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The tests were performed during routine pavement construction on III-Pla-17-A, Roc,B, under Contract 59-3TC17-FIPD; A. Teichert & Sons, Contractor.

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STATE OF CALIFORNIA

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DIVISION OF HIGHWAYS

A report on

TESTS OF PERFORMANCE OF A PAVING MIXER AS AFFECTED BY MIXING TIME AND SIZE OF BATCH

59-16

DND

MATERIALS & RESEARCH DEPARTMENT

SAGACITAS - SCIENTIA - STVDIVM

State of California
Department of Public Works
Division of Highways

MATERIALS AND RESEARCH DEPARTMENT

December 1, 1959

Laboratory Authorization
No. 5034-R-54
Work Order No. 59-13NN9

Mr. J. W. Trask
Assistant State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A report on

TESTS OF PERFORMANCE OF A PAVING MIXER AS AFFECTED BY MIXING TIME AND SIZE OF BATCH

Study made by . . . . Technical Section
Under general direction of . . . . . . Bailey Tremper
Work supervised by . . . . D. L. Spellman
Report written by . . . . Bailey Tremper and D. L. Spellman

Very truly yours

F. N. Hveem
Materials and Research Engineer

cc: Dept. Heads
District Engineers
District Materials Engrs.

December 1, 1959

TESTS OF PERFORMANCE OF A PAVING MIXER AS AFFECTED BY MIXING TIME AND SIZE OF BATCH

This report presents results of tests performed on a 34 E dual drum paving mixer operating at three levels of batch size and at three periods of mixing time, a total of nine combinations. The study was suggested by Mr. Harold Allen, Chief, Division of Physical Research, U.S. Bureau of Public Roads, in a memorandum dated December 2, 1957.

The tests were performed during routine pavement construction on III-Pla-17-A,Roc,B, under Contract 59-3TC17-FIPD; A. Teichert & Sons, Contractor.

The test program departed from that suggested by Mr. Allen in the following particulars:

1. Samples of concrete for test were obtained from the first and last quarters of the batch directly from the discharge of the mixer. Mr. Allen proposed obtaining samples from the first, second and third portions of the batch after it had been discharged from the bucket of the mixer.

2. Mr. Allen proposed that both compression and flexure tests be made upon each portion of the concrete that was sampled. Flexure tests were not made in our study.

3. Mr. Allen proposed that air content tests be made with Chace meter as well as the pressure meter. The Chace meter was not used in our tests.

Test data that were obtained and which are available for judging the effectiveness of mixing with respect to the uniformity of distribution of the ingredients throughout the batch, based on differences between the first and last portions of the discharge are:

1. Variation in slump
2. Variation in air content
3. Variation in unit weight of air-free mortar
4. Variation in weight of coarse aggregate per unit volume of concrete
5. Variation in compressive strength of molded test cylinders

6. Variation in cement factor

Test data available for judging the quality of the batches as mixed as indicated by strength are the average compressive strengths of molded test cylinders in which all specimens from a given group of batches are compared to those from the other groups.

All tests were performed on concrete mixed by a Koehring 34-E dual drum paver, Serial No. 27322, which was purchased new in July, 1956. The batches mixed were 34.0, 37.4 and 40.8 cubic feet in size representing overloads of 0, 10 and 20 per cent respectively in this mixer. The contractors' records indicated that approximately 60,000 cubic yards of concrete had been mixed prior to these tests. The mixer was in good condition. New blades had been installed in the rear drum and one new blade had been installed in the front drum; the other blades were only slightly worn. Details of the blade measurements at the start and end of this project are given in Table 1.

Table 1
Mixer Blade Wear Data

	Front Drum			Rear Drum	
Position*	New Blade	At Start of Proj.	At End of Proj.	At Start of Proj.	At End of Proj.
1	1.29	1.27	1.23	0.59	0.56
2	1.37	1.35	1.34	1.59	1.52
3	1.20	1.14	1.09	1.32	1.25
4	1.09	1.09	1.09		

*Measurements taken at intervals along length of blades designated as "Position". The blades were measured at the same "positions" after completion of the project. Figures shown are in feet.

Approximately 37,000 cubic yards were mixed between the time the first and last measurements were taken.

The section being paved at the time of the tests was essentially level and on tangent. The pavement was constructed to a width of 24 feet in one operation and was placed on the south side of a 4-lane divided highway. Two mixers were used in tandem. Tests were made on the leading mixer. Both mixers used the same size batches during the test period but only the lead mixer varied the mixing time. The completed pavement can be studied for effect of batch size but not for effect of mixing time since it is not possible to distinguish accurately between the concrete placed by the two mixers.

