STUDY of the MIXING EFFICIENCY of a 34-E DUAL-DRUM PAVING MIXER

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MICHIGAN
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Testing Laboratory Division
Office of Testing and Research

Michigan State Highway Department
John C. Mackie, Commissioner
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INTRODUCTION

State Highway Department specifications for concrete pavement throughout the nation are variable as to required mixing time and size of batch when using 34E dual drum paving mixers. The minimum mixing time varies from 50 seconds to 120 seconds, some agencies including and others excluding transfer time between drums. The maximum allowable batch varies from the rated capacity to 20 percent over the rated capacity.

A search of the literature fails to provide a study of the effect of batch size and mixing time since one reported in Public Roads, January, 1932, on the 27E single drum mixer. (1)* In order to secure such information on the 34E dual drum mixer, the Michigan State Highway Department, along with other states, entered into a cooperative program initiated by the Bureau of Public Roads by letter dated December 3, 1957. The results of the Michigan study are reported herein.

DESCRIPTION OF PROJECT

A. Location

The Michigan paver study was conducted as an addition (No. 2002, Authorization E) on project IN 81041 C2-R (IN 02-5(6)) relocating a section of US-12 near the Willow Run Airport, southeast of Ypsilanti, Michigan. The project consisted of approximately 2.6 miles of limited access divided expressway construction with dual 24-foot pavement, plus bridges and interchange ramps at each end of the project.

The prime contractor was the Denton Construction Company of Grosse Pointe Woods, Michigan, which specializes in concrete paving.

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*Refers to list of references at the end of this report.

B. Contractor's Equipment

Basic to the job is the particular paver used, in this case a Rex 34E dual drum paver, serial number GD364, made by the Chain Belt Company. This mixer was new in late 1957. It was in excellent condition at the time of the testing program. The paver was equipped with an electronic drumspeed indicator, so that the number of revolutions of the drum for a batch of concrete could be accurately determined. Job specifications permitted the use of only this one paver in the laying of concrete in the test sections. The contractor had two other identical Rex pavers on the job which were used in tandem when paving outside of the test sections.

The remainder of the paving train consisted of a Jaeger screw-type spreader for the bottom course of concrete and another Jaeger screw-type spreader with an oscillating screed for the top course. Machine finishing was done by a Flex-Plane finisher-float combination having two screeds and a sliding shoe float. Following the hand finishing was a canvas belt and burlap drag machine, and finally a Flex-Plane curing compound spreader.

The concrete materials were batched from a Butler automatic batching plant with electrical interlocks. The materials were transported in a fleet of four-compartment batch trucks. Tank trucks supplied water for paving and for wetting the subgrade.

C. Materials

The coarse aggregate for the concrete was air-cooled blast furnace slag supplied from steel mills in the Detroit area. The slag was furnished in two sizes, Michigan specification 4A (approximately 2 inch to 1 inch) and 10A (approximately 1 inch to No. 4) and batched with each size 50 percent by weight of the total coarse aggregate. The use of slag was the contractor's choice, and was accepted with the knowledge that its use might complicate some of the testing procedures, but realizing also that many similar test projects being performed in other states would probably make use of gravel or crushed stone coarse aggregates, whereas this might be the only project using slag coarse aggregate. Results of tests on samples of the slag obtained at the batch plant during laying the test sections are shown in Table V-A in the appendix.

The fine aggregate for the concrete was a natural sand from a pit located a short distance from the project. It has an average fineness modulus of 2.80. Test results on samples of the sand are shown in Table VI-A.

The portland cement for the project came from a mill in Detroit. The cement was type I-A (air-entraining) as required by Michigan specifications. Laboratory tests, presented in Table VII-A, indicate the cement to be normal in all respects. Air-entraining admixture was on hand at the batch plant, but its use was not necessary to obtain the required 5.5 ± 1.5 percent air in the concrete. The water for the concrete was from the Ypsilanti City water system.

The concrete mix was designed by the Mortar-Void Method, under the standard Michigan procedure, to contain 5.5 sacks of cement per cubic yard with 4 to 7 percent entrained air. Specifications require such concrete to have a 28 day compressive strength of 3500 psi, and modulus of rupture (using center-point loading) of 550, 600, and 650 psi at 7, 14, and 28 days respectively. The batch weights used for each test section are presented in Table VIII-A.

The pavement slab is 9 inches thick and 24 feet wide poured full width, with steel mesh reinforcement. Curing was provided by white pigmented concrete curing compound. The transverse joints were of weakened plane type with steel load transfer dowels. The longitudinal center joint was made by sawing several days after placing the concrete.

DESCRIPTION OF TEST PROGRAM

A. General

The purpose of the testing program was to evaluate the performance of the paver in mixing batches of various sizes and for different lengths of time. The sizes of the batches represent the range permitted by the various state highway departments, namely, 100, 110, and 120 percent of rated capacity (34.0, 37.4, and 40.8 cubic feet, respectively, for a 34E paver). The mixing times used were 30, 50, and 70 seconds plus transfer time. The transfer door was open 11 seconds, but actual transfer time was considered to be 8 seconds (the average time required for two revolutions of the drum), since most of the concrete appeared to be transferred in that time. Thus the total mixing times used were 38, 58, and 78 seconds as indicated in Table I. The drum revolved uniformly at 16 revolutions per minute, so that for the 78, 58, and 38 second mixing times, there were about 21, 15-1/2, and 10 revolutions of the drum, respectively.

A test section of pavement, consisting of 200 consecutive batches, was constructed for each of the nine combinations of variables. In general, each twentieth batch was sampled.

TABLE I

MIXING TIME AND BATCH SIZE FOR TEST SECTIONS

Test Section	Mixing Time,* sec.	Batch Size	
		Percent of Rated Capacity	Cubic Feet
1	78	100	34.0
2	78	110	37.4
3	78	120	40.8
4	58	100	34.0
5	58	110	37.4
6	58	120	40.8
7	38	100	34.0
8	38	110	37.4
9	38	120	40.8

*Including 8 sec. transfer time.

One group of tests was performed on batches 20, 80, and 140, another group of tests on batches 40, 100, and 160, and a third group of tests on batches 60, 120, and 180. The three repetitions of each group of tests made it possible to determine variations in the concrete from batch to batch and provide sufficient replication to reliably establish trends exhibited by the particular test section. Three samples were obtained from each batch sampled, these samples representing the first, middle, and last portions of the batch as it comes out of the mixer bucket. To obtain these samples, three pans, each of one cubic foot capacity, were placed on the subgrade. The paver operator then discharged the concrete from the paver bucket in such a manner that concrete from the first portion of the batch dropped into the first pan, concrete from the middle of the batch dropped into the second pan, and concrete from the end of the batch dropped into the third pan, as shown in Figures 7, 8, and 9. The samples were then moved to the road shoulder where the tests were performed on the concrete and test specimens fabricated.

B. Tests Performed and Procedure

The tests performed on the fresh concrete consisted of slump and ball penetration for consistency, air determinations by both the volumetric method (Roll-A-Meter) and using the Chace AE-55 Air Indicator, unit weight of concrete, temperature of concrete, and a washout test to determine gradation of the concrete mixture. Specimens were made for compressive and flexural strength tests. In general, all tests were performed in accordance with applicable ASTM procedures where such procedures exist.

Table II lists the various tests performed on each of the batches sampled and also the number of tests on each batch.

TABLE II

TESTS PERFORMED ON EACH BATCH OF CONCRETE SAMPLED

Batch No.	Tests Performed and Number on Each Batch Sampled
20-80-140	Temperature of Concrete - 1; Slump - 3; Air Content, Volumetric Method - 1; Air Content, Chace Method - 1; Cylinders for Compression Testing - 9.
40-100-160	Temperature of Concrete - 1; Ball Penetration - 3; Unit Weight of Concrete - 3, Beams for Flexural Testing - 3.
60-120-180	Temperature of Concrete - 1; Air Content, Chace Method - 3; Washout and Grading - 3.

The first test made on all the batches sampled was the determination of the temperature of the concrete. This was taken on one of the three samples from each batch.

Slump tests were conducted on each of the three samples of concrete from batches 20, 80, and 140 in each test section. Immediately following the slump test, three 6x12 inch compression test cylinders were fabricated from each of the three samples. Waxed pasteboard molds with metal bottoms were used. After the concrete had started to set, the cylinders were covered with wet burlap which in turn was covered with a generous layer of damp sand. Simultaneously with testing the slump and making the cylinders, a small amount of concrete was taken from the three samples and was mixed, after which it was used to determine the air content by the volumetric method and also using the Chace AE-55 Air Indicator.

The three samples of concrete from batches 40, 100, and 160 were each tested for consistency using the ball penetration method. This test was made in the sample collecting pans without disturbing the concrete except for a small amount of smoothing of the surface with a wood float. Two ball penetrations were made on each pan of concrete. A determination of the unit weight of the concrete was then made on each of the three samples, from which it was possible to determine the yield and cement content of each portion of the batch. One test beam, 6x6x36 inches, was then fabricated from each sample to be used for determining the flexural strength of the concrete. When the concrete started to set, the beams were covered with burlap and damp sand in the same manner as the cylinders.

From batches 60, 120, and 180, the air content was determined on each of the three samples using the Chace Air Indicator. Approximately 80 to 95 pounds of concrete was taken from each sample to be used for a washout test. The washout sample was weighed in the field and then immediately transported to the Highway Department Laboratory in Ann Arbor, approximately 12 miles away, for actual washout over a No. 100 sieve. After the first day's work, a considerable overdose of a dispersing and retarding agent was added to the concrete when it was put in containers in the field in order to facilitate later washing. The fact that slag was used as the coarse aggregate complicated the washing since mortar would get into the large pores of the slag and be difficult to dislodge. After the cement was washed out of the concrete, the remaining sand and coarse aggregate was put in canvas bags for a sieve analysis at a later time.

The cylinder and beam specimens were taken to the laboratory the morning after molding and were placed in a moist-fog room for storage at 65-75^{o}F until they were tested at 28 days' age. The cylinders were capped with Hydrostone capping plaster before being tested in compression. The beams were broken using third-point loading on an 18 inch span, two flexural tests being made on each beam. Beams were removed singly from the moist curing room and broken at once to avoid drying of the specimen surface.

After the completion of the field work in this study, the aggregates from the washout samples were dried in an oven and sieve analysis made on each of the 81 samples. The entire sample was used in determining the grading through the No. 4 sieve, the sieves used being the 2-1/2, 2, 1-1/2, 1, 3/4, 1/2, 3/8 inch, and No. 4. The material passing the No. 4 was reduced to a 600-700 gram sample by repetitive splitting in a mechanical splitter and was then screened through the No. 8, 16, 30, 50, and 100 sieves. The procedure generally follows that reported by Walker and Bloem (2).

When the concrete had been in place for about 2 months, cores were drilled from the pavement for testing in compression at 90 days' age. Three cores, six inches in diameter by approximately nine inches long (the pavement thickness), were obtained from each test section. The strength of these cores provide a comparison with the cylinder strengths and will provide a base for comparison with any cores which may be drilled at later ages to study effect of time and use on the pavement. After the cores were drilled, they were stored in air in the laboratory for about two weeks before they were capped with neat cement, after which they were stored in the moist-fog room until the concrete had reached 90 days' age.

C. Location of Test Sections

As stated previously, the paver study was conducted on a project relocating a section of US-12, a limited access divided highway. The test sections are all located on the Eastbound traffic lanes, as indicated in Fig. 1, and due to the limited access feature, it is not possible for traffic to enter or leave the highway in this area. Thus, all the test sections will be exposed to the same traffic load.

Precise stationing of the beginning and ending of the sections cannot be given in most cases because the concrete was placed in two layers and construction joints were not required at the limits of the test sections. Generally, two test sections were placed each day, the first being started when work commenced in the morning and the next starting just as soon as the first section was completed. Thus, there is a short overlapping of the two sections. The approximate stationing limits are given in Table III.

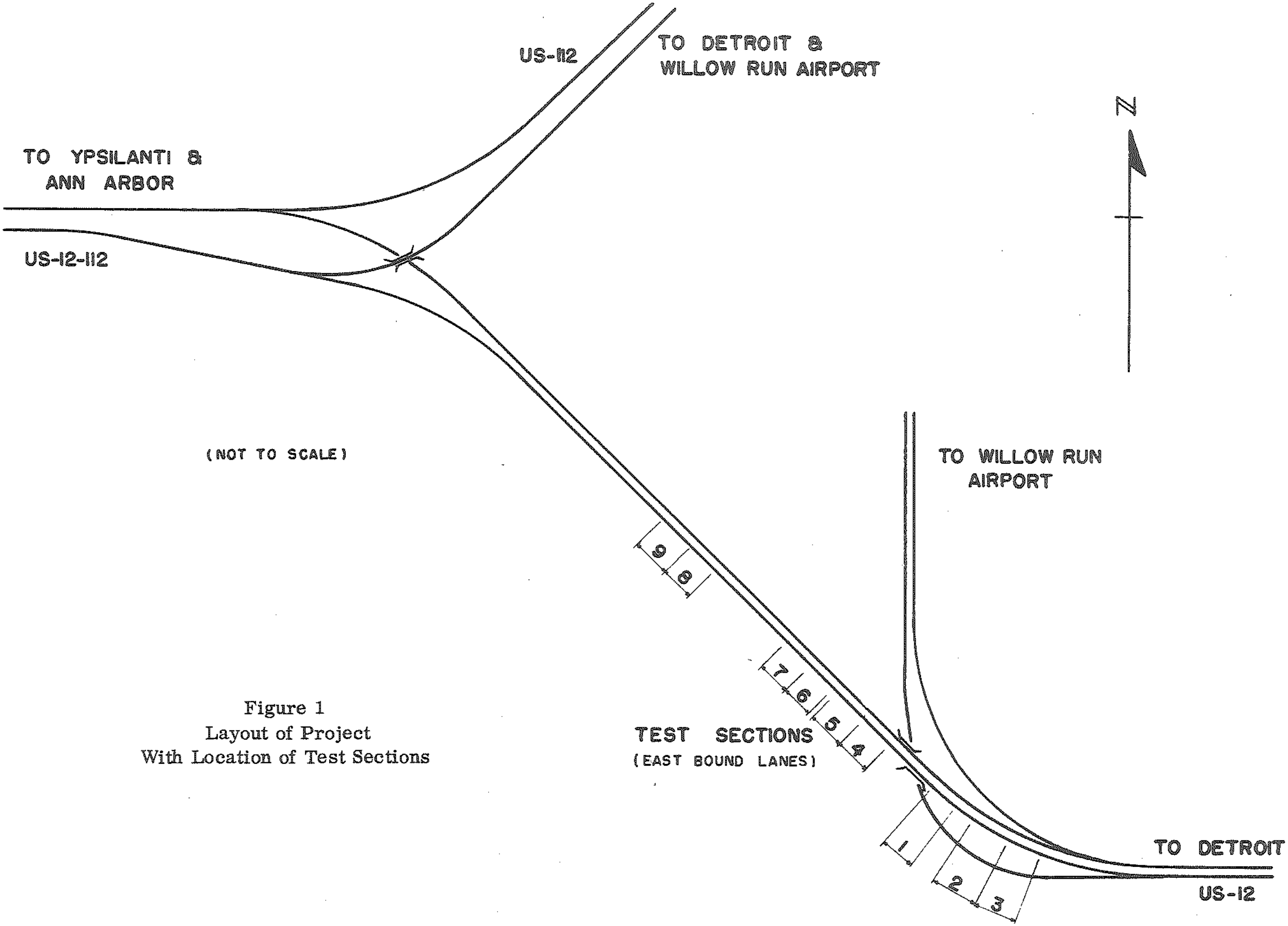

Figure 1
Layout of Project
With Location of Test Sections

D. Performance in Individual Test Sections

Section 1. The paving on test section 1 commenced the first day of paving on the project June 24, 1958. Both the paving crew and the testing personnel had to work out some difficulties in procedure. The paving crew was used to working with two or three pavers in tandem and it was quite a change to slow down to one paver operating at a longer cycle than normal. The testing personnel likewise were not too experienced in such a large scale testing operation. Generally, 11 testing personnel were used in the field, including recorders and a driver, and 6 in the Laboratory for the washout tests.

TABLE III

STATIONING LIMITS OF TEST SECTIONS

Test Section	Total Mixing Time, sec.	Batch Size, cu ft	Date Placed (1958)	Stationing Limits* (Approximate)	
				Start	End
1	78	34.0	6-24	343+50	347+00
2	78	37.4	6-26	349+10	353+25
3	78	40.8	6-26	353+25	357+00
4	58	34.0	6-28	339+10	335+25
5	58	37.4	6-28	335+25	331+50
6	58	40.8	7-1	331+00	327+00
7	38	34.0	7-1	327+00	323+15
8	38	37.4	7-2	311+40	307+40
9	38	40.8	7-2	307+40	303+00

*Eastbound Lanes.

