overlay operation.

Photograph 20. This RC-2 asphalt is both tacky and sticky, as evidenced by Mr. Bobby Stone's coveralls. The tack coat in the WBL was greatly reduced. To date, there is no noticeable difference in the performance of the two lanes.

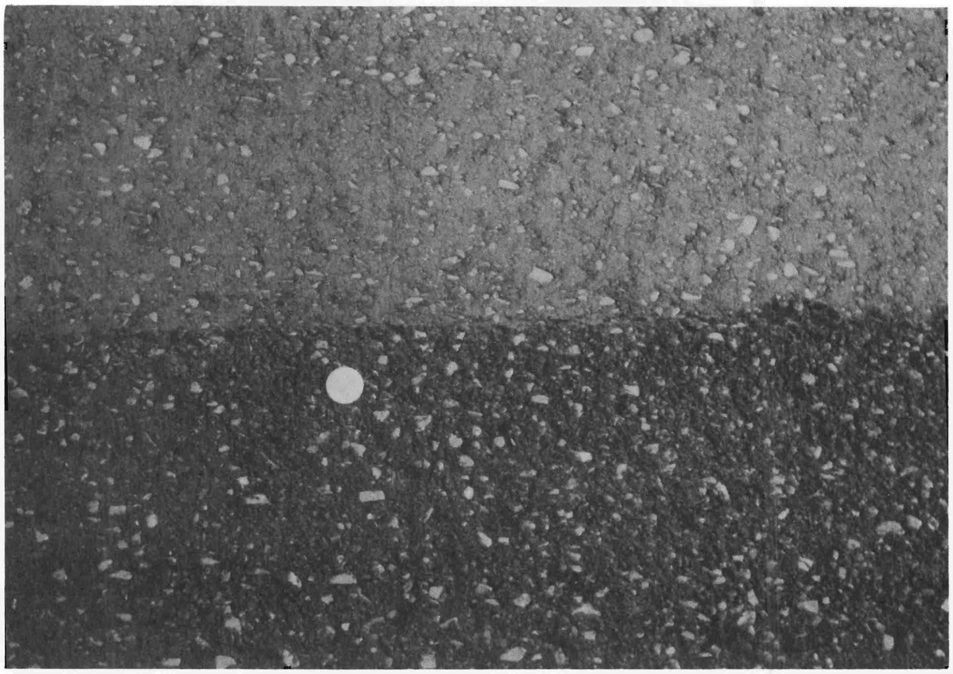
Photograph 21. Site location of the third bottom ash test section on IH 30 EBL at MP 128.5.

Photograph 22. An 11 percent optimum asphalt content and lighter tack was utilized in this bottom ash test section. There has been no slippage or rutting after 1.5 years service.

Photograph 23. Laying operations on IH 30 at Sulphur Springs. Maintenance Forces rented the equipment shown.