All tests were performed during two days of operation, July 25 and 26, 1959. Paving operations on this project were started about July 15. Station limits are shown for each combination of batch size and mixing time in Table 2.

Table 2
Mix Schedules and Station Limits
(All in eastbound lanes; paving direction east to west)

Date Placed	Batch Size Cubic Feet	Mixing Time Seconds	Station Limits (In order placed)
July 25	(40.8	50	187+05 to 182+90
	(37.4	50	182+67 to 179+00
	(34.0	50	178+60 to 175+00
July 26	(34.0	30	160+12 to 156+10
	(34.0	70	156+10 to 151+65
	(37.4	30	150+80 to 147+30
	(37.4	70	146+80 to 141+85
	(40.8	30	141+00 to 136+60
	(40.8	70	136+50 to 131+50

The values given above for batch size and mixing time are nominal. Data on exact mixing times are given in Tables 3, 4 and 5.

Approximately 100 batches of each combination were mixed in succession. Four batches were sampled and tested for each combination involving mixing times of 50 and 70 seconds. Three batches were sampled and tested for each combination involving the 30-second mixing time.

The mixing time of each batch was measured by personnel of the Bureau of Public Roads. Time was started when all the dry ingredients were in the first drum and ended when the concrete appeared at the discharge chute. Time of transfer between drums was thus counted as part of the mixing time.

Sampling Procedure

It was planned that samples of concrete from the first quarter and last quarter of the batch as discharged from the mixer be obtained for comparative tests. To accomplish this result the contractor cut a hole in the side of the discharge bucket at the top and installed a swivel chute which could be swung in and out of the discharge stream of concrete while filling the bucket. When a batch was to be sampled, one wheelbarrow was placed near the bucket under the chute. As the concrete started out of the discharge chute, the sampling chute was swung into the stream. As soon as the desired amount of concrete had been obtained, the wheelbarrow was pulled away. The concrete was allowed to continue to flow down the sampling chute onto the ground until about three-fourths of a batch had been discharged into the bucket. A second wheelbarrow was then pushed under the chute and filled with the required amount of concrete. The sampling chute was then swung away from the mixer drum discharge chute. The whole operation took place in about 7 to 9 seconds, the discharge time for a batch of concrete. Occasionally the sampling operation was not performed as intended. When this happened, the samples were discarded and other batches were sampled.

Testing Procedure

Immediately after sampling, the slump was determined in the wheelbarrows by means of the Kelly Ball. The slump was then marked on a test card which was partially filled out showing batch number, batch size, and nominal mixing time, and whether from the first or last quarter of the batch. The samples were then wheeled to the test site on the opposite shoulder of the roadway and dumped into large pans where they were remixed with shovels. Three separate crews performed the necessary tests and fabricated the test cylinders. Two of the three crews processed portions of the samples to determine the air content, unit weight, and amount of coarse aggregate in the sample and the test values were then entered on the sample card. One crew tested the sample from the first quarter of the batch while a second crew tested the sample from the last quarter. The order of samples tested by the two crews was reversed on each succeeding batch.

The third crew fabricated three 6x12-inch concrete cylinders and wet-screened a mortar sample from each of the two samples. The test batches were selected to avoid variations that might occur near the beginning and end of the series of 100 batches and were spaced to allow testing and moving time as paving progressed. The planned schedule was as follows:

Mixing Time	Proposed Test Batches
30 second mixing time	10th, 50th and 90th
50 " " "	10th, 35th, 70th, & 90th
70 " " "	10th, 35th, 70th, & 90th

The exact batch sampled varied from the planned schedule because of timing involved in making tests, moving the test equipment ahead and rejection of some samples that were not representative of the first and last quarter of the batch.

The various tests were performed as follows:

1. Slump was determined by the Kelly Ball and results are expressed as twice the measured penetration.

2. Air content was determined with a pressure meter of the modified Washington type and is expressed as percentage by volume.

3 and 4. Unit weight of air-free mortar, pounds per cubic foot, and weight of coarse aggregate in pounds per cubic foot of concrete were determined in accordance with Designation 26 of the Concrete Manual of U.S. Bureau of Reclamation, 6th edition.

5. Compressive strength was determined on 6x12-inch cylinders. They were molded at the jobsite in accordance with ASTM Designation: C 31-57 except that metal cans were used for molds and they did not have machined base plates. Three cylinders were molded from each portion of the test batch. The cans were covered with close fitting lids and were stored on the work for two days under wet cotton mats or several layers of wet burlap. They were then transported to the laboratory and stored in the fog room at 100 per cent relative humidity and 73±2 F until tested for compressive strength at the age of 14 days in accordance with ASTM Designation: C 39-56 T.