Michigan concrete design proportions are based on the dry, loose, unit weight of the coarse aggregate with a b/b_0 of 0.78 for paving concrete. When this weight was first determined in the field before the start of paving, a value of 78 pounds per cubic foot was obtained. The resulting mix proved to be quite harsh and difficult to finish. The mixer was required to move back several times to place additional concrete in front of the finishing machine. As a result, a number of the batches were mixed in excess of the designated 78 seconds. Subsequent tests indicated the correct unit weight to be 76 or 75 pounds per cubic foot, the former causing a decrease of about 40 pounds of coarse aggregate and an increase of about the same weight of fine aggregate per cubic yard. In subsequent test sections, the lower unit weight was used and the concrete was much more workable.

Section 2. This section was started shortly after lunch on June 24, but before any tests were performed rain forced the cancellation of testing for that day. The section was started again on June 26 and proceeded without incident. The proper mixing times were held much closer than for section 1.

Section 3. The batches for section 3 were to yield 40. 8 cubic feet of concrete. This was more material than a single compartment in the batch trucks would hold, so that two compartments had to be used for each batch. This procedure was used in sections 6 and 9 which also had this large size batch.

On occasion, the batch designated for sampling was intentionally skipped and another batch sampled. This was done whenever the designated batch was mixed slightly too long, or for some other reason it was believed it would not be typical of the test section.

Section 4. Too much water was added at the mixer at the start of this section, and it was not reduced fast enough. As a result, batch 20 had a very high slump and relatively high water-cement ratio. The water was brought into proper adjustment before the next batch was sampled.

Sections 5 and 6. These sections were paved without any unusual incidents.

Section 7. The 38-second mixing of batches was done one at a time, except for preliminary trials. A man with a stopwatch was stationed next to the paver operator to advise him when to discharge the batch. For the longer mixing times, the automatic batchmeter was set for the proper mixing time and the concrete was discharged just as soon as the controls permitted it. The batchmeter could not be set for less than 50 seconds total mixing time, hence the need of the stopwatch for timing.

The paver operator briefly tried mixing two batches at a time (a batch in each drum), but with the additional manual operations necessary without use of the batchmeter, the mixing ran 4 to 6 seconds too long.

Mixing two batches at a time, with total mixing time of 42 to 44 seconds per batch, produced about a 33 second cycle. Mixing one batch at a time, with total mixing time of 38 seconds, produced a cycle of about 55 seconds.

Section 8. Starting about batch 20, the concrete appeared to get drier so the water was increased to get workable concrete. Then about batch 37, the concrete suddenly became very wet. The water was decreased and the sampling was delayed to batch 48 when the concrete was more normal. The water was decreased further until there was a reduction of greater than 25 percent in the amount of water added at the paver. After that, the water requirements remained quite constant the rest of the day. The reason for this change in water requirement is not known.

Section 9. The concrete appeared to be uniformly mixed. No difficulties were experienced during the paving of this section.

DISCUSSION OF TEST RESULTS

A complete tabulation of the results of tests on the fresh concrete and hardened concrete specimens will be found in Table III-A with a summary in Table I-A. Table II-A is a summary of the washout test results, with a complete tabulation being found in Table IV-A. Each value for batch-to-batch variation, presented in Tables I-A and II-A, is the range of the average values for the three batches within a test section. Each value for within-batch variation is the average of the range of values for each of the three batches within a test section. Summaries of important features have been made and are included in the body of the report.

A. Consistency

The consistency of the concrete was measured by two methods, the slump test and the ball penetration test. Comparison of the results by the two methods cannot be made directly since these tests were conducted on different batches.

The average ball penetration for all test sections is 1.73 inches. The average slump is 1.94 inches, excluding the results of batch 20, section 4. The results from this one batch are excluded since too much water was being added at the mixer, but this was corrected by the time the next batch was sampled. With the one batch excluded, the results of the ball penetration test average 89 percent of the results of the slump test.

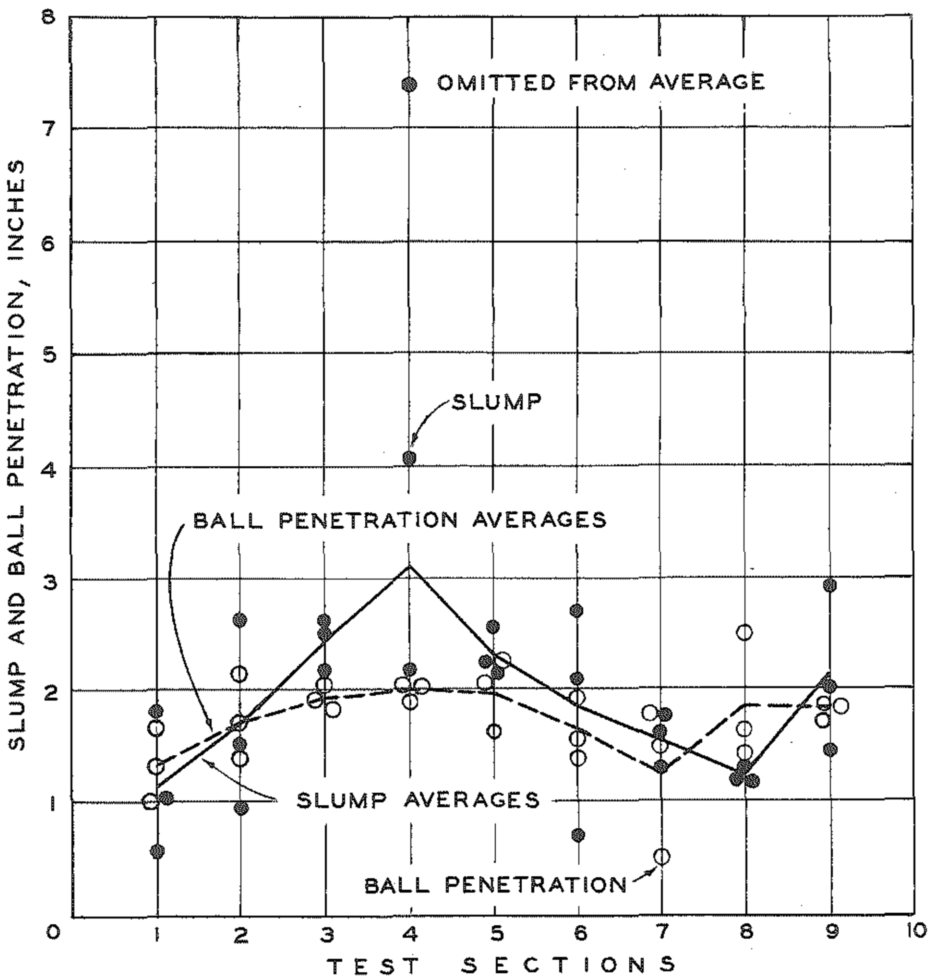

Figure 2
Comparison of Slump and Ball Penetration
Test Results

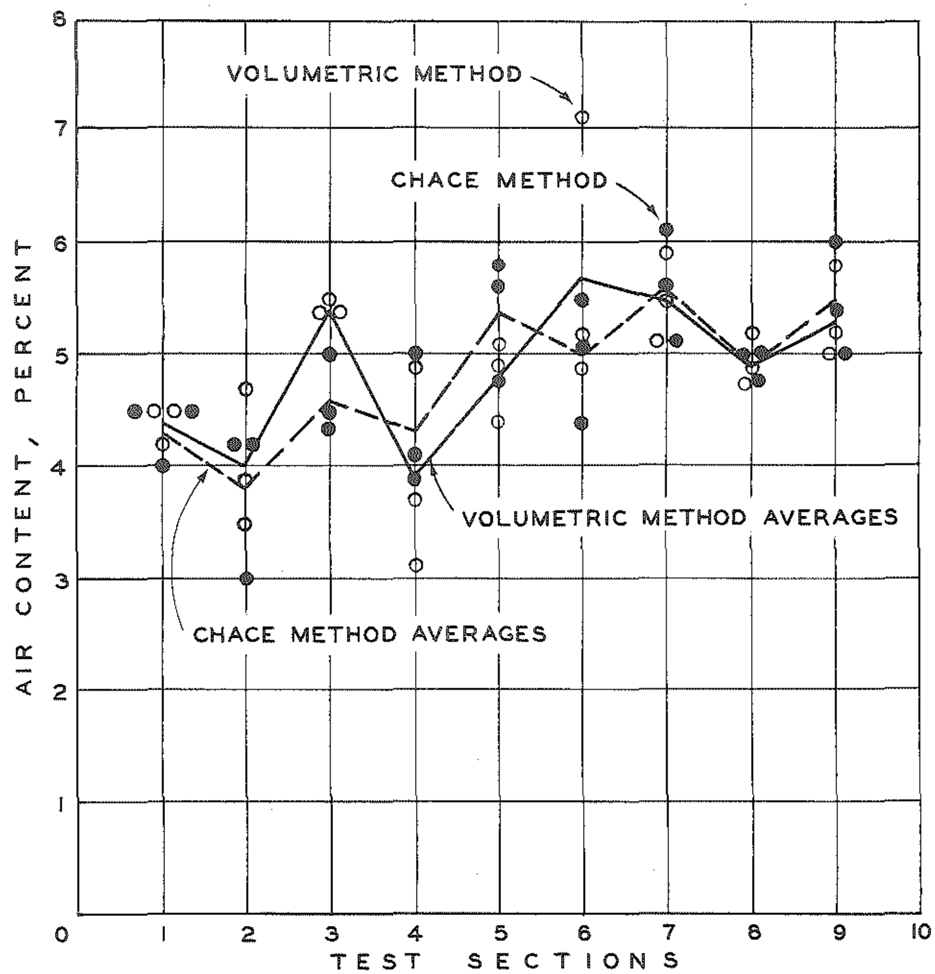

Figure 3
Air Content of Concrete Determined by Volumetric
and Chace Methods

As Figure 2 indicates, the relative magnitude of the results of the two tests are not too consistent, the ball penetration ranging from 0.6 inch greater to 1.1 inch less than the slump.

Michigan specifications require a slump of 1-1/2 to 2-1/2 inches for paving concrete. The average values for the slump in six of the sections were within these limits. In two sections, the average value for the slump was low by 1/4 and 3/8 inches, respectively. In one section, the average slump was 2 inches high. The average slump is controlled by the paving inspector and is not determined by characteristics of the mixer. However, the uniformity of the slump within a batch is affected by mixer behavior. In 11 of the 27 batches tested for slump on the entire project, the range of slumps within the batch was in excess of 1 inch, indicating that it was impossible for the entire batch to be within specification tolerance limits. Eight of these eleven batches with the larger variations in slump contained 40.8 cubic feet of concrete, only one of the nine 40.8 cubic foot batches tested having a slump uniform within 1 inch throughout the batch.

To determine if there was consistent variation within the batch, the three values for slump from the first part of the three batches tested in each section were averaged. The same was done for the three values from the second part of the batches and from the third part of the batches. Thus, three average values for slump were obtained representing the concrete from the beginning, middle, and end of discharge of batches for each test section, as summarized in Table IV. In each of the nine test sections, the concrete in the first part of the batch had the highest slump. The third part of the batch had the lowest slump in seven of the test sections, and the middle of the batch had the lowest slump in the other two sections. A similar analysis for the ball penetration, summarized in Table V, shows a tendency toward the same pattern, although not as prominent. The ball penetration test does not show the extreme variation within the large size batches that was indicated by the slump test. It appears characteristic of this mixer to provide concrete of somewhat greater fluidity during the early portion of the discharge and the disparity in slumps from beginning to end of discharge tends to be larger for the greater overloads.

B. Air Content of Mixes

The air content was measured on three of the batches from each section by the volumetric (Roll-A-Meter) method. The results obtained were average values for the batch since the sample was obtained by compositing

TABLE IV

AVERAGE VALUES OF SLUMP FOR EACH THIRD OF BATCH
(Expressed in inches)

Mixing Time, Sec.	Batch Size, cu. ft.	Section and Batch No.	1st Part	2nd Part	3rd Part	Average
		1-20	0.88	0.38	0.38	
		80	2.38	1.75	1.25	
78	34.0	140	1.50	1.25	0.50	
		Average:	1.59	1.13	0.71	1.14
		2-20	2.75	3.75	1.38	
		80	2.00	1.25	1.25	
78	37.4	140	1.25	0.63	1.00	
		Average:	2.00	1.88	1.21	1.70
		3-20	2.25	1.50	2.88	
		81	3.25	2.63	1.63	
78	40.8	140	3.13	1.50	3.13	
		Average:	2.88	1.88	2.55	2.43
		4-20	7.75	7.50	7.00	
		81	2.50	2.00	1.88	
58	34.0	140	4.50	3.75	4.00	
		Average:	4.92	4.42	4.29	4.54
		5-21	3.50	1.63	1.37	
		80	2.75	2.13	1.75	
58	37.4	140	3.00	2.25	2.37	
		Average:	3.08	2.00	1.83	2.31
		6-23	3.13	2.00	3.00	
		82	0.63	0.75	0.75	
58	40.8	140	2.75	1.25	2.37	
		Average:	2.17	1.33	2.04	1.85
		7-20	1.75	2.00	1.50	
		80	1.50	1.50	0.88	
38	34.0	143	1.75	1.13	2.00	
		Average:	1.67	1.54	1.46	1.56
		8-20	1.25	1.50	0.88	
		80	1.25	1.13	1.25	
38	37.4	140	1.63	1.13	1.25	
		Average:	1.38	1.25	1.13	1.25
		9-21	2.37	1.37	0.63	
		80	3.00	1.75	1.25	
38	40.8	140	3.88	2.75	2.13	
		Average:	3.08	1.96	1.34	2.13
Grand Average:			2.53	1.93	1.84	2.10

TABLE V

AVERAGE VALUES OF BALL PENETRATION FOR EACH THIRD OF BATCH
(Expressed in inches)

Mixing Time, Sec.	Batch Size, cu. ft.	Section and Batch No.	1st Part	2nd Part	3rd Part	Average
		1-40	1.25	1.00	0.75	
		100	2.00	1.00	1.00	
78	34.0	160	1.75	1.75	1.50	
		Average:	1.67	1.25	1.08	1.33
		2-40	1.75	1.25	1.13	
		100	1.75	1.75	1.50	
78	37.4	160	2.50	2.00	1.88	
		Average:	2.00	1.67	1.50	1.72
		3-40	2.25	2.00	1.50	
		100	2.38	1.63	2.13	
78	40.8	160	2.25	1.50	1.75	
		Average:	2.29	1.71	1.79	1.93
		4-42	2.75	1.88	1.25	
		100	2.13	2.00	2.00	
58	34.0	162	2.25	2.13	1.75	
		Average:	2.38	2.00	1.67	2.02
		5-42	1.75	1.75	1.37	
		100	2.75	2.25	1.75	
58	37.4	160	2.75	1.75	1.75	
		Average:	2.42	1.92	1.62	1.99
		6-41	1.50	1.50	1.25	
		101	1.50	1.50	1.75	
58	40.8	162	2.00	1.75	2.00	
		Average:	1.67	1.58	1.67	1.64
		7-40	0.37	0.37	0.63	
		100	2.00	1.50	1.75	
38	34.0	160	1.50	1.50	1.50	
		Average:	1.29	1.12	1.29	1.23
		8-48	2.75	2.50	2.25	
		100	1.13	1.75	2.00	
38	37.4	160	1.50	1.50	1.25	
		Average:	1.79	1.92	1.83	1.85
		9-40	1.75	1.75	1.75	
		100	2.37	1.50	2.00	
38	40.8	160	2.00	2.00	1.63	
		Average:	2.04	1.75	1.79	1.86
Grand Average:			1.95	1.66	1.58	1.73

TABLE VI

AIR CONTENT (CHACE METHOD) AVERAGES FOR EACH THIRD OF BATCH
(Expressed in Percent)

Mixing Time, Sec.	Batch Size, cu. ft.	Section and Batch No.	1st Part	2nd Part	3rd Part	Average
		1-60	4.5	4.5	4.7	
		120	5.0	5.0	4.1	
78	34.0	180	4.4	4.0	4.5	
		Average:	4.6	4.5	4.4	4.5
		2-60	4.3	4.1	4.0	
		120	5.0	4.3	5.1	
78	37.4	180	4.0	4.5	5.1	
		Average:	4.4	4.3	4.7	4.5
		3-66	5.0	4.0	5.0	
		121	5.0	4.9	4.5	
78	40.8	180	4.3	5.0	4.6	
		Average:	4.8	4.6	4.7	4.7
		4-60	4.5	4.1	4.9	
		120	4.5	3.9	5.1	
58	34.0	181	5.1	5.0	5.0	
		Average:	4.7	4.3	5.0	4.7
		5-64	4.0	4.5	4.4	
		120	5.5	5.8	5.4	
58	37.4	180	6.1	5.6	5.9	
		Average:	5.2	5.3	5.2	5.3
		6-61	5.1	4.9	5.0	
		120	6.1	5.1	5.8	
58	40.8	180	5.6	5.5	5.1	
		Average:	5.6	5.2	5.3	5.4
		7-63	5.9	6.0	5.6	
		121	6.0	6.0	6.1	
38	34.0	180	5.5	5.9	5.4	
		Average:	5.8	6.0	5.7	5.8
		8-60	5.3	6.0	5.0	
		120	5.5	5.5	5.1	
38	37.4	180	5.9	5.1	5.7	
		Average:	5.6	5.5	5.3	5.5
		9-60	6.3	5.5	6.0	
		120	6.0	5.5	6.0	
38	40.8	180	5.5	6.0	6.0	
		Average:	5.9	5.7	6.0	5.8
Grand Average:			5.2	5.0	5.1	5.1

each third of the batch. Another composite sample from the same batch of concrete was used to determine the air content by means of the Chace AE-55 Air Indicator, providing a direct comparison between the two methods. The air content was also determined on each third of three other batches sampled in each test section by use of the Air Indicator only.