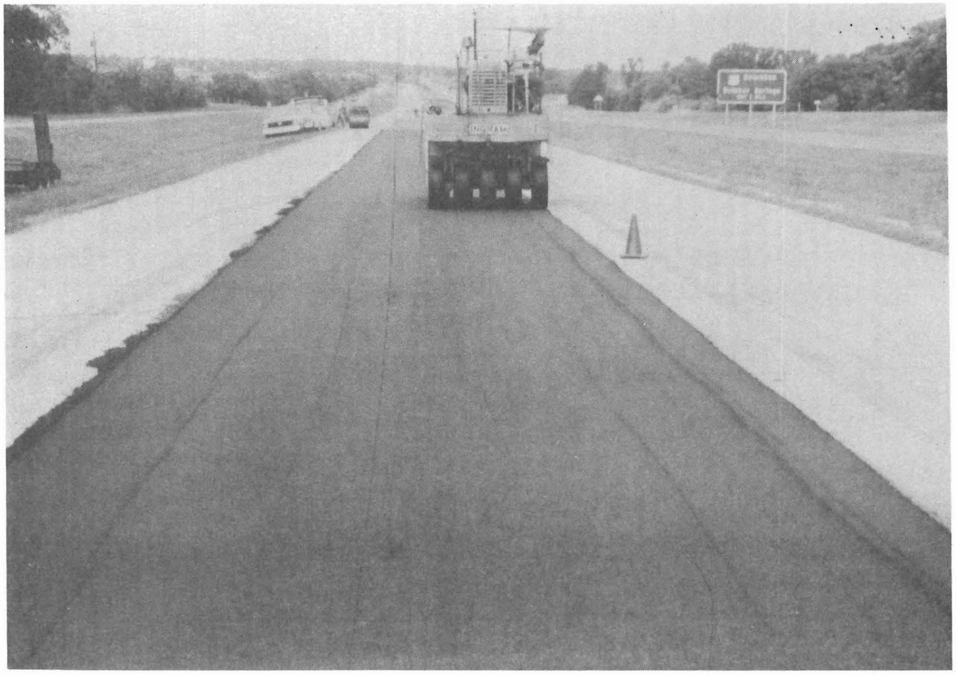


Photograph 24. Dark textured lines on each site were caused by a box extension on the left and a tapering extension on the right. Raking in the foreground made for a smooth transition from existing concrete pavement to the bottom ash and gravel asphalt concrete pavement.

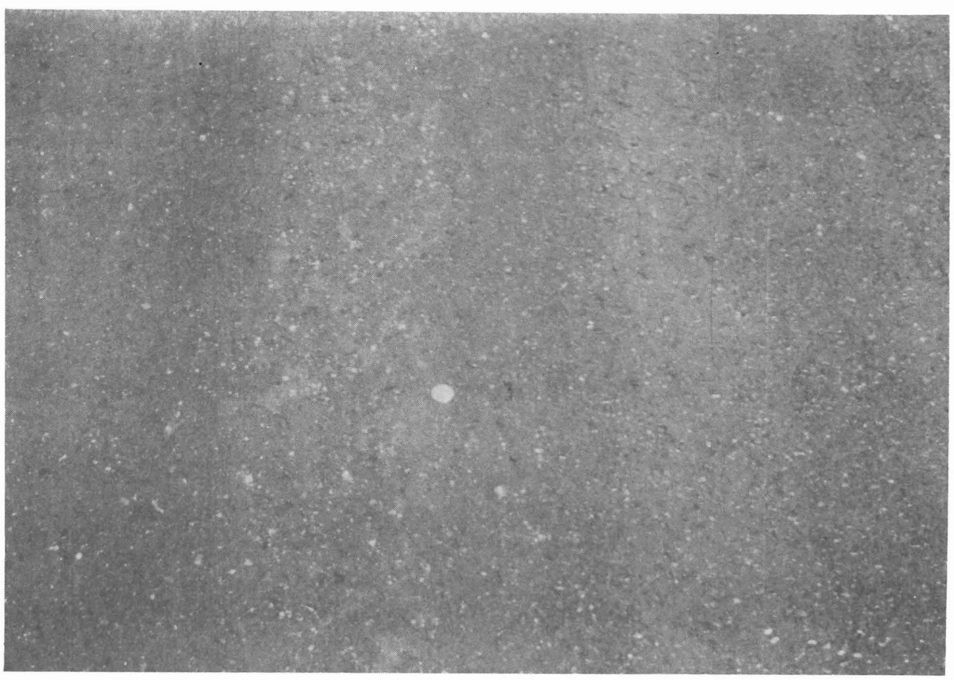


Photograph 25. Close-up view of the uncompacted mat. Again, note the abundance of siliceous gravel in the mix.

Photograph 26. A light coat of diesel being applied to the flat-wheel roller by Mr. Charles Wingfield prior to the breakdown rolling. This prevents pickup of the bottom ash-gravel asphaltic concrete pavement.



Photograph 27. Finish rolling being applied to the bottom ash-gravel mat in the EBL of IH 30.



Photograph 28. Close-up view of the compacted bottom ash-gravel mat.