6. Cement factor was determined as follows on samples of pulverized, hardened mortar that had been wet-sieved from each portion of the test batches. Loss on ignition was determined on a portion of the prepared sample. CaO was determined on that portion of the prepared sample

that was soluble in dilute HCl. A blank determination for acid soluble CaO in the sand was applied as a correction factor to the CaO found in the pulverized mortar. The average corrected value of CaO (ignited basis) of all samples was taken to represent a cement factor of 5.00 sacks per cubic yard which was the design amount. The cement factor of each sample was computed as being proportional to its CaO content (ignited basis) with relation to the average value. Values for loss on ignition were found to be relatively uniform and not high since the greater part of the readily evaporable water was driven off during pulverizing. The blank correction for CaO in the sand was relatively low.

Data of the Tests

Tables 3, 4 and 5 show the determined values for the two portions of each batch that was tested. Table 6 gives the variations in test values between the first and last portions of the mixer discharge, calculated as the average of individual batch variations for each combination of mixing time and size of batch. Table 7 shows the variation in test results for each time of mixing based on the average of all batch sizes and for each batch size based on the average of all mixing times. It should be noted that variations as shown are the differences in test values between the two portions of the batch, not the variation from the average of the two portions.

Discussion

The criteria given in Designation 26 of the Concrete Manual of the U.S. Bureau of Reclamation, are that mixing is considered to be acceptable if,

(1) The variation in unit weight of air-free mortar does not exceed 0.8 percent from the average of samples from the front and back of the mixer. This is equivalent to a variation between the first and last portions of the batch of 2.2 pounds per cubic foot for the concrete under consideration.

(2) The variation in weight of coarse aggregate per cubic foot of concrete does not exceed 5 percent from the average of

samples from the front and back of the mixer. This is equivalent to a variation between the first and last portions of the batch of 8.2 pounds per cubic foot of the concrete under consideration.

The largest average variation in unit weight of air-free mortar found in these tests is 2.1 pounds per cubic foot. The largest variation in weight of coarse aggregate found in these tests is 6.9 pounds per cubic foot of concrete. Therefore all combinations of mixing time and batch size produced satisfactory mixtures in accordance with Bureau of Reclamation criteria. However, batch No. 90 of the 37.4 cu. ft. series, mixed for 50 seconds, was poorly mixed as judged by the variation in coarse aggregate and other criteria. Test results for this batch in terms of variation between the first and last portions are as follows:

Slump	1.75 inches
Air content	1.4 percent
Unit wt. of air-free mortar	1.8 lbs./cu.ft.
Coarse aggregate per cu.ft. of concrete	8.8 lbs.
Compressive strength	880 psi
Cement factor	0.35 sks/cu.yd.

These results demonstrate the possibility of producing poorly mixed concrete in a mixer that on the whole operated very well. Batch No. 90 was the last one discharged before the noon hour. The mixing time was 44.4 seconds. It is possible that poor mixing was connected with the transfer chute remaining open thus permitting remnants of concrete in the first drum to dribble into the second drum without sufficient time for thorough intermingling.

The results for this batch No. 90 have not been included in the computation of average results for batches of 37.4 cu. ft. mixed for 50 seconds. The reason is that it is desired to examine the trend of normal results for indications that might point to unsatisfactory performance in a less efficient mixer.

The unit weight of air-free paste (w/c = 0.60) is about 109 pounds per cubic foot. The solid unit weight of the sand (bulk sp.g = 2.67) is about 167 pounds per cubic foot. Variations in the cement content from different parts of a batch can be calculated from variations in unit weight of the air-free mortar. It has been calculated that a change of 0.2 sack of cement per cubic yard of concrete will produce a change in the opposite direction of 1 pound in the weight per cubic foot of the air-free mortar. Such a relationship is borne out within probable experimental error by a plot of the test data.

The variability in cement factor has been computed from the data on unit weight of air-free mortar with results as follows:

Variation in Cement Factor, Sacks per Cu.Yd.

	By Chemical Analysis	By Unit Weight of Air-free Mortar
Mixing time, 30 sec.	0.22	0.26
" " 50 sec.	0.18	0.26
" " 70 sec.	0.19	0.16
Batch Size, 34.0 cu. ft.	0.21	0.18
" " 37.4 cu. ft.	0.21	0.24
" " 40.8 cu. ft.	0.18	0.26

The above tabulation shows that minor evidences of trend are obscured by experimental error. The conclusion to be reached is that within the range of variability found in these tests, as shown in Table 7, positive conclusions with respect to the uniformity of distribution of the cement are not warranted.