In a few batches, the measured air content fell below the 4.0 percent minimum specified by the Michigan specifications, but since the air content was only slightly low, and preceding and/or subsequent batches had satisfactory air contents, no air entraining admixture was added thus avoiding an additional variable. The lower air contents were obtained, generally, in test sections 1, 2, 3, and 4, as shown in Figure 3. The other test sections had higher air contents, - approximately 5 to 6 percent. The change after section 4 may have been affected by a change in the silos from which the cement was shipped which occurred about that time.

An analysis was made, in Table VI, of the variations of the air content between the first, middle, and last portions of each batch, as determined by the Chace Method, similar to that made with the slumps. No definite pattern develops to indicate that any one portion of the batch has higher air contents than the other portions. In fact, the average range between the average air contents for the portions of batches was only 0.3 percent, which is very good considering the accuracy of the Air Indicator.

The air content as indicated by the Chace Air Indicator did not always agree too well with the value obtained by the volumetric method. In 5 of the 27 batches tested by both methods, the Air Indicator gave an air content differing from the volumetric method results by 1.0 percent or more, with the greatest difference being 2.0 percent. It is quite easy for an error to be made in performing the test with the Air Indicator, - a little alcohol may escape from the opening in the stem of the glass vial, causing too high a reading, or a large particle of aggregate may be included in the mortar in the cup, causing too low a reading. The rubber stopper may be slightly displaced during shaking causing a possible error in either direction. A few repetitions yields a fairly reliable average for the air content. The greatest difference in average air content by the two methods in any of the test sections was 0.8 percent (averages of three tests by each method). For the entire nine test sections the difference by the two methods was less than 0.1 percent (averages of 27 tests by each method).

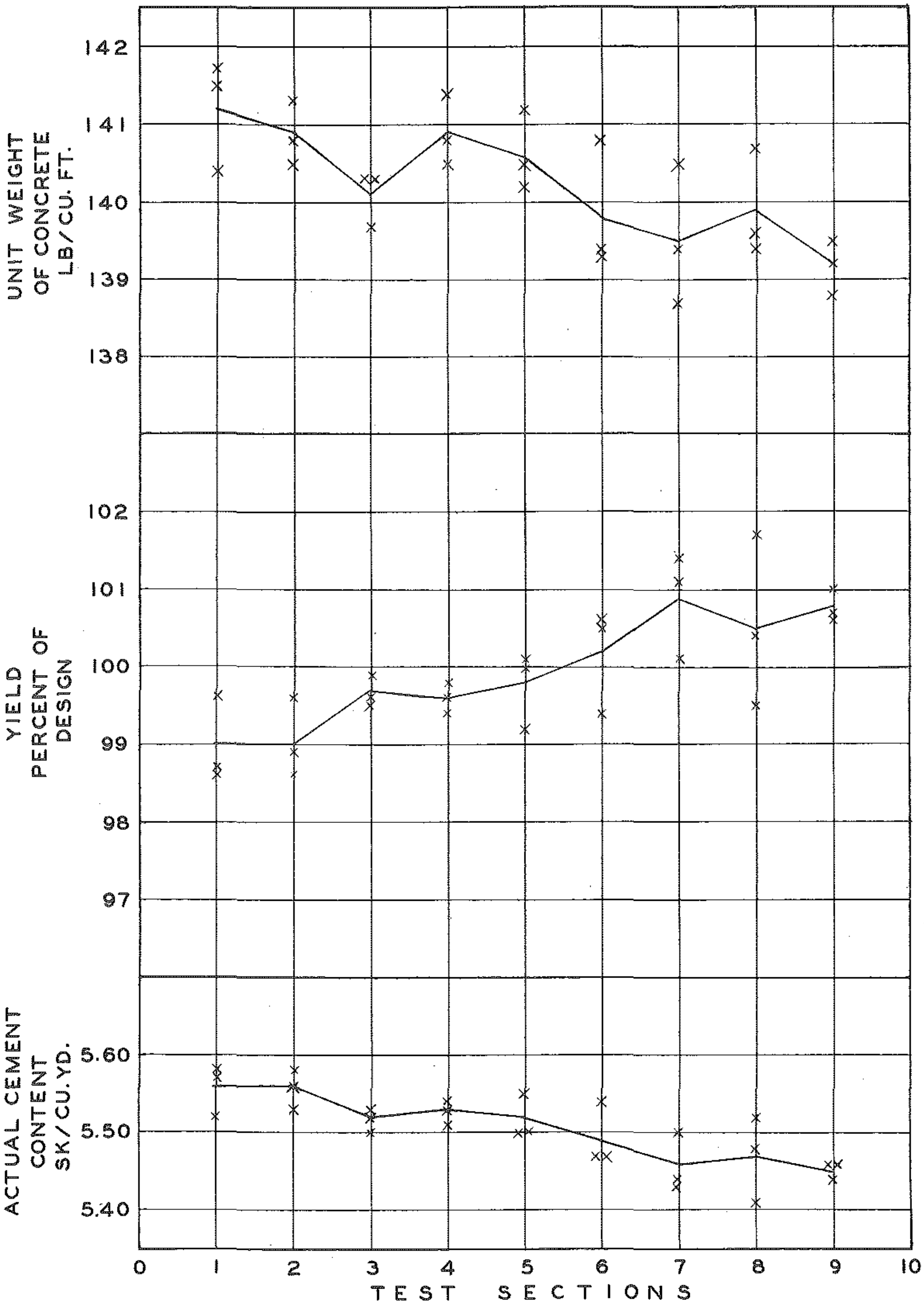

Figure 4
Unit Weight, Yield,
and Actual Cement Content of Concrete

C. Unit Weight and Yield of Concrete

The unit weight of the concrete was determined on the three portions of three batches in each test section. From these unit weights and with knowledge of the weight of materials batched, it was possible to compute the yield and actual cement content for each portion of the batch.

The unit weight, yield, and actual cement content vary from section to section (see Fig. 4) somewhat in line with the air content. In a few batches the unit weight varied quite widely between portions of the batch, but this may have been due to faulty testing procedures in striking off the surface of the concrete in the 1/2 cu. ft. measure. The average yield of batches for the various test sections ranged from 99.0 to 100.9 percent of the design quantity. The average actual cement content also was within one percent of the design cement content of 5.5 sacks per cubic yard.

There appears to be no consistent variation in regard to the unit weights and actual cement contents between the portions of the batches.

D. Gradation of Concrete Mixture

The gradation of the samples of concrete was determined by washing out the fine material, including cement, over a No. 100 sieve and then performing sieve analyses on the retained material. Results from four samples were discarded because of obviously faulty technique, two because of incomplete washing out of the cement, and two because of intermixing of the fine aggregate, by mistake, in two samples.

In general, the first portion of the batch tended to have a larger amount of the fine material and less coarse aggregate, while the third portion tended to have more coarse aggregate and less of the fine material. The variations in the material passing No. 100 sieve (i.e. cement plus water plus sand fines) averaged less than 1.5 percent between the first portion and last portion of the batch.

To obtain a single value to represent the grading of each sample of the concrete that was washed, a "grading factor" was calculated. This grading factor, used by Walker and Bloem (2), is the sum of the cumulative percentages, by weight of the fresh concrete, passing twelve sieves - the 2, 1-1/2, 1, 3/4, 1/2, and 3/8 inch, No. 4, 8, 16, 30, 50, and 100. The finer the material in the sample, the higher will be the grading factor.

TABLE VII

GRADING FACTOR AVERAGES FOR EACH THIRD OF BATCH

Mixing Time, Sec.	Batch Size, cu.ft.	Section and Batch No.	1st Part	2nd Part	3rd Part	Range
		1-60	755	735	715	
		120	744	717	660*	
78	34.0	180	757	712	661*	
		Average:	752	721	715	37
		2-60	756	726	744	
		120	776	753	750	
78	37.4	180	749	717	680	
		Average:	760	732	725	35
		3-66	732	721	694	
		121	730	731	734	
78	40.8	180	749	735	716	
		Average:	737	729	715	22
		4-60	742	718	727	
		120	792	761	758	
58	34.0	181	766	766	693	
		Average:	767	748	726	41
		5-64	727	740	745	
		120	721	714	715	
58	37.4	180	743	718	715	
		Average:	730	724	725	6
		6-61	752	728	735	
		120	753	735	734	
58	40.8	180	756	737	740	
		Average:	754	733	736	21
		7-63	756	746	725	
		121	753	741	740	
38	34.0	180	747	713	728	
		Average:	752	733	731	21
		8-60	761	729	742	
		120	759	748	726	
38	37.4	180	772	757	737	
		Average:	764	745	735	29
		9-60	744	770*	705*	
		120	736	739	747	
38	40.8	180	764	744	724	
		Average:	748	742	736	12
Grand Average:			752	734	727	25

*Faulty Sample, not included in average

In every test section, the grading factors from the first portion of the batches averaged higher than the factors for the middle and last portions, indicating finer material during initial discharge as seen from Table VII. On the average, the sample from the first part of the batch had about 2 percent more material passing each sieve than the sample from the last part of the batch. This tendency towards fineness in the first portion of the batch is quite evident from the ratio of sand to total aggregate shown in Table VIII. In every section the percentage of sand is greatest at the beginning of discharge. The last two portions of the batch are more in agreement. While the percentage of sand appears high, it must be remembered that the coarse aggregate was slag and had a relatively low specific gravity.

Another approach to gradation variability is to study the resulting values of b/b_o (volume of dry, loose coarse aggregate per unit volume of concrete) for each portion of the batch. The concrete mix was designed using a value of 0.78 but the actual values within the batch (assuming uniform unit weight) ranged from 0.74 to 0.83, as shown in Table IX. Again, the first portion of the batch is indicated as having the lowest coarse aggregate content, while the second and third portions have nearly equal amounts. One aspect which should be noted is that, with the paver operating outside of the forms, the first portion of the batch is deposited next to the form near the paver, resulting in a more sandy mix at the one edge of the pavement. How much effect the spreaders may have in correcting this non-uniformity is not known.

The percentages of the coarse aggregate (retained on No. 4 sieve), the fine aggregate (passing the No. 4, retained on No. 100 sieve), and cement plus water plus fines (passing No. 100 sieve) for each sample are shown graphically in Fig. 5. The observed variations in the grading <u>between</u> test sections and even <u>between</u> batches within a test section presumably reflect minor variations in the grading of the material furnished to the mixer. There is a tendency toward smaller <u>within</u> batch variations in the larger size batches.

E. <u>Strength of Concrete</u>

The strength of the concrete was determined in three ways, (1) by compression testing at 28 days' age of standard 6x12 inch cylinders molded from the fresh concrete, (2) by testing 6x6x36 inch beams in flexure at 28 days' age, and (3) by compression testing at 90 days' age of cores drilled from the pavement. The results of these tests are shown in Figure 6.

TABLE VIII

FINE AGGREGATE AS PERCENT OF TOTAL AGGREGATE

Test Section	1st Portion	2nd Portion	3rd Portion
1	45.1	41.6	41.7*
2	45.9	43.5	42.4
3	44.7	42.9	41.6
4	49.0	45.7	44.0
5	41.8	40.6	41.4
6	46.5	44.3	44.7
7	46.8	44.2	43.7
8	46.9	43.1	43.6
9	45.4	44.3**	44.4**
Average:	45.8	43.4	43.1

* One value only
** Average of two values only

TABLE IX

ACTUAL b/b_o* VALUES FOR EACH PORTION OF BATCH

Test Section	1st Portion	2nd Portion	3rd Portion
1	0.74	0.80	0.80
2	0.74	0.79	0.80
3	0.76	0.78	0.80
4	0.74	0.77	0.83
5	0.77	0.79	0.78
6	0.76	0.80	0.79
7	0.75	0.79	0.80
8	0.74	0.79	0.81
9	0.77	0.78	0.79
Average:	0.75	0.79	0.80

* Volume of dry, loose coarse aggregate per unit volume of concrete

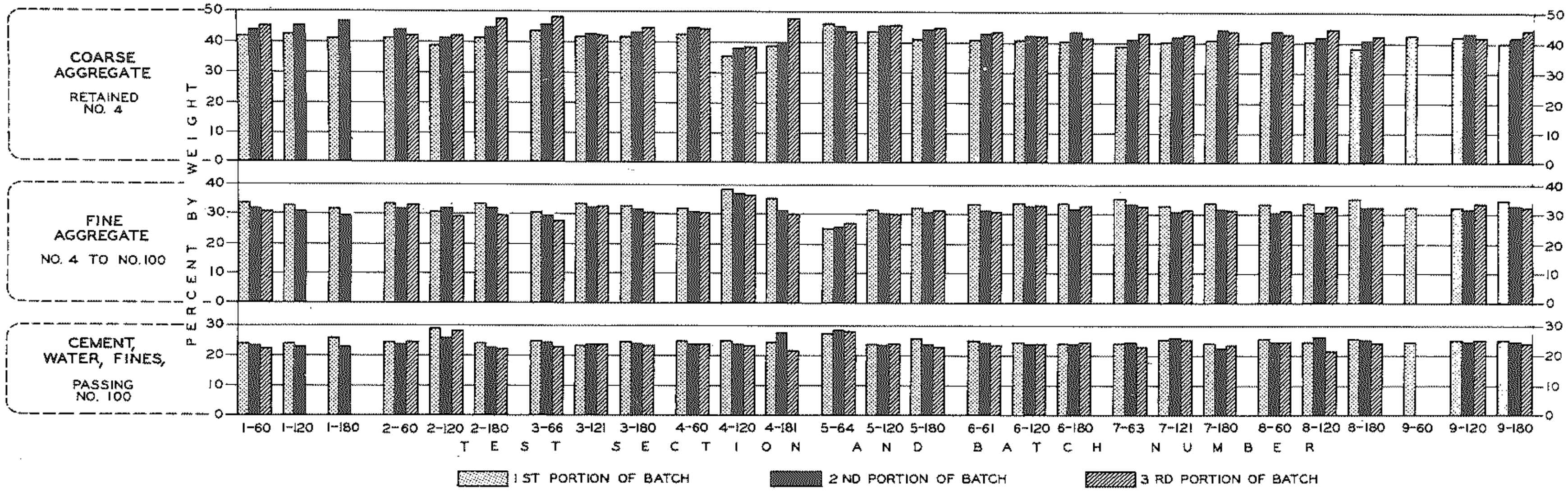

Figure 5. Major Components of Paving Mixes from Washout and Grading Tests

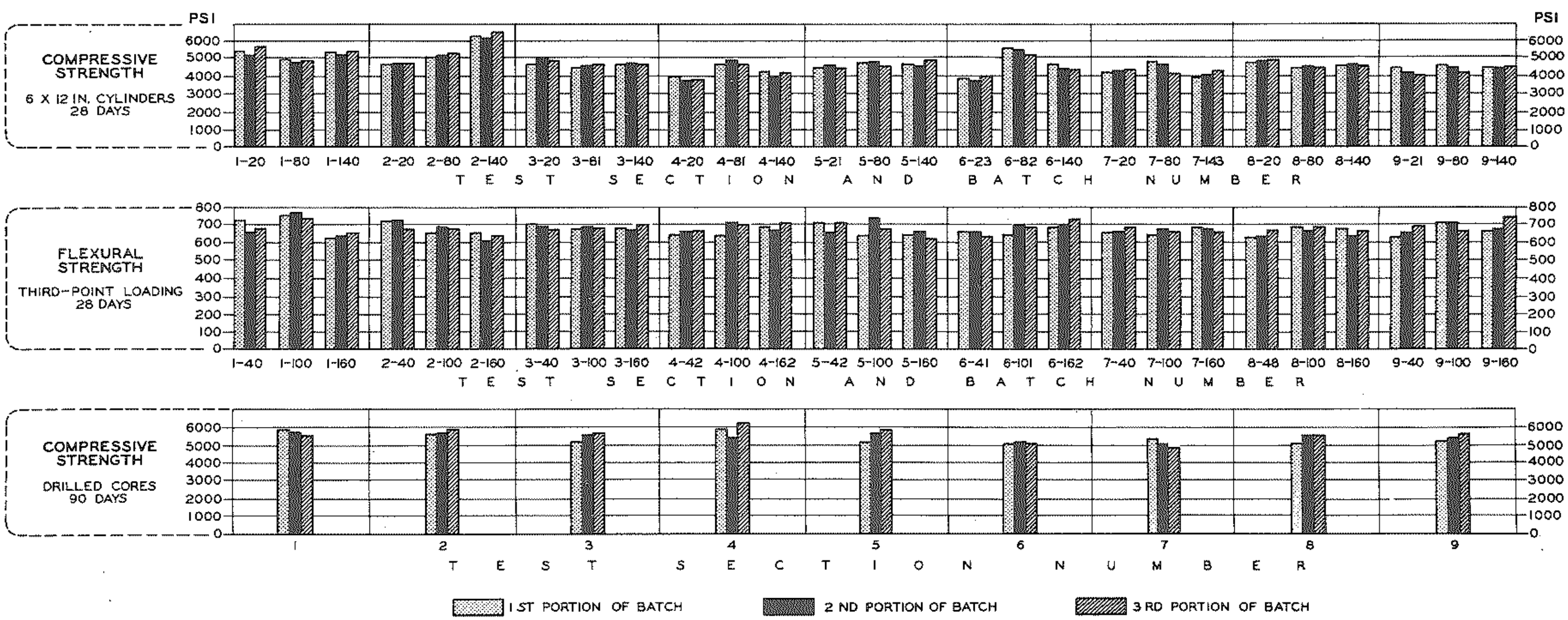

Figure 6. 28-Day Strength of Test Cylinders and Beams and 90-Day Strength of Drilled Cores

In all cases, the compressive strengths of the cylinders were above the Michigan requirement of 3500 psi, the averages for each batch ranging from about 3800 to over 6000 psi. The variations within each batch were not large, the greatest being 383 psi. The variation between batches within a test section were considerably larger, ranging up to 1600 psi.

The average flexural strength of laboratory cured specimens in the various test sections ranged from 660 to 695 psi when tested under third-point loading at 28 days. The flexural strength results from testing under third-point loading will be lower, possibly by more than 12 percent (3), than if center-point loading were used, as provided for in Michigan specifications. The advantage with the use of third-point loading is the constant moment over the center one-third of the span, permitting the concrete to fail in the weakest point and giving more uniform results. It was for this reason, and to give a better basis for nation-wide comparison, that third-point loading was selected in preference to center-point loading in this study. The flexural strengths are quite uniform, both within batch and between batches.

The 90-day strengths of the cores drilled from the pavement, shown in Table IX-A, provide indication of the compressive strength of the concrete in place. The average strengths of all of the test sections are in quite good agreement, ranging from 5060 to 5795 psi with a grand average of 5450 psi. The range of strengths of cores within a test section was greater in some cases, but such variation was not excessive.

For both the compressive strength of cylinders and flexural strength of beams, there is no clear pattern showing that any one portion of the batch has strengths consistently superior to any other portion of the batch. The compressive and flexural strength results were used to rank the various portions of the batches from highest strength to lowest strength. The results are shown in Table X.

In seven sections, the portion of the batch with the highest compressive strength had the lowest flexural strength, and the portion with the lowest compressive strength had the highest flexural strength. In one test section, there was complete agreement between compressive and flexural strengths and in one test section there was partial agreement. The compressive and flexural strength test specimens were not made from the same batches of concrete, but averaging the test results of each strength test from three batches in each section should produce fairly reliable values. In view of the small range in the strengths for each section (about 5 percent of the average strengths, maximum variation), and the random order in which portions of batches are high or low, there seems to be no reason to believe that the observed consistent variations in the slump or grading have corresponding effects on the flexural or compressive strengths.

TABLE X

COMPARISON OF RANKING OF FLEXURAL STRENGTHS AND COMPRESSIVE STRENGTHS FOR EACH PORTION OF BATCH FOR EACH TEST SECTION

Mixing Time, Sec.	Batch Size, cu. ft.	Test Section	Portion of Batch with Highest and Lowest Compressive Strength		Flexural Strength	
			High	Low	High	Low
78	34.0	1	3	2	1	2
78	37.4	2	3	1	1, 2*	3
78	40.8	3	2	1	1	2, 3*
58	34.0	4	1	2, 3*	3	1
58	37.4	5	2	1	2	1
58	40.8	6	1	3	3	1
38	34.0	7	2	3	3	1, 2*
38	37.4	8	2	1	1	2
38	40.8	9	1	3	3	1

*Tie

F. Water Content of Concrete

The average net water in the concrete varied a maximum of about 3/4 gallon per sack of cement between the various test sections or 3.5 gallons per cubic yard of concrete. This compares with a batch-to-batch variation within a test section of 0.3 gallon per sack maximum, except for test section 8. These variations are actually quite small when it is considered that a change of one percent in the moisture in the aggregate would mean a corresponding change of about 3.5 gallons per cubic yard in the concrete. While the attempt is made to get a representative sample for moisture determinations, there may be variations within the stockpile. These factors would affect batch-to-batch variations over a relatively short period of time.

Changes in water requirements over a longer period of time would result mainly from changes in materials. Slag from one source may have absorption values varying over a range of 1 or 2 percent. Changes in properties of the cement, or in grading of the aggregates, may effect a change in the water requirement. The unit weight of the coarse aggregate varied somewhat requiring adjustments in the batch weights so that test sections 7, 8, and 9 had proportionately more sand and less coarse aggregate, and test section 1 had proportionately less sand and more coarse aggregate, than sections 2, 3, 4, 5, and 6. The amounts of these variations can be seen by examination of Table VIII-A.

There does not appear to be any significant difference in water requirement for the different size batches at a given mixing time. However, as the mixing time decreases, the water requirement tends to increase from, on the average, 5.62 gallons per sack for the 78 second mixing time, to 6.02 gallons per sack for the 58 second mixing time, to 6.13 gallons per sack for the 38 second mixing time. The significance of this variation is questionable since it may be due entirely to changes in the material weights or characteristics mentioned previously. Variations in the strength due to the variations in water-cement ratio appear to be masked by variations in air content, or by other factors. It seems necessary to speculate that in a full scale paving operation such as this, possibly slump variations observed are not indicative of water-cement ratio changes that would be detected by compressive strength variations but are rather the result of changes in aggregate gradation. We tend possibly to overstress improper slump as being due to incorrect water content due to the familiar observation that slump can always be changed by suitable revisions in water. Persistent downswings of slump which must be compensated for by adding water should be viewed with suspicion if simultaneously there is positive indication of change in water-cement ratio. In view of uncertainties regarding absorption, free water on aggregates, calibration of water meter system, etc., water-cement ratio on a paving operation is one of the values least amenable to accurate determination.

G. Temperature of Concrete

The temperature of the concrete, presented in Table X-A, indicates only a small variation in line with the air temperature. There is generally not more than 4F temperature variation within a test section. The air temperatures given are approximate averages of the temperature during the time of placing the concrete in each section.

CONCLUSIONS

The uniformity of the consistency of the concrete provided by the 34E dual drum mixer used in this study appears to be affected to some extent by the size of batch. Irrespective of batch size or mixing time, however, there is a consistent variation in the slumps within a batch, the first portion of the batch generally having a higher slump than the last portion. The batches with 20 percent overload had the greatest variation in slump, usually in excess of one inch, indicating that at least a portion of the batch must, of necessity, be outside of specification limits. The ball penetration results are inconclusive with respect to uniformity of the concrete as influenced by batch size.

The gradation of the aggregate in the concrete mixture varies similarly to the slump, in that the first portion of the batch out of the mixer generally is finer.

The water content of the concrete has some variation from section to section with an indication, at least superficially, that the shorter mixing times require more water. However, further investigation might indicate that the greater amounts of water used in the mixes with shorter mixing times may have been inadvertent and due to chance. During the course of this study, there were changes made in the sand-total aggregate ratio which would be expected to change the water demand.

In addition to the results presented above, there are additional factors to be considered in regard to batch size and mixing time limitations.

(1) The mixer used was designed to contain 34.0 cubic feet of concrete per batch. Excessive overloads may cause increased wear, especially in the wearing ring at the discharge end of the drum which would permit increased loss of mortar if not properly maintained. There is a greater tendency for spillage of materials while dumping the larger batches into the mixer skip if the batch trucks are not positioned properly. Very stiff consistency mixes may bulk up so that the paver bucket may not be able to hold an entire batch.

(2) The batchmeter on this paver could not be set for less than 50 seconds. Shorter mixing times would require excessive manual operation of the mixer cycle and there would be no positive control of the mixing time as is done presently by the batchmeter. Batchmeters could undoubtedly be made with adjustment for shorter mixing times.

(3) This study as conducted by the Michigan State Highway Department was on one mixer (in very good condition) with one combination of materials. It would be highly desirable to know what effects, if any, may be caused by mixers made by other manufacturers, use of mixers in poorer condition, other types of coarse aggregate, or other variables. Perhaps some of the answers will be developed by other agencies cooperating in this program.

Acknowledgments:

This project was a combined effort of Road Construction and Testing and Research. Road Construction activities were supervised by Frank Engle, Project Engineer, who enthusiastically supported the testing work. All testing activities were under the direct charge of Ralph Vogler, Physical Testing Engineer, who also analyzed the data and prepared the final report. James Hampton aided in the early planning of the testing program. General supervision of the testing program was given by Frank Legg, Materials Consultant. The Denton Construction Company aided in every way to make the testing program a success. Particular thanks are due M. Palmer, Superintendent, of the Denton Company.

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2. S. Walker and D. L. Bloem, Tests of Concrete Truck Mixers, Publication No. 50, National Ready Mixed Concrete Association, 1954.

3. W. F. Kellermann "Effect of Size of Specimen, Size of Aggregate, and Method of Loading Upon the Uniformity of Flexural Strength Tests," Public Roads, Vol. 13, No. 11 January, 1933, p. 177.

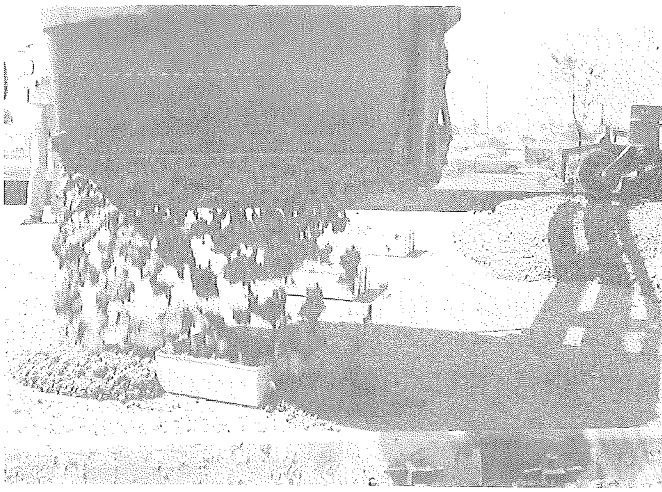

Figure 7. Depositing the Concrete From the Paver Bucket Into the First Collecting Pan.

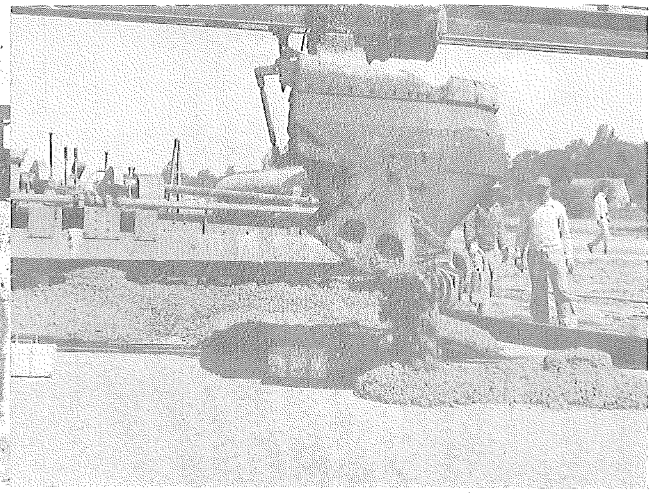

Figure 8. Some Concrete is Discharged on the Subgrade Before Filling the Second Pan with Concrete From the Middle of the Batch.

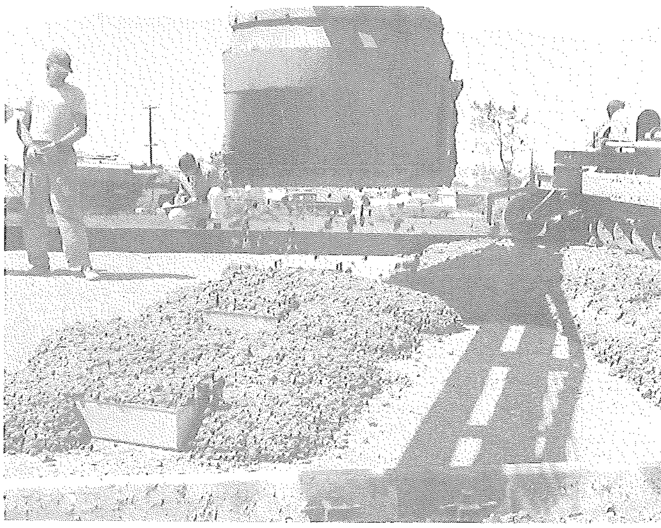

Figure 9. With Most of the Concrete Out of the Bucket, the Gate is Closed Until the Bucket is Moved Over the Third Collecting Pan.

Figure 10. Measuring the Slump of the Concrete.

Figure 11. Three Compression Test Cylinders Were Molded From Each of the Three Samples in the Batch.

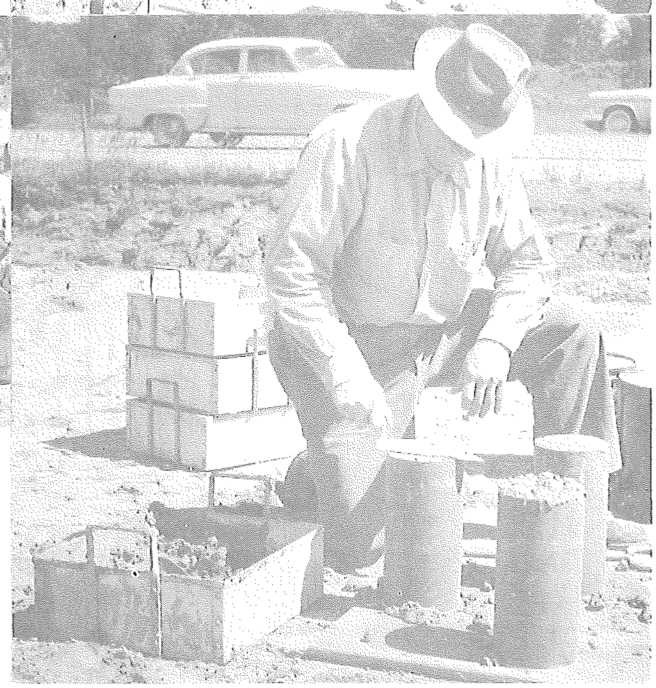

Figure 12. Smoothing the Tops of the Cylinders. The Five Gallon Cans were Used for Transporting Concrete Samples to the Laboratory for Washout Tests.

Figure 13. Testing to Determine the Air Content of Concrete by the Volumetric (Roll-A-Meter) Method.

Figure 14. Concrete Consistency Was Measured by the Ball Penetration Method and the Same Concrete Used for a Unit Weight Determination.

Figure 15. Following the Unit Weight Determination, the Concrete Was Used to Mold One Flexural Test Beam From Each Pan.

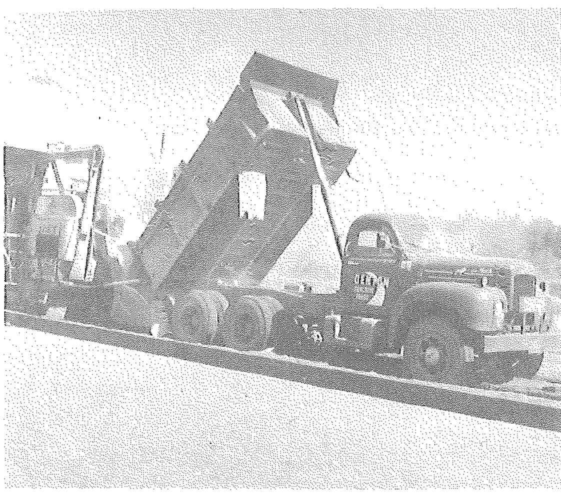

Figure 16. Concrete Materials Were Brought to the Paver in a Fleet of Four-Batch Trucks.