The variability in compressive strength as shown in Table 7 is not consistent with respect to mixing time. The variations do not exceed 5 per cent and it is probable that they are within experimental error and are not significant.

Table 7 shows that size of batch or time of mixing had no significant effect on variations with respect to slump or air content. On the other hand, a mixing time of 70 seconds produced about 0.5 percent more air than did a mixing time of 30 seconds.

The most significant test with respect to the uniformity of the mixed concrete appears to be that for distribution of the coarse aggregate. Table 7 shows little effect of mixing time but does show increasing variability with increasing size of batch.

A review of all the factors that measure the uniformity of distribution of the components, as shown in Table 7, indicate that, if a trend is evident, it tends to follow that of the distribution of coarse aggregate. This is illustrated in Figure 1. The latter test is relatively simple to make. It is believed that this test alone could be used to measure mixer performance satisfactorily.

Based on the premise that the values for variation in coarse aggregate are the most significant, it can be deduced that with mixers in poorer condition than the one studied or with mixers that are inherently less efficient, a substantial percentage of unsatisfactory mixtures could be produced with a batch size of 40.8 cu. ft.

Table 8 indicates that time of mixing had no effect on the compressive strength of the concrete. The results however, may not be free of bias for the reason that all of the 50-second mixes were made on one day and the remainder on another day. Differences in weather conditions or in the cement could have been responsible for an apparent uniformity that did not in fact exist. It should be recognized also that the samples from which strength tests were made did not truly represent the entire batch but only the first and last portions of the discharge.

The effect of size of batch, as shown in Table 8 appears to be clear cut and without bias with respect to different days of operation. The average slump for all samples of each batch size was as follows:

34.0 cu. ft.	2.08"
37.4 cu. ft.	2.12"
40.8 cu. ft.	2.18"

It has been calculated that the increase in water-cement ratio necessary to increase the slump 0.1 inch should not reduce the compressive strength by more than 20 psi. This appears to be relatively insignificant with respect to the measured differences in strength. The results therefore, indicate that a moderate loss in strength must be expected if batches larger than that rated capacity of the mixer are used.

Conclusions

The particular mixer that was studied in these tests produced acceptable intermingling of the ingredients at all levels of mixing time and size of batch that were included in the program, with the exception of one batch that appears to have been produced under abnormal circumstances.

The data indicate that a moderate loss in strength resulted from the use of batches larger than the rated capacity of the mixer. On the other hand, the time of mixing did not appear to have an influence on the development of concrete strength.

The trend of the test data point to the possibility that mixers in poorer condition or those that may be inherently less efficient, could produce unsatisfactory mixtures when operated with overloads of 20 percent or more.

Table 3
Data of Batches Mixed 30 Seconds

Batch Size Cu.Ft.	Batch Number	Measured Mixing Time, Sec.	Slump Inches		Air Percent		Unit Weight Air-free Mortar Lbs/cu.ft.		Coarse Aggt. Lbs/cu.ft. of Concrete		Compr. Strength psi (Avg. of 3 cyls.		Cement Factor Sks/cu.yd.	
			1*	4*	1	4	1	4	1	4	1	4	1	4
34.0	13	30.0	1.75	2	3.1	3.1	142.4	139.5	82.7	80.1	2590	2600	5.08	5.12
	50	33.0	2	2	2.2	2.5	138.3	138.0	90.9	85.1	2270	2300	4.66	5.08
	73	30.0	2	2.50	2.9	3.1	139.0	139.2	81.3	84.6	2490	2510	5.15	5.05
Average		31.0	1.9	2.2	2.7	2.9	139.9	138.9	85.0	83.3	2450	2470	4.96	5.08
37.4	12	33.6	2	2.25	4.7	4.1	141.1	140.1	77.8	78.8	2100	2160	5.21	5.12
	50	28.2	2	1.75	3.5	3.4	141.5	140.5	83.7	85.8	2150	2330	5.15	5.05
	81	37.2	2.5	1.75	4.7	3.8	141.4	141.1	78.3	84.6	2150	2240	4.60	5.05
Average		33.0	2.2	1.9	4.3	3.8	141.3	140.6	79.9	83.1	2130	2240	4.99	5.07
40.8	10	28.8	1.75	2.5	4.3	4.4	141.5	139.5	84.8	80.0	2070	1890	4.57	4.70
	49	40.2	2.75	2.75	3.8	4.0	138.6	140.7	83.2	84.5	1830	2050	4.66	5.31
	81	34.2	1.75	2	2.3	2.9	141.4	139.3	93.4	78.9	2300	2400	4.92	4.95
Average		34.4	2.1	2.4	3.5	3.8	140.5	139.8	87.1	81.1	2070	2110	4.72	4.99

*Note: Numerals 1 and 4 refer to first and last quarters of each batch.