Figure 17. The Paver Has Just Deposited a Batch of Concrete, While the Spreader Levels the Bottom Course. Note the Load Transfer Dowel Assembly. Man in Foreground Recorded All Field Data.

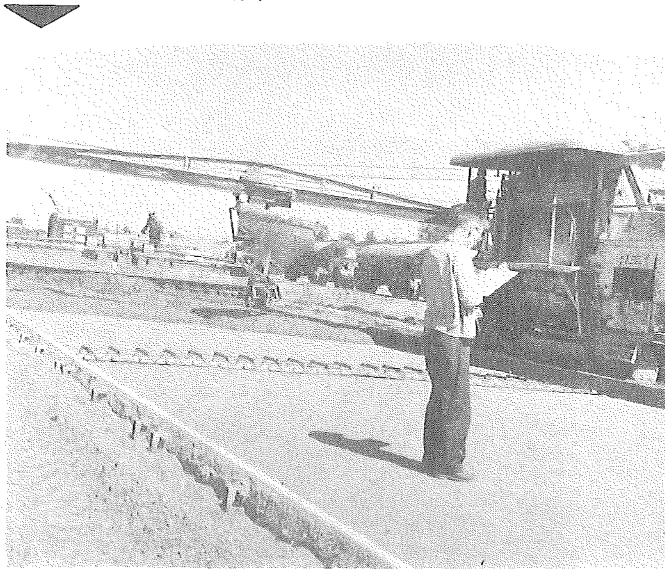

Figure 18. The Spreader Levels the Concrete for the Placing of Steel Reinforcing Mesh, After Which the Top Course of Concrete is Placed.

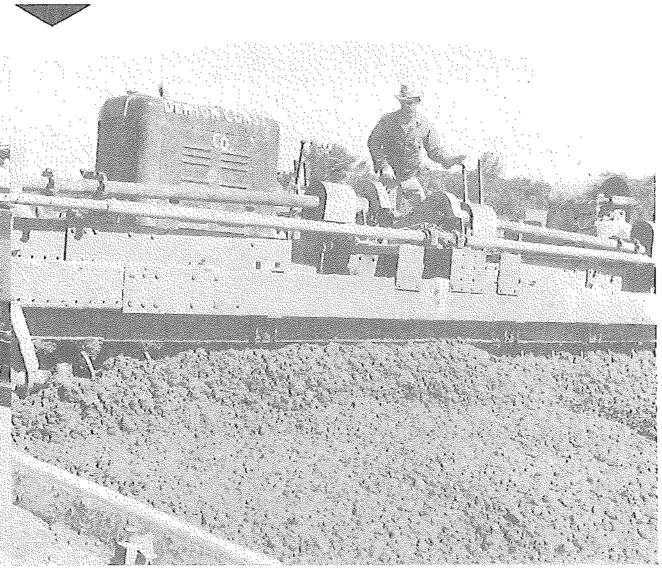

Figure 19. After Partial Smoothing by the Second Spreader, the Finisher-Float Combination Completes the Mechanical Finishing of the Concrete.

Figure 20. Hand Finishing Operations Touch Up Any Minor Variations in the Pavement Surface. The Canvas Belt and Burlap Drag Provide the Final Finish.

Figure 21. The Curing Compound Spreader Brings Up the Rear of the Paving Train.

APPENDIX

TABLE I - A

SUMMARY - RESULTS OF TESTS ON FRESH CONCRETE AND HARDENED CONCRETE SPECIMENS

	Section No.	Slump, in.	Air Content, Percent			Compressive Strength, psi	Ball Penetration, in.	Unit Weight of Concrete lb/cu ft	Yield of Batch, cu ft	Yield, Percent of Design	Actual Cement Content sk/cu yd	Flexural Strength, psi	Water Content	
			Volumetric Method	Chace * Meter #1	Chace ** Meter #2								gal/cu yd	gal/sk
Average	1	1.14	4.4	4.3	4.5	5265	1.33	141.2	33.66	99.0	5.56	695	31.4	5.62
	2	1.70	4.0	3.8	4.5	5400	1.73	140.9	37.03	99.0	5.56	665	30.6	5.54
	3	2.43	5.4	4.6	4.7	4725	1.93	140.1	40.67	99.7	5.52	675	31.4	5.69
	4	4.54	3.9	4.3	4.7	4270	2.01	140.9	33.86	99.6	5.53	675	33.4	6.05
	5	2.31	4.8	5.4	5.3	4655	1.98	140.6	37.32	99.8	5.52	670	33.4	6.06
	6	1.85	5.7	5.0	5.4	4630	1.64	139.8	40.86	100.2	5.49	675	32.6	5.94
	7	1.56	5.5	5.6	5.8	4360	1.24	139.5	34.30	100.9	5.46	670	34.1	6.26
	8	1.25	4.9	4.9	5.5	4705	1.85	139.9	37.61	100.5	5.47	660	33.5	6.12
	9	2.13	5.3	5.5	5.8	4480	1.86	139.2	41.11	100.8	5.45	690	32.9	6.02
Batch to Batch Variation (Range of Averages)	1	1.24	0.3	0.5	0.4	530	0.67	1.3	0.37	1.0	0.06	120	1.3	0.24
	2	1.67	1.2	1.2	0.7	1600	0.75	0.8	0.38	1.0	0.05	70	1.6	0.30
	3	0.38	0.1	0.6	0.2	310	0.22	0.6	0.19	0.4	0.03	5	0.5	0.08
	4	5.29	1.8	1.1	0.5	930	0.08	0.9	0.21	0.7	0.03	40	1.6	0.29
	5	0.37	0.7	1.0	1.6	160	0.63	1.0	0.32	0.9	0.05	55	1.2	0.24
	6	2.00	2.2	1.1	0.7	1560	0.50	1.5	0.49	1.2	0.07	60	0.9	0.18
	7	0.46	0.8	1.0	0.4	505	1.29	1.8	0.45	1.3	0.07	45	1.3	0.24
	8	0.13	0.5	0.2	0.2	380	1.08	1.3	0.82	2.2	0.11	40	4.5	0.85
	9	1.46	0.7	1.0	0.1	310	0.21	0.7	0.14	0.4	0.02	40	1.1	0.20
Within Batch Variation (Average of Ranges)	1	0.88	-	-	0.5	257	0.58	0.9	0.21	0.6	0.04	47	-	-
	2	1.25	-	-	0.7	228	0.50	0.6	0.16	0.5	0.02	42	-	-
	3	1.54	-	-	0.7	185	0.75	0.6	0.16	0.4	0.03	23	-	-
	4	0.71	-	-	0.7	255	0.71	1.8	0.42	1.2	0.07	38	-	-
	5	1.29	-	-	0.5	215	0.79	1.2	0.33	0.8	0.05	68	-	-
	6	0.92	-	-	0.6	308	0.25	0.7	0.21	0.5	0.03	45	-	-
	7	0.66	-	-	0.3	383	0.25	0.6	0.15	0.4	0.02	32	-	-
	8	0.41	-	-	0.7	117	0.54	0.8	0.22	0.6	0.03	48	-	-
	9	1.75	-	-	0.6	280	0.41	1.1	0.32	0.8	0.04	63	-	-

* Tests performed on batches 20, 80, and 140, each test section.
** Tests performed on batches 60, 120, and 180, each test section.

TABLE II - A

SUMMARY - RESULTS OF WASHOUT AND GRADING TESTS

	Section No.	Percent by Weight of Fresh Concrete														Grading Factor
		Coarse Agg Retained #4	Fine Agg #4 - #100	Gradation - Percent Passing												
				2"	1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	
Average	1	44.2	31.8	99.7	95.8	86.0	78.5	66.2	61.1	55.8	50.7	45.4	39.5	30.6	24.1	734
	2	42.8	31.9	98.8	94.5	84.4	78.3	66.9	62.1	57.2	52.3	46.6	40.7	31.8	25.2	739
	3	44.0	31.6	98.6	93.8	83.4	76.7	65.5	60.6	56.0	51.2	45.6	39.9	31.1	24.4	727
	4	41.4	33.9	99.5	95.7	85.4	78.4	67.9	63.5	58.6	53.3	47.3	41.0	31.6	24.8	747
	5	44.5	29.8	98.9	94.2	83.7	75.8	64.2	59.7	55.5	49.9	45.6	40.2	31.9	25.7	726
	6	42.3	33.1	98.9	94.7	85.4	78.6	67.3	62.5	57.7	52.5	46.8	40.7	31.4	24.6	741
	7	42.4	33.0	99.2	94.5	84.4	78.1	67.1	62.5	57.6	52.5	46.6	40.5	31.3	24.6	739
	8	42.5	32.7	99.8	96.4	86.3	79.8	67.8	62.5	57.5	52.8	47.0	41.2	31.8	24.9	748
	9	42.8	32.4	99.5	95.4	85.1	78.1	66.5	61.6	57.2	52.6	47.1	41.4	31.9	24.8	742
Batch to Batch Variation (Range of Averages)	1	0.3	1.4	0.2	0.8	0.6	1.1	1.6	0.9	0.3	0.4	0.2	0.4	1.2	1.4	4
	2	3.7	2.0	1.9	3.4	4.0	3.1	3.4	3.4	3.7	4.0	4.0	4.1	4.6	4.5	45
	3	3.4	3.7	1.3	1.7	0.6	2.0	3.1	3.7	3.4	2.9	1.8	1.3	0.6	0.4	17
	4	6.6	6.2	0.9	1.2	2.4	4.1	7.6	7.7	6.6	5.2	4.1	2.9	1.7	0.9	41
	5	1.5	5.3	0.9	2.4	1.3	1.6	1.6	0.7	1.5	1.1	1.7	2.6	3.7	4.2	20
	6	0.6	1.5	0.8	1.3	1.3	1.8	0.7	0.3	0.6	0.8	0.7	0.9	0.8	0.8	6
	7	1.8	2.2	0.6	0.8	0.3	0.4	2.0	2.1	1.8	1.7	2.4	2.4	2.2	2.3	16
	8	1.6	1.3	0.1	1.5	1.2	1.8	1.9	1.6	1.6	2.5	1.7	1.9	1.0	0.9	11
	9	1.4	1.6	0.2	1.7	1.6	0.3	0.9	1.0	1.4	0.8	0.6	0.9	0.9	0.5	4
Within Batch Variation (Average of Ranges)	1	4.1	2.2	0.4	2.0	2.9	4.3	4.5	4.3	4.1	3.6	3.7	3.2	2.7	1.9	37
	2	4.0	2.9	2.3	2.5	5.3	5.7	4.8	4.3	4.0	3.9	3.9	3.7	3.1	2.4	42
	3	2.8	2.1	1.2	2.4	3.2	2.5	3.1	2.9	2.8	2.7	2.5	2.1	1.5	1.1	25
	4	4.5	2.9	0.7	2.8	5.0	5.8	5.4	5.1	4.6	4.8	3.7	3.3	3.2	2.9	34
	5	2.6	1.6	1.2	1.1	1.2	1.7	2.4	2.7	2.6	3.1	1.7	1.5	1.3	1.3	18
	6	2.1	1.8	1.2	2.7	3.5	2.4	2.3	2.4	2.1	1.6	1.7	1.4	0.8	0.4	21
	7	2.9	2.3	1.2	2.8	3.0	3.5	3.3	3.2	2.9	3.2	2.3	1.9	1.2	1.1	26
	8	4.1	3.0	0.5	1.2	3.2	4.1	4.5	4.5	4.1	3.6	3.2	2.6	2.3	2.3	33
	9	2.4	1.9	1.1	2.0	3.4	3.3	2.6	2.4	2.4	2.9	1.6	1.4	1.2	0.9	26

TABLE III - A

RESULTS OF TESTS ON FRESH CONCRETE AND HARDENED CONCRETE SPECIMENS

Test Section	Portion of Batch	Batch No.	Slump, in.	Air Content Percent		Compressive Strength, psi (28 days)				Water Content		Batch No.	Ball Penetration, in.	Unit Wt. of Concrete lb/cu ft	Yield of Batch cu ft	Yield, Percent of Design	Actual Cement Content sk/cu yd	Flexural Strength, psi (28 days)			Water Content		Batch No.	Air Content Percent, Chace Meter	Water Content	
				Volumetric Method	Chace Meter	1	2	3	Avg.	gal/cu yd	gal/sk							1	2	Avg.	gal/cu yd	gal/sk			gal/cu yd	gal/sk
TEST SECTION 1 (34.0 cu. ft. - 78 sec. total mixing time)	First		0.88			5300	5830	5475	5535				1.25	141.0	33.64	98.9	5.56	750	705	730				4.5		
	Middle		0.38			5390	5210	5035	5210				1.00	140.8	33.69	99.1	5.55	685	645	665				4.5		
	Last	20	0.38			6005	5565	5655	5740			40	0.75	142.7	33.24	97.8	5.63	685	690	690			60	4.7		
	Average		0.55	4.2	4.5				5495	28.9	5.20		1.00	141.5	33.52	98.6	5.58			695	30.6	5.48		4.6	31.7	5.70
	Range		0.50						530				0.50	1.9	0.45	1.3	0.08			65				0.2		
	First		2.38			5035	4860	5125	5005				2.00	141.4	33.64	98.9	5.56	785	720	755				5.0		
	Middle		1.75			4945	5125	4680	4915				1.00	141.6	33.59	98.8	5.57	760	775	770				5.0		
	Last	80	1.25			4860	4945	5125	4975			100	1.00	142.1	33.47	98.4	5.59	780	685	735			120	4.1		
	Average		1.79	4.5	4.5				4965	31.7	5.70		1.33	141.7	33.57	98.7	5.57			755	31.8	5.71		4.7	31.7	5.70
	Range		1.13						90				1.00	0.7	0.17	0.5	0.03			35				0.9		
	First		1.50			5390	5475	5300	5390				1.75	140.4	33.88	99.6	5.52	670	560	615				4.4		
	Middle		1.25			5210	5125	5390	5240				1.75	140.3	33.90	99.7	5.52	640	640	640				4.0		
	Last	140	0.50			5655	5390	5125	5390			160	1.50	140.4	33.88	99.6	5.52	650	655	655			180	4.5		
	Average		1.08	4.5	4.0				5340	31.7	5.70		1.67	140.4	33.89	99.6	5.52			635	31.5	5.71		4.3	31.7	5.70
	Range		1.00						150				0.25	0.1	0.02	0.1	0.00			40				0.5		
	Grand Average		1.14	4.4	4.3				5265	30.8	5.53		1.33	141.2	33.66	99.0	5.56			695	31.3	5.63		4.5	31.7	5.70
TEST SECTION 2 (37.4 cu. ft. - 78 sec. total mixing time)	First		2.75			4595	4860	4505	4655				1.75	141.2	36.90	98.7	5.57	715	710	715				4.3		
	Middle		3.75			4595	4770	4945	4770				1.25	141.5	36.82	98.4	5.59	675	755	715				4.1		
	Last	20	1.38			4860	4415	4945	4740			40	1.13	141.3	36.87	98.6	5.58	680	660	670			60	4.0		
	Average		2.63	3.9	4.2				4720	31.4	5.64		1.38	141.3	36.86	98.6	5.58			700	30.4	5.45		4.1	30.3	5.45
	Range		2.37						115				0.62	0.3	0.08	0.3	0.02			45				0.3		
	First		2.00			4910	5035	5125	5025				1.75	140.5	37.08	99.1	5.55	635	665	650				6.0		
	Middle		1.25			5300	4945	5210	5150				1.75	140.4	37.11	99.2	5.55	690	680	685				4.3		
	Last	80	1.25			5035	5565	5300	5300			100	1.50	141.4	36.85	98.5	5.58	700	655	680			120	5.1		
	Average		1.50	4.7	4.2				5160	29.9	5.38		1.67	140.8	37.01	98.9	5.56			670	30.3	5.45		4.8	30.3	5.45
	Range		0.75						275				0.25	1.0	0.26	0.7	0.03			35				0.8		
	First		1.25			6625	6450	5830	6300				2.50	140.3	37.28	99.7	5.52	670	630	650				4.0		
	Middle		0.63			6360	6185	6005	6185				2.00	140.3	37.28	99.7	5.52	625	585	605				4.5		
	Last	140	1.00			6715	6450	6270	6480			160	1.88	140.8	37.15	99.3	5.54	615	655	635			180	5.1		
	Average		0.96	3.5	3.0				6320	30.3	5.45		2.13	140.5	37.24	99.6	5.53			630	31.9	5.77		4.5	32.1	5.77
	Range		0.62						295				0.62	0.5	0.13	0.4	0.02			45				1.1		
	Grand Average		1.70	4.0	3.8				5400	30.5	5.49		1.73	140.9	37.03	99.0	5.56			665	30.9	5.56		4.5	30.9	5.56
TEST SECTION 3 (40.8 cu. ft. - 78 sec. total mixing time)	First		2.25			4595	4770	4770	4710				2.25	139.4	40.85	100.1	5.49	-*	700	700				5.0		
	Middle		1.50			4945	5035	5210	5065				2.00	139.5	40.82	100.0	5.50	700	655	680				4.0		
	Last	20	2.88			4595	4945	5125	4890			40	1.50	140.1	40.65	99.6	5.52	685	645	665			66	5.0		
	Average		2.21	5.5	5.0				4890	31.2	5.66		1.92	139.7	40.77	99.9	5.50			680	31.1	5.66		4.7	31.2	5.66
	Range		1.38						355				0.75	0.7	0.20	0.5	0.03			35				1.0		
	First		3.25			4595	4505	4415	4505				2.38	140.1	40.65	99.6	5.52	705	635	670				5.0		
	Middle		2.63			4770	4595	4415	4595				1.63	140.9	40.42	99.1	5.55	660	695	680				4.9		
	Last	81	1.63			4490	4770	4680	4645			100	2.13	140.0	40.68	99.7	5.51	625	720	675			121	4.5		
	Average		2.50	5.4	4.5				4580	31.2	5.66		2.05	140.3	40.58	99.5	5.53			675	31.3	5.66		4.8	31.5	5.72
	Range		1.62						140				0.75	0.9	0.26	0.6	0.04			10				0.5		
	First		3.13			4595	4680	4770	4680				2.25	140.3	40.65	99.6	5.52	705	645	675				4.3		
	Middle		1.50			4595	4680	4945	4740				1.50	140.3	40.65	99.6	5.52	665	660	665				5.0		
	Last	140	3.13			4680	4770	4595	4680			160	1.75	140.2	40.68	99.7	5.51	690	-*	690			180	4.6		
	Average		2.59	5.4	4.4				4700	31.5	5.72		1.83	140.3	40.66	99.6	5.52			675	31.9	5.78		4.6	31.5	5.72
	Range		1.63						60				0.75	0.1	0.03	0.1	0.01			25				0.7		
	Grand Average		2.43	5.4	4.6				4725	31.3	5.68		1.93	140.1	40.67	99.7	5.52			675	31.4	5.70		4.7	31.4	5.70

*Faulty test, not included in average.

TABLE III - A (Continued)

RESULTS OF TESTS ON FRESH CONCRETE AND HARDENED CONCRETE SPECIMENS

Test Section	Portion of Batch	Batch No.	Slump in.	Air Content Percent		Compressive Strength, psi (28 days)				Water Content		Batch No.	Ball Penetration in.	Unit Wt. of Concrete, lb/cu ft	Yield of Batch cu ft	Yield, Percent of Design	Actual Cement Content sk/cu yd	Flexural Strength, psi (28 days)			Water Content		Batch No.	Air Content Percent, Chace Meter	Water Content	
				Volumetric Method	Chace Meter	1	2	3	Avg.	gal/cu yd	gal/sk							1	2	Avg.	gal/cu yd	gal/sk			gal/cu yd	gal/sk
TEST SECTION 4 (34.0 cu. ft. - 58 sec. total mixing time)	First		7.75			4065	3885	3975	3975				2.75	140.5	33.99	100.0	5.50	595	685	640				4.5		
	Middle		7.50			4065	3535	3710	3770				1.38	141.1	33.85	99.6	5.53	740	565	655				4.1		
	Last	20	7.00			3800	3710	3885	3800			42	1.25	142.6	33.49	98.5	5.59	645	670	660			60	4.9		
	Average		7.42	3.7	3.9				3850	35.8	6.48		1.96	141.4	33.78	99.4	5.54			650	33.9	6.12		4.5	33.4	6.05
	Range		0.75						205				1.50	2.1	0.50	1.5	0.09			20				0.8		
	First		2.50			4680	4770	4680	4710				2.13	140.3	33.96	99.9	5.51	580	685	635				4.5		
	Middle		2.00			4945	4770	5125	4945				2.00	142.0	33.55	98.7	5.58	650	760	705				3.9		
	Last	81	1.88			4770	4770	4505	4680			100	2.00	140.0	34.03	100.1	5.50	685	710	700			120	5.1		
	Average		2.13	4.9	4.1				4780	32.6	5.90		2.04	140.8	33.85	99.6	5.53			680	32.6	5.90		4.5	33.0	5.97
	Range		0.62						265				0.13	2.0	0.48	1.4	0.08			70				1.2		
	First		4.50			4330	4150	4415	4300				2.25	139.8	34.11	100.3	5.49	670	685	680				5.1		
	Middle		3.75			3800	4150	4065	4005				2.13	141.0	33.82	99.5	5.53	690	680	685				5.0		
	Last	140	4.00			4065	4240	4415	4240			162	1.75	140.7	33.89	99.7	5.52	670	735	705			181	5.0		
	Average		4.08	3.1	5.0				4180	33.0	5.97		2.04	140.5	33.94	99.8	5.51			690	32.9	5.97		5.0	33.4	6.05
	Range		0.75						295				0.50	1.2	0.29	0.8	0.04			25				0.1		
	Grand Average		4.54	3.9	4.3				4270	33.8	6.12		2.01	140.9	33.86	99.6	5.53			675	33.1	6.00		4.7	33.3	6.02
TEST SECTION 5 (37.4 cu. ft. - 58 sec. total mixing time)	First		3.50			4310	4505	4680	4500				1.75	141.8	36.95	98.8	5.57	680	725	705				4.0		
	Middle		1.63			4505	4770	4680	4650				1.75	140.5	37.29	99.7	5.52	595	700	650				4.5		
	Last	21	1.37			4415	4595	4505	4505			42	1.37	141.3	37.08	99.1	5.55	670	745	710			64	4.4		
	Average		2.17	4.9	4.8				4550	32.6	5.91		1.62	141.2	37.11	99.2	5.55			690	32.7	5.91		4.3	32.9	5.97
	Range		2.13						150				0.38	1.3	0.34	0.9	0.05			60				0.5		
	First		2.75			4680	4860	4680	4740				2.75	140.5	37.35	99.9	5.51	675	580	630				5.5		
	Middle		2.13			4860	4770	4770	4800				2.25	140.3	37.40	100.0	5.50	730	740	735				5.8		
	Last	80	1.75			4860	4505	4415	4595			100	1.75	139.8	37.53	100.3	5.48	680	665	675			120	5.4		
	Average		2.21	4.4	5.6				4710	33.3	6.04		2.25	140.2	37.43	100.1	5.50			680	33.2	6.04		5.6	34.0	6.17
	Range		1.00						205				1.00	0.7	0.18	0.4	0.03			105				0.4		
	First		3.00			4505	4595	4680	4595				2.75	141.5	37.14	99.3	5.54	620	650	635				6.1		
	Middle		2.25			4595	4770	4595	4655				1.75	140.2	37.49	100.2	5.49	625	680	655				5.6		
	Last	140	2.37			4770	4945	4945	4885			160	1.75	139.8	37.60	100.5	5.47	625	600	615			180	5.9		
	Average		2.54	5.1	5.8				4710	34.0	6.17		2.08	140.5	37.41	100.0	5.50			635	33.9	6.17		5.9	34.0	6.17
	Range		0.75						290				1.00	1.7	0.46	1.2	0.07			40				0.5		
	Grand Average		2.31	4.8	5.4				4655	33.3	6.04		1.98	140.6	37.32	99.8	5.52			670	33.3	6.04		5.3	33.6	6.10
TEST SECTION 6 (40.8 cu. ft. - 58 sec. total mixing time)	First		3.13			3800	4065	3885	3915				1.50	140.8	40.54	99.4	5.54	645	665	655				5.1		
	Middle		2.00			3800	3710	3800	3770				1.50	140.2	40.71	99.8	5.51	660	640	650				4.9		
	Last	23	3.00			3975	3975	4065	4005			41	1.25	141.4	40.37	98.9	5.56	650	605	630			61	5.0		
	Average		2.71	5.2	5.5				3895	32.1	5.85		1.42	140.8	40.54	99.4	5.54			645	32.4	5.85		5.0	32.1	5.85
	Range		1.13						235				0.25	1.2	0.34	0.9	0.05			25				0.2		
	First		0.63			5390	5830	5740	5655				1.50	139.8	40.89	100.2	5.49	595	685	640				6.1		
	Middle		0.75			5655	5390	5565	5535				1.50	139.0	41.12	100.8	5.46	720	675	700				5.1		
	Last	82	0.75			5210	5035	5300	5180			101	1.75	139.2	41.06	100.6	5.46	700	670	685			120	5.8		
	Average		0.71	4.9	4.4				5455	32.1	5.85		1.58	139.3	41.02	100.5	5.47			675	32.6	5.97		5.7	32.8	5.97
	Range		0.12						475				0.25	0.8	0.23	0.6	0.03			60				1.0		
	First		2.75			4595	4520	4770	4630				2.00	139.4	41.03	100.6	5.47	690	675	685				5.6		
	Middle		1.25			4505	4505	4680	4565				1.75	139.5	41.00	100.5	5.47	675	705	690				5.5		
	Last	140	2.37			4415	4415	4415	4415			162	2.00	139.3	41.06	100.6	5.46	710	760	735			180	5.1		
	Average		2.12	7.1	5.1				4535	33.1	6.03		1.92	139.4	41.03	100.6	5.47			705	33.0	6.03		5.4	33.1	6.03
	Range		1.50						215				0.25	0.2	0.06	0.1	0.01			50				0.5		
	Grand Average		1.85	5.7	5.0				4630	32.4	5.91		1.64	139.8	40.86	100.2	5.49			675	32.7	5.95		5.4	32.7	5.95

TABLE III - A (Continued)

RESULTS OF TESTS ON FRESH CONCRETE AND HARDENED CONCRETE SPECIMENS

	Portion of Batch	Batch No.	Slump in.	Air Content Percent		Compressive Strength, psi (28 days)				Water Content		Batch No.	Ball Penetration in.	Unit Wt. of Concrete, lb/cu ft	Yield of Batch cu ft	Yield, Percent of Design	Actual Cement Content sk/cu yd	Flexural Strength, psi (28 days)			Water Content		Batch No.	Air Content Percent, Chace Meter	Water Content	
				Volumetric Method	Chace Meter	1	2	3	Avg.	gal/cu yd	gal/sk							1	2	Avg.	gal/cu yd	gal/sk			gal/cu yd	gal/sk
TEST SECTION 7 (34.0 cu. ft. - 38 sec. total mixing time)	First		1.75			4330	4310	4065	4235				0.37	140.7	33.99	100.0	5.50	625	685	655				5.9		
	Middle		2.00			4170	4415	4240	4275				0.37	140.6	34.01	100.0	5.50	645	680	665				6.0		
	Last	20	1.50			4415	4330	4505	4415			40	0.63	140.2	34.11	100.3	5.49	720	655	690			63	5.6		
	Average		1.75	5.9	5.1				4310	33.7	6.18		0.46	140.5	34.04	100.1	5.50			670	33.9	6.18		5.8	33.7	6.18
	Range		0.50						180				0.26	0.5	0.12	0.3	0.01			35				0.4		
	First		1.50			4680	5035	4945	4885				2.00	138.4	34.55	101.6	5.41	645	645	645				6.0		
	Middle		1.50			4770	4595	4945	4770				1.50	138.7	34.48	101.4	5.43	645	610	630				6.0		
	Last	80	0.88			4150	4415	4240	4270			100	1.75	138.9	34.43	101.3	5.44	655	665	660			121	6.1		
	Average		1.29	5.5	5.6				4640	33.7	6.18		1.75	138.7	34.49	101.4	5.43			645	33.5	6.18		6.0	33.7	6.18
	Range		0.62						615				0.50	0.5	0.12	0.3	0.03			30				0.1		
	First		1.75			4065	3975	3885	3975				1.50	139.4	34.39	101.1	5.44	655	745	700				5.5		
	Middle		1.13			3975	4065	4240	4095				1.50	139.9	34.27	100.8	5.46	675	715	695				5.9		
	Last	143	2.00			4415	4240	4330	4330			160	1.50	139.0	34.49	101.4	5.43	740	600	670			180	5.4		
	Average		1.63	5.1	6.1				4135	33.7	6.18		1.50	139.4	34.38	101.1	5.44			690	34.8	6.39		5.6	36.4	6.68
	Range		0.87						355				0.00	0.9	0.22	0.6	0.03			30				0.5		
	Grand Average		1.56	5.5	5.6				4360	33.7	6.18		1.24	139.5	34.30	100.9	5.46			670	34.1	6.25		5.8	34.6	6.35
TEST SECTION 8 (37.4 cu. ft. - 38 sec. total mixing time)	First		1.25			4680	4945	4875	4835				2.75	139.6	38.04	101.7	5.41	705	540	625				5.3		
	Middle		1.50			4860	5020	4860	4915				2.50	139.8	37.99	101.6	5.42	660	605	635				6.0		
	Last	20	0.88			4770	5125	5125	5005			48	2.25	139.4	38.10	101.9	5.40	655	680	670			60	5.0		
	Average		1.21	4.7	5.0				4920	37.3	6.82		2.50	139.6	38.04	101.7	5.41			645	38.0	7.02		5.4	34.1	6.23
	Range		0.62						170				0.50	0.4	0.11	0.3	0.02			45				1.0		
	First		1.25			4505	4380	4595	4495				1.13	139.4	37.56	100.4	5.48	735	640	690				5.5		
	Middle		1.13			4505	4595	4680	4595				1.75	139.4	37.56	100.4	5.48	695	635	665				5.5		
	Last	80	1.25			4415	4860	4330	4535			100	2.00	139.4	37.56	100.4	5.48	700	700	700			120	5.1		
	Average		1.21	5.2	4.8				4540	31.9	5.84		1.63	139.4	37.56	100.4	5.48			685	32.0	5.84		5.4	31.9	5.84
	Range		0.12						100				0.87	0.0	0.00	0.0	0.00			35				0.4		
	First		1.63			4695	4680	4595	4625				1.50	139.8	37.45	100.1	5.49	710	645	680				5.9		
	Middle		1.13			4860	5020	4240	4705				1.50	141.9	36.90	98.7	5.57	685	585	635				5.1		
	Last	140	1.25			4415	4860	4680	4650			160	1.25	140.3	37.32	99.8	5.51	610	620	615			180	5.7		
	Average		1.34	4.9	5.0				4660	31.9	5.84		1.42	140.7	37.22	99.5	5.52			645	32.3	5.84		5.6	31.9	5.84
	Range		0.50						80				0.25	2.1	0.55	1.4	0.08			65				0.8		
	Grand Average		1.25	4.9	4.9				4705	33.7	6.17		1.85	139.9	37.61	100.5	5.47			660	34.1	6.23		5.5	32.6	5.97
TEST SECTION 9 (40.8 cu. ft. - 38 sec. total mixing time)	First		2.37			4770	4415	4330	4505				1.75	138.9	41.17	100.9	5.45	655	615	635				6.3		
	Middle		1.37			4150	4240	4450	4280				1.75	138.6	41.26	101.1	5.44	645	670	660				5.5		
	Last	21	0.63			4240	4150	3885	4090			40	1.75	140.2	40.79	100.0	5.50	730	665	700			60	6.0		
	Average		1.46	5.2	6.0				4290	31.9	5.85		1.75	139.2	41.07	100.7	5.46			665	32.6	5.97		5.9	33.2	6.09
	Range		1.74						415				0.00	1.6	0.47	1.1	0.06			65				0.8		
	First		3.00			4680	4770	4680	4710				2.37	139.0	41.14	100.8	5.45	700	730	715				6.0		
	Middle		1.75			4595	4595	4505	4565				1.50	138.7	41.23	101.1	5.44	715	715	715				5.5		
	Last	80	1.25			4240	4450	4415	4370			100	2.00	138.7	41.23	101.1	5.44	655	680	670			120	6.0		
	Average		2.00	5.0	5.0				4550	33.2	6.09		1.96	138.8	41.20	101.0	5.44			700	33.2	6.09		5.8	33.2	6.09
	Range		1.75						340				0.87	0.3	0.09	0.3	0.01			45				0.5		
	First		3.88			4525	4415	4770	4570				2.00	138.8	41.27	101.2	5.43	715	635	675				5.5		
	Middle		2.75			4680	4595	4450	4575				2.00	140.2	40.86	100.1	5.49	660	705	685				6.0		
	Last	140	2.13			4595	4770	4595	4655			160	1.63	139.5	41.06	100.6	5.46	725	785	755			180	6.0		
	Average		2.92	5.8	5.4				4600	33.2	6.09		1.88	139.5	41.06	100.6	5.46			705	33.3	6.09		5.8	31.9	5.85
	Range		1.75						85				0.37	1.4	0.41	1.1	0.06			80				0.5		
	Grand Average		2.13	5.3	5.5				4480	32.8	6.01		1.86	139.2	41.11	100.8	5.45			690	33.0	6.05		5.8	32.8	6.01

TABLE IV - A

RESULTS OF WASHOUT AND GRADING TESTS

Test Section	Portion of Batch	Batch No.	Coarse Agg. Retained #4	Fine Agg. #4 - #100	2"	1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	Grading Factor
			Percent by Weight of Fresh Concrete		Gradation - Percent Passing												
TEST SECTION 1 (34.0 cu. ft. - 78 sec. total mixing time)	First		41.9	33.8	100.0	97.0	88.5	81.5	69.6	64.0	58.1	52.7	47.1	40.7	31.2	24.3	755
	Middle		44.4	31.9	99.4	96.4	86.7	79.4	66.8	61.4	55.6	50.4	45.4	39.4	30.1	23.7	735
	Last	60	45.8	31.6	99.5	95.5	83.6	75.9	64.3	59.4	54.2	49.1	43.8	38.1	28.6	22.6	715
	Average		44.0	32.4	99.6	96.3	86.3	78.9	66.9	61.6	56.0	50.7	45.4	39.4	30.0	23.5	735
	Range		3.9	2.2	0.6	1.5	4.9	5.6	5.3	4.6	3.9	3.6	3.3	2.6	2.6	1.7	40
	First		42.9	32.9	99.6	96.8	86.9	79.8	66.9	62.3	57.1	51.9	46.7	40.6	31.3	24.2	744
	Middle*		45.7	30.9	100.0	94.1	85.2	75.8	63.6	59.1	54.3	49.8	43.9	38.1	29.6	23.4	717
	Last**	120	51.8	28.9	97.8	93.7	80.0	68.5	56.3	52.3	48.2	44.6	39.3	34.0	25.5	19.3	660
	Average		44.3	31.9	99.8	95.5	86.1	77.8	65.3	60.7	55.7	50.9	45.3	39.4	30.5	23.8	731
	Range		2.8	2.0	0.4	2.7	1.7	4.0	3.3	3.2	2.8	2.1	2.8	2.5	1.7	0.8	27
	First		41.4	32.1	99.6	96.4	86.7	80.5	68.7	63.7	58.6	58.1	47.9	42.0	33.1	26.5	757
	Middle		47.0	29.8	99.5	94.7	84.6	77.2	63.9	58.5	53.0	47.9	43.0	37.6	29.2	23.2	712
	Last**	180	52.1	26.5	98.3	89.7	78.4	70.2	57.6	52.7	47.9	44.2	39.3	34.4	26.9	21.4	661
	Average		44.2	31.0	99.6	95.6	85.7	78.9	66.3	61.1	55.8	50.5	45.5	39.8	31.2	24.9	735
	Range		5.6	2.3	0.1	1.7	2.1	3.3	4.8	5.2	5.6	5.2	4.9	4.4	3.9	3.3	45
	Grand Average		44.2	31.8	99.7	95.8	86.0	78.5	66.2	61.1	55.8	50.7	45.4	39.5	30.6	24.1	734
TEST SECTION 2 (37.4 cu. ft. - 78 sec. total mixing time)	First		41.3	33.7	99.5	95.0	85.6	81.5	68.7	63.6	58.7	54.4	48.6	42.4	32.5	25.0	756
	Middle		44.3	32.0	100.0	94.7	82.8	76.5	65.4	60.5	55.7	51.3	45.6	39.6	30.3	23.7	726
	Last	60	42.1	33.3	98.0	94.2	86.2	79.9	67.5	62.7	57.9	53.3	47.2	40.8	31.4	24.6	744
	Average		42.6	33.0	99.2	94.6	84.9	79.3	67.2	62.3	57.4	53.0	47.1	40.9	31.4	24.4	742
	Range		3.0	1.7	2.0	0.8	3.4	5.0	3.3	3.1	3.0	3.1	3.0	2.8	2.2	1.3	30
	First		39.5	31.0	100.0	96.1	86.8	80.6	69.7	65.2	60.5	55.4	50.6	45.0	36.2	29.5	776
	Middle		41.6	32.5	99.5	96.3	87.5	80.3	68.9	63.7	58.4	53.3	46.6	40.6	32.1	25.9	753
	Last	120	42.2	29.4	99.1	95.9	84.0	77.1	66.6	62.3	57.8	53.4	47.9	42.6	34.6	28.4	750
	Average		41.1	31.0	99.5	96.1	86.1	79.3	68.4	63.7	58.9	54.0	48.4	42.7	34.3	27.9	760
	Range		2.7	3.1	0.9	0.4	3.5	3.5	3.1	2.9	2.7	2.1	4.0	4.4	4.1	3.6	26
	First		41.6	33.7	99.5	95.7	86.3	80.2	68.8	63.8	58.4	53.3	46.8	40.6	31.3	24.7	749
	Middle		45.0	31.9	97.7	93.0	82.9	76.8	65.3	60.2	55.0	49.8	44.5	38.7	29.6	23.1	717
	Last	180	47.8	29.8	95.5	89.5	77.2	71.5	60.8	56.9	52.2	46.9	42.0	36.6	28.3	22.4	680
	Average		44.8	31.8	97.6	92.7	82.1	76.2	65.0	60.3	55.2	50.0	44.4	38.6	29.7	23.4	715
	Range		6.2	3.9	4.0	6.2	9.1	8.7	8.0	6.9	6.2	6.4	4.8	4.0	3.0	2.3	69
	Grand Average		42.8	31.9	98.8	94.5	84.4	78.3	66.9	62.1	57.2	52.3	46.6	40.7	31.8	25.2	739
TEST SECTION 3 (40.8 cu. ft. - 78 sec. total mixing time)	First		43.7	30.9	98.8	93.8	83.9	77.4	65.9	60.7	56.3	51.9	46.1	40.4	31.8	25.4	732
	Middle		45.8	29.5	98.4	95.0	85.0	75.9	63.8	58.7	54.2	49.5	44.9	39.6	31.1	24.7	721
	Last	66	48.4	28.2	98.6	92.6	81.0	73.6	61.0	55.9	51.6	47.1	42.5	37.4	29.6	23.4	694
	Average		46.0	29.5	98.6	93.8	83.3	75.6	63.6	58.4	54.0	49.5	44.5	39.1	30.8	24.5	716
	Range		4.7	2.7	0.4	2.4	4.0	3.8	4.9	4.8	4.7	4.8	3.6	3.0	2.2	2.0	38
	First		42.3	33.9	97.2	92.1	82.9	76.9	67.1	62.3	57.7	52.1	46.5	40.2	30.9	23.8	730
	Middle		42.8	32.8	97.0	93.1	82.7	77.0	66.4	62.0	57.2	52.7	46.4	40.4	31.4	24.4	731
	Last	121	42.8	32.9	99.6	93.6	84.0	76.8	66.6	62.1	57.2	52.4	46.1	40.1	31.2	24.3	734
	Average		42.6	33.2	97.9	92.9	83.2	6.9	66.7	62.1	57.4	52.4	46.3	40.2	31.2	24.2	732
	Range		0.5	1.1	2.6	1.5	1.3	0.2	0.7	0.3	0.5	0.6	0.4	0.3	0.5	0.6	4
	First		41.9	33.1	99.3	96.0	85.4	79.4	68.0	63.0	58.1	53.1	47.8	41.8	32.4	25.0	749
	Middle		43.4	32.1	99.4	95.3	84.9	77.7	66.1	61.3	56.6	51.3	46.1	40.4	31.4	24.5	735
	Last	180	45.1	30.7	98.9	92.6	81.1	75.8	64.4	59.4	54.9	50.5	44.4	38.9	30.5	24.2	716
	Average		43.5	32.0	99.2	94.6	83.8	77.6	66.2	61.2	56.5	51.6	46.1	40.4	31.4	24.6	733
	Range		3.2	2.4	0.5	3.4	4.3	3.6	3.6	3.6	3.2	2.6	3.4	2.9	1.9	0.8	33
	Grand Average		44.0	31.6	98.6	93.8	83.4	76.7	65.5	60.6	56.0	51.2	45.6	39.9	31.1	24.4	727

*Several small pieces of hardened concrete in sieve sample.
**Pores of slag coarse aggregate appear to be filled with mortar; values from sample not included in analysis.

TABLE IV - A (Continued)

RESULTS OF WASHOUT AND GRADING TESTS

Test Section	Portion of Batch	Batch No.	Coarse Agg. Retained #4	Fine Agg. #4 - #100	2"	1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	Grading Factor
			Percent by Weight of Fresh Concrete		Gradation - Percent Passing												
TEST SECTION 4 (34.0 cu. ft. - 58 sec. total mixing time)	First		42.7	32.3	99.0	97.0	86.4	78.5	66.4	61.8	57.3	52.5	46.5	40.4	31.4	25.0	742
	Middle		45.0	31.1	99.5	94.5	83.9	75.1	63.6	59.2	55.0	49.8	44.6	38.9	29.9	23.9	718
	Last	60	44.8	31.0	99.6	95.7	86.6	77.5	64.3	59.5	55.2	50.4	44.7	38.9	30.3	24.2	727
	Average		44.2	31.5	99.4	95.7	85.6	77.0	64.8	60.2	55.8	50.9	45.3	39.4	30.5	24.4	729
	Range		2.3	1.3	0.6	2.5	2.7	3.4	2.8	2.6	2.3	2.7	1.9	1.5	1.5	1.1	24
	First		35.7	38.8	100.0	97.5	89.1	84.0	74.9	70.2	64.3	58.4	50.9	43.6	33.1	25.5	792
	Middle		38.4	37.2	98.5	96.4	85.2	79.3	71.3	66.8	61.6	54.9	48.6	41.7	31.8	24.4	761
	Last	120	38.8	37.2	98.8	94.9	85.3	80.0	70.9	66.6	61.2	55.0	48.7	41.6	31.3	24.0	758
	Average		37.6	37.7	99.1	96.3	86.5	81.1	72.4	67.9	62.4	56.1	49.4	42.3	32.1	24.6	770
	Range		3.1	1.6	1.5	2.6	3.9	4.7	4.0	3.6	3.1	3.5	2.3	2.0	1.8	1.5	34
	First		39.2	35.7	100.0	96.3	87.8	80.9	70.3	65.8	60.8	55.8	48.8	42.2	32.4	25.1	766
	Middle		39.9	31.7	100.0	95.9	85.2	79.0	68.6	64.5	60.1	54.9	49.8	44.0	35.3	28.4	766
	Last	181	47.7	30.0	100.0	93.1	79.3	71.5	60.8	56.6	52.3	47.6	43.0	37.5	29.0	22.3	693
	Average		42.3	32.5	100.0	95.1	84.1	77.1	66.6	62.3	57.7	52.8	47.2	41.2	32.2	25.3	742
	Range		8.5	5.7	0.0	3.2	8.5	9.4	9.5	9.2	8.5	8.2	6.8	6.5	6.3	6.1	73
	Grand Average		41.1	33.9	99.5	95.7	85.4	78.4	67.9	63.5	58.6	53.3	47.3	41.0	31.6	24.8	747
TEST SECTION 5 (37.4 cu. ft. - 58 sec. total mixing time)	First		46.4	25.7	99.6	95.6	83.7	75.4	63.5	58.4	53.6	49.4	45.4	40.7	33.4	27.8	727
	Middle		45.1	26.1	99.5	95.5	84.9	77.1	65.6	60.1	54.9	50.8	46.6	41.8	34.5	28.8	740
	Last	64	43.8	27.7	99.0	96.4	85.0	77.6	66.3	61.3	56.2	52.2	46.7	41.5	34.2	28.5	745
	Average		45.1	26.5	99.4	95.8	84.5	76.7	65.1	59.9	54.9	50.8	46.2	41.3	34.0	28.4	737
	Range		2.6	2.0	0.6	0.9	1.3	2.2	2.8	2.9	2.6	2.8	1.3	1.1	1.1	1.0	18
	First		43.6	32.0	98.2	92.8	83.3	75.7	64.5	60.6	56.4	51.4	44.7	38.6	30.4	24.4	721
	Middle		45.3	30.7	99.1	94.5	83.2	75.3	63.0	58.6	54.7	49.2	44.1	38.5	30.1	24.0	714
	Last	120	45.5	30.4	99.4	93.1	83.3	74.2	60.0	58.7	54.5	50.4	44.6	38.9	30.4	24.1	714
	Average		44.8	31.0	98.9	93.5	83.3	75.1	63.5	59.3	55.2	50.3	44.5	38.7	30.3	24.2	717
	Range		1.9	1.6	1.2	1.7	0.1	1.5	1.5	2.0	1.9	2.2	0.6	0.4	0.3	0.4	7
	First		41.5	32.5	98.9	93.8	84.1	76.3	65.8	61.9	58.5	54.1	48.3	42.5	33.0	26.0	743
	Middle		44.5	31.4	97.4	93.3	83.5	76.0	63.4	59.3	55.5	50.2	45.3	39.6	30.7	24.1	718
	Last	180	44.9	31.6	99.1	93.2	82.0	74.9	62.9	58.8	55.1	49.9	45.1	39.7	30.6	23.5	715
	Average		43.6	31.8	98.5	93.4	93.2	75.7	64.0	60.0	56.4	51.4	46.2	40.6	31.4	24.5	725
	Range		3.4	1.1	1.7	0.6	2.1	1.4	2.9	3.1	3.4	4.2	3.2	2.9	2.4	2.5	28
	Grand Average		44.5	29.8	98.9	94.2	83.7	75.8	64.2	59.7	55.5	50.8	45.6	40.2	31.9	25.7	726
TEST SECTION 6 (40.8 cu. ft. - 58 sec. total mixing time)	First		41.2	33.6	99.3	95.8	86.5	79.2	68.3	63.9	58.8	53.3	47.9	41.8	32.1	25.2	752
	Middle		43.5	31.7	96.9*	92.5	83.4	77.0	66.2	61.5	56.5	51.3	46.1	40.3	31.4	24.8	728
	Last	61	43.4	31.5	99.6	94.4	84.4	77.0	66.2	61.4	56.6	52.1	46.3	40.5	31.7	25.1	735
	Average		42.7	32.3	98.6	94.2	84.8	77.7	66.9	62.3	57.3	52.2	46.8	40.9	31.7	25.0	738
	Range		2.3	2.1	2.7	3.3	3.1	2.2	2.1	2.5	2.3	2.0	1.8	1.5	0.7	0.3	24
	First		41.1	34.4	98.9	95.4	88.5	81.4	68.7	63.7	58.9	53.1	47.5	41.0	31.5	24.5	753
	Middle		42.7	33.4	98.8	94.2	85.5	78.8	66.9	62.0	57.3	51.5	45.9	39.7	30.5	23.9	735
	Last	120	42.4	33.5	98.3	93.7	84.4	78.4	66.8	62.1	57.6	52.3	45.7	39.5	30.6	24.1	734
	Average		42.1	33.8	98.7	94.4	86.1	79.5	67.5	62.6	57.9	52.3	46.4	40.1	30.9	24.2	741
	Range		1.6	1.0	0.6	1.7	4.1	3.0	1.9	1.7	1.6	1.6	1.8	1.5	1.0	0.6	19
	First		40.9	34.3	99.1	97.1	86.2	79.8	69.0	64.1	59.1	53.6	48.1	41.7	31.9	24.8	756
	Middle		43.4	32.1	99.5	95.4	84.5	78.2	66.2	61.2	56.6	52.4	46.5	40.5	31.3	24.5	737
	Last	180	42.1	33.2	99.5	94.0	84.0	77.9	67.5	62.6	57.9	53.1	46.7	40.7	31.6	24.7	740
	Average		42.1	33.2	99.4	95.5	85.2	78.6	67.6	62.6	57.9	53.0	47.1	41.0	31.6	24.7	744
	Range		2.5	2.2	0.4	3.1	3.2	1.9	2.8	2.9	2.5	1.2	1.6	1.2	0.6	0.3	19
	Grand Average		42.3	33.1	98.9	94.7	85.4	78.6	67.3	62.5	57.7	52.5	46.8	40.7	31.4	24.6	741

*Mortar adhering to 2" particle.

TABLE IV - A (Continued)

RESULTS OF WASHOUT AND GRADING TESTS

Test Section	Portion of Batch	Batch No.	Coarse Agg. Retained #4	Fine Agg. #4 - #100	2"	1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	Grading Factor
			Percent by Weight of Fresh Concrete		Gradation - Percent Passing												
TEST SECTION 7 (34.0 cu. ft. - 38 sec. total mixing time)	First		39.9	35.8	100.0	94.4	86.0	80.0	69.9	65.4	60.1	54.2	48.4	41.7	31.4	24.3	756
	Middle		41.6	33.7	99.1	95.7	85.2	78.8	68.2	63.7	58.4	53.4	46.9	40.5	31.2	24.7	746
	Last	63	43.5	33.1	99.3	93.7	82.4	76.0	65.6	61.2	56.5	51.1	45.8	39.6	30.1	23.4	725
	Average		41.7	34.2	99.5	94.6	84.5	78.3	67.9	63.4	58.3	52.9	47.0	40.6	30.9	24.1	742
	Range		3.6	2.7	0.9	2.0	3.6	4.0	4.3	4.2	3.6	3.1	2.6	2.1	1.3	1.3	31
	First		40.9	33.1	99.0	94.9	84.9	79.2	68.7	63.9	59.1	54.6	48.3	42.0	32.5	26.0	753
	Middle		42.4	31.3	98.3	93.6	84.2	77.4	66.8	62.2	57.6	52.6	47.6	41.9	32.9	26.3	741
	Last	121	42.7	31.6	99.5	95.9	83.6	77.1	66.7	62.0	57.3	52.2	46.9	40.9	32.3	25.7	740
	Average		42.0	32.0	98.9	94.8	84.2	77.9	67.4	62.7	58.0	53.1	47.6	41.6	32.6	26.0	745
	Range		1.8	1.8	1.2	2.3	1.3	2.1	2.0	1.9	1.8	2.4	1.4	1.1	0.6	0.6	13
	First		41.5	34.2	98.8	94.5	86.3	80.4	68.0	63.4	58.5	53.8	47.1	40.7	31.3	24.3	747
	Middle		44.7	32.4	98.5	91.7	82.2	75.9	64.5	60.0	55.3	49.7	44.1	38.2	29.6	22.9	713
	Last	180	44.3	31.9	100.0	95.9	85.0	77.8	65.3	60.6	55.7	50.8	44.5	38.6	30.2	23.8	728
	Average		43.5	32.8	99.1	94.0	84.5	78.0	65.9	61.3	56.5	51.4	45.2	39.2	30.4	23.7	729
	Range		3.2	2.3	1.5	4.2	4.1	4.5	3.5	3.4	3.2	4.1	3.0	2.5	1.5	1.4	34
	Grand Average		42.4	33.0	99.2	94.5	84.4	78.1	67.1	62.5	57.6	52.5	46.6	40.5	31.3	24.6	739
TEST SECTION 8 (37.4 cu. ft. - 38 sec. total mixing time)	First		40.6	33.6	100.0	95.2	87.1	81.1	69.2	64.2	59.4	54.9	48.9	42.7	32.9	25.8	761
	Middle		44.5	30.6	100.0	95.1	83.6	76.6	65.1	60.0	55.5	51.2	45.5	40.1	31.4	24.9	729
	Last	60	43.3	31.8	99.5	96.6	85.7	78.5	66.5	61.6	56.7	52.0	47.0	41.3	32.0	24.9	742
	Average		42.8	32.0	99.8	95.6	85.5	78.7	66.9	61.9	57.2	52.7	47.1	41.4	32.1	25.2	744
	Range		3.9	3.0	0.5	1.5	3.5	4.5	4.1	4.2	3.9	3.7	3.4	2.6	1.5	0.9	32
	First		41.1	34.2	99.5	97.6	87.5	81.6	69.8	64.5	58.9	53.4	47.0	41.4	31.9	24.7	759
	Middle		42.8	30.1	100.0	96.4	86.3	79.3	67.3	62.2	57.2	50.2	46.8	41.2	32.8	26.3	748
	Last	120	45.3	32.9	100.0	97.2	86.2	80.5	65.7	60.0	54.7	49.3	43.7	37.8	28.8	21.8	726
	Average		43.1	32.7	99.8	97.1	86.7	80.5	67.6	62.2	56.9	51.6	46.1	40.1	31.2	24.3	744
	Range		4.2	3.3	0.5	1.2	1.3	2.3	4.1	4.5	4.2	4.1	4.1	3.6	4.0	4.5	33
	First		39.2	35.1	100.0	96.7	88.7	82.7	71.6	66.0	60.8	55.6	48.8	42.7	32.8	25.7	772
	Middle		41.9	32.4	99.6	96.7	87.4	81.0	68.7	63.3	58.1	53.9	47.9	42.2	32.6	25.7	757
	Last	180	43.3	32.4	99.4	95.8	83.9	77.3	66.2	61.2	56.7	52.7	46.8	41.0	31.3	24.3	737
	Average		41.5	33.3	99.7	96.4	86.7	80.3	68.8	63.5	58.5	54.1	47.8	42.0	32.2	25.2	755
	Range		4.1	2.7	0.6	0.9	4.8	5.4	5.4	4.8	4.1	2.9	2.0	1.7	1.5	1.4	35
	Grand Average		42.5	32.7	99.8	96.4	86.3	79.8	67.8	62.5	57.5	52.8	47.0	41.2	31.8	24.9	748
TEST SECTION 9 (40.8 cu. ft. - 38 sec. total mixing time)	First		42.9	32.3	99.5	95.1	86.2	78.9	66.9	61.8	57.1	53.1	47.4	41.7	31.9	24.8	744
	Middle		43.1	22.1	100.0	95.6	85.5	78.5	66.7	61.5	56.9	54.1	50.2	46.3	39.8	34.8	770
	Last	60	44.7	40.4	98.7	95.6	84.5	76.7	65.1	60.2	55.3	49.5	43.4	36.3	24.3	14.9	705
	Average		43.6	31.6	99.4	95.4	85.4	78.0	66.2	61.2	56.4	52.2	47.0	41.4	32.0	24.8	740
	Range		1.8	18.3*	1.3	0.5	1.7	2.2	1.8	1.6	1.8	4.6*	6.8*	10.0*	15.5*	19.9*	65*
	First		42.8	32.1	99.5	93.3	82.6	76.4	65.7	61.2	57.2	52.5	47.7	42.1	32.6	25.1	736
	Middle		43.2	32.0	99.1	95.1	84.7	78.7	66.1	61.1	56.8	52.0	47.1	41.6	32.2	24.8	739
	Last	120	41.9	33.1	100.0	95.4	85.4	78.9	67.1	62.3	58.1	53.7	47.6	41.8	32.0	25.0	747
	Average		42.6	32.4	99.5	94.6	84.2	78.0	66.3	61.5	57.4	52.7	47.5	41.8	32.3	25.0	741
	Range		1.3	1.1	0.9	2.1	2.8	2.5	1.4	1.2	1.3	1.7	0.6	0.5	0.6	0.3	11
	First		40.2	34.7	100.0	98.1	88.8	81.3	69.6	64.4	59.8	54.9	48.1	41.8	32.2	25.1	764
	Middle		42.3	32.9	100.0	96.1	85.4	77.6	66.9	62.2	57.7	53.2	47.2	41.3	31.6	24.8	744
	Last	180	44.2	32.1	98.9	94.7	83.1	76.0	64.9	60.1	55.8	50.8	45.5	39.6	30.5	23.7	724
	Average		42.2	33.2	99.6	96.3	85.8	78.3	67.1	62.2	57.8	53.0	46.9	40.9	31.4	24.5	744
	Range		4.0	2.6	1.1	3.4	5.7	5.3	4.7	4.3	4.0	4.1	2.6	2.2	1.7	1.4	40
	Grand Average		42.8	32.4	99.5	95.4	85.1	78.1	66.5	61.6	57.2	52.6	47.1	41.4	31.9	24.8	742

*Starred values for Range not included in analysis.
Some of Fine Aggregate from middle portion of batch was apparently mixed with sample from last portion of batch during washing operation.

TABLE V-A

RESULTS OF TESTS ON STOCKPILED COARSE AGGREGATE (SLAG) AT BATCHING PLANT

(MSHD Specification 10A)

Laboratory No. 58A-	11074	11075	11076	11077	11078	11079	11080	11081	11082	Average	Spec. Limits
Date and Time Sampled	6-24 –	6-24 –	6-26 10:00 am	6-26 2:30 pm	6-28 11:00 am	6-28 3:00 pm	7-1 8:30 am	7-1 1:00 pm	7-2 10:30 am		
Sieve Size, % Passing											
1 1/2 in.	100	100	100	100	100	100	100	100	100	100	100 min.
1 in.	100	100	100	100	99	100	100	99	99	100	95-100
1/2 in.	41	37	37	39	30	32	21	27	25	32	35-65
No. 4	4.8	2.3	4.0	3.6	2.3	3.4	0.9	2.3	1.1	2.7	0-8
Loss on Washing, %	0.2	0.2	0.4	0.6	0.7	0.9	0.5	0.9	0.5	0.5	1.5 max.
Disintegrated & Non-durable particles, %	1.1	0.3	0.5	0.8	0.1	0.9	0.7	0.9	0.3	0.6	3 max.
Thin or elongated pieces, %	0.2	0.1	0.1	0.1	0.1	0.4	0.0	0.3	0.0	0.1	15 max.
Glassy Particles, %	0.4	0.1	0.0	0.1	0.1	0.1	0.3	0.0	0.2	0.1	

Note Samples 58A-11078 through 11082 deficient in material passing 1/2 inch.

TABLE V-A (Continued)

RESULTS OF TESTS ON STOCKPILED COARSE AGGREGATE (SLAG) AT BATCHING PLANT

(MSHD Specification 4A)

Laboratory No. 58A-	11083	11084	11085	11086	11087	11088	11089	11090	11091	Average	Spec. Limits
Date and Time Sampled	6-24 –	6-24 –	6-26 10:00 am	6-26 2:30 pm	6-28 11:00 am	6-28 3:00 pm	7-1 8:30 am	7-1 1:00 pm	7-2 10:30 am		
Sieve Size, % Passing											
2 1/2 in.	100	100	100	100	100	100	100	100	100	100	100 min.
2 in.	97	98	91	91	95	94	92	85	94	93	95-100
1 1/2 in.	80	80	83	60	75	61	54	49	69	68	65-90
1 in.	40	37	36	13	24	13	14	8	15	22	10-40
1/2 in.	8	3	3	1	2	1	1	0.5	1	2	0-20
3/8 in.	5.7	1.9	1.5	0.8	1.3	0.8	0.5	0.4	0.5	1.5	0-5
Loss on Washing, %	0.5	0.3	0.5	0.3	0.4	0.3	0.2	0.2	0.3	0.3	1.5 max.
Disintegrated & Non-durable particles, %	0.2	0.1	0.0	0.9	0.1	0.0	1.0	0.0	0.1	0.3	3 max.
Thin or elongated pieces, %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15 max.
Glassy Particles, %	0.0	0.7	0.0	0.0	0.2	0.0	0.0	1.5	0.0	0.3	

Note: Samples 58A-11085, 11086, 11088-11091, deficient in material passing 2 inches.
Samples 58A-11086, 11088-11090 deficient in material passing 1 1/2 inches.
Sample 58A-11090 deficient in material passing 1 inch.
Sample 58A-11083 excessive in material passing 3/8 inch.

TABLE VI-A

RESULTS OF TESTS ON STOCKPILED FINE AGGREGATE (NATURAL SAND) AT BATCHING PLANT
(MSHD Specification 2NS)

Laboratory No. 58A-	11069	11070	11071	11072	11073	Average	Spec. Limits
Date Sampled	6-24	6-26	6-28	7-1	7-2		
Sieve Size, % Passing							
3/8 in.	100	100	100	100	100	100	100 min.
No. 4	96	96	96	96	97	96	95-100
No. 8	82	82	81	82	83	82	65-95
No. 16	66	67	66	67	68	67	35-75
No. 30	48	50	49	50	52	50	20-55
No. 50	22	22	21	22	23	22	10-30
No. 100	3.7	4.1	4.8	4.0	4.8	4.3	0-10
Loss on washing, %	1.4	1.0	1.7	1.2	1.4	1.3	3 max.
Fineness Modulus	2.81	2.80	2.82	2.79	2.71	2.79	
Organic Matter, Plate No.	1	1	1	1	1	1	3 max.
Mortar Strength Ratio, 7 day	1.18	1.25	1.19	1.21	1.17	1.20	1.0

TABLE VII-A

RESULTS OF TESTS ON PORTLAND CEMENT
Type I-A (Air-Entraining)

		Silo No. 4, Laboratory No. 58 C-1560-1595	Silo No. 7, Laboratory No. 1808-1843
Physical Properties			
Setting Time (Gillmore), hr.-min.			
Initial		3:30	3:35
Final		5:30	5:35
Air Content of Mortar, percent		19.5	19.8
Specific Surface, Air Permeability Test, sq. cm. per gm.		3008	3028
Autoclave Expansion, percent		+0.08	+0.08
Compressive Strength, psi.			
7 days		2983	2821
28 days		4118	4107
Chemical Analysis, Percent			
Silicon dioxide	SiO_2	21.8	21.6
Aluminum oxide	Al_2O_3	5.2	4.9
Ferric oxide	Fe_2O_3	2.6	2.7
Calcium oxide	CaO	64.0	64.1
Magnesium oxide	MgO	2.5	2.4
Sulfur trioxide	SO_3	2.0	1.8
Loss on ignition		1.2	1.6
Sodium oxide	Na_2O	0.32	0.32
Potassium oxide	K_2O	0.69	0.68
Total alkali expressed as Na_2O		0.77	0.77
Compound Composition, Percent			
3 CS		50	55
2 CS		25	21
3 CA		9	8
4 CAF		8	8

Note: Cement withdrawn for this project from:

Silo 4 - June 23-26, 1958
Silo 7 - June 26-July 7, 1958

TABLE VIII-A

BATCH WEIGHTS OF CONCRETE MATERIALS

Test Section No.	1	2	3	4	5	6	7	8	9
Design Volume of Batch, cu. ft.	34.0	37.4	40.8	34.0	37.4	40.8	34.0	37.4	40.8
Weight of Coarse Aggregate, dry, loose, lb/cu. ft.	78	76	76	76	76	76	75	75	75
Design Batch Weights, lb.									
Cement	651	716	781	651	716	781	651	716	781
Fine Aggregate	1631	1848	2015	1681	1848	2015	1708	1878	2048
Coarse Aggregate, 4A	1035	1109	1209	1008	1109	1209	996	1095	1194
Coarse Aggregate, 10A	1035	1109	1209	1008	1109	1209	996	1095	1194
Water, Total	357.4	396.2	432.1	360.4	396.2	432.1	361.1	397.0	433.0
Batch Weights, lb., adjusted for moisture									
Fine Aggregate	1700	1929	2096	1767	1935	2106	1790	1968	2148
Coarse Aggregate, 4A	1056	1149	1250	1035	1139	1242	1019	1120	1222
Coarse Aggregate, 10A	1070	1145	1247	1044	1149	1254	1030	1132	1235

	Specific Gravity (Dry)	Absorption
Cement	3.17	--
Fine Aggregate	2.61	1.16
Coarse Aggregate, 4A	2.25	2.34
Coarse Aggregate, 10A	2.38	3.12

TABLE IX-A

COMPRESSIVE STRENGTH OF DRILLED CORES
(90 Days' Age)

Section	Station*	Location from ℄	Compressive Strength psi **
1	344+15	10.3L	5895
	345+26	4.7L	5630
	346+38	1.7L	5465
Average:			5665
2	349+68	1.7R	5535
	351+30	7.5R	5600
	351+99	9.9R	5820
Average:			5650
3	354+31	4.8R	5080
	355+48	1.5R	5485
	356+34	2.0L	5600
Average:			5390
4	336+20	1.5R	5810
	337+00	2.0L	5360
	337+98	4.2L	6215
Average:			5795
5	332+35	5.4R	5150
	333+20	10.0R	5600
	334+25	6.7R	5820
Average:			5525
6	328+05	5.2L	5075
	329+04	1.3L	5170
	330+45	1.7R	5075
Average:			5105
7	324+06	1.3L	5290
	325+01	5.5L	4985
	325+94	9.1L	4900
Average:			5060
8	307+80	10.6R	5160
	308+90	5.7R	5430
	309+27	1.1R	5445
Average:			5345
9	303+78	1.3L	5340
	305+14	1.4R	5520
	306+16	6.1R	5740
Average:			5535
Grand Average:			5450

*Eastbound Lanes

**Corrected to conform to a cylinder whose height is twice its diameter

TABLE X-A

TEMPERATURE OF CONCRETE, DEGREES, F.

Batch Number	Test Section								
	1	2	3	4	5	6	7	8	9
20	70	67	70	70	73	78	78	78	78
40	70	68	70	70	73	78	80	78	81
60	70	64	72	70	75	82	79	79	81
80	72	69	71	71	76	80	79	80	81
100	72	68	70	71	75	80	80	79	81
120	72	69	71	72	75	80	80	80	81
140	72	71	72	72	76	78	80	80	82
160	72	69	71	72	78	79	80	78	80
180	74	70	71	73	78	79	80	79	81
Average:	72	68	71	71	75	79	80	79	81
Air Temperature, Approx.	75	65	68	82	88	88	92	88	92