Table 4

Data of Batches Mixed 50 Seconds

Batch Size Cu. Ft.	Batch Number	Measured Mixing Time, Sec.	Slump Inches		Air Percent		Unit Weight Air-free Mortar Lbs/cu.ft.		Coarse Aggt. Lbs/cu.ft. of Concrete		Compr. Strength psi (Avg. of 3 cyls.)		Cement Factor Sks/cu.yd.	
			1*	4*	1	4	1	4	1	4	1	4	1	4
34.0	10	50.4	3.75	2.0	4.7	4.5	140.6	140.9	73.4	84.5	2160	1920	5.02	5.18
	35	48.6	2.5	1.75	3.0	3.2	137.0	139.6	82.5	82.1	2550	2610	5.02	5.18
	70	50.4	2.75	2.25	2.7	2.9	138.8	137.8	81.6	82.8	2270	2380	5.05	4.92
	90	49.8	1.75	2.0	3.9	3.3	140.8	141.4	81.5	87.6	2570	2650	4.92	5.21
	Average	49.8	2.7	2.0	3.6	3.5	139.3	139.9	79.8	84.3	2390	2390	5.00	5.12
37.4	10	49.2	2.0	2.25	3.1	3.3	140.0	139.0	85.8	84.5	2520	2530	5.12	5.21
	35	50.4	2.0	2.0	3.8	3.7	138.1	140.3	75.0	83.6	2360	2510	4.82	5.08
	75	48.6	2.0	2.25	4.1	4.5	139.5	137.9	87.0	83.4	1990	2000	5.12	4.82
	90**	44.4	1.75	3.5	4.5	3.1	138.2	136.4	80.4	89.2	2060	1180	5.25	5.60
	Average	49.4	2.0	2.18	3.7	3.8	139.2	139.1	82.6	83.8	2290	2280	5.02	5.04
40.8	10	45.6	3.5	1.75	5.3	5.1	140.7	139.6	78.8	80.7	2010	2080	5.27	5.12
	35	46.8	2.0	1.5	4.3	4.4	142.4	140.4	81.1	83.4	2340	2180	5.05	5.15
	70	48.6	1.5	1.25	4.4	4.4	142.2	140.5	77.7	84.6	2280	2320	5.12	5.05
	90	50.4	1.75	1.75	4.2	4.0	140.3	140.1	77.0	86.8	2240	2180	5.40	5.12
	Average	47.8	2.2	1.6	4.6	4.5	141.4	140.2	78.7	83.9	2220	2190	5.21	5.11

*Numerals 1 and 4 refer to first and last quarters of batch.
**Test results for Batch No. 90 not included in average.

Table 5
Data of Batches Mixed 70 Seconds

Batch Size Cu.Ft.	Batch Number	Measured Mixing Time, Sec.	Slump Inches		Air Percent		Unit Weight Air-free Mortar Lbs/cu.ft.		Coarse Aggt. Lbs/cu.ft. of Concrete		Compr. Strength psi (Avg. of 3 cyls.)		Cement Factor Sks/cu.yd.	
			1*	4*	1	4	1	4	1	4	1	4	1	4
34.0	11	70.7	2	2	4.3	4.4	138.8	139.4	87.8	87.9	2160	2280	4.76	5.05
	36	70.0	2.25	2	4.8	5.3	139.4	139.0	83.4	82.1	1860	2100	4.88	4.85
	71	70.7	2.50	1.75	4.8	4.5	140.9	141.7	79.8	82.7	2080	2170	4.95	4.70
	91	70.7	1.5	2.0	3.5	4.3	140.1	139.5	90.6	87.4	1960	2070	4.53	5.02
	Average	70.5	2.1	1.9	4.4	4.6	139.8	139.9	85.4	85.0	2020	2160	4.78	4.91
37.4	11	68.3	2.5	2	3.2	3.4	139.8	139.0	83.2	82.5	2130	2390	4.82	5.15
	37	69.5	1.5	2.25	2.8	2.8	141.1	141.6	87.4	86.5	2290	2660	4.95	5.12
	63	70.0	2.25	2.25	3.2	3.1	140.2	141.2	78.1	90.6	2310	2340	5.27	5.05
	80	70.7	2	2	2.9	2.7	138.3	141.0	81.2	85.2	2330	2440	5.02	4.98
	Average	69.6	2.1	2.1	3.0	3.0	139.9	140.7	82.5	86.2	2270	2460	5.01	5.08
40.8	10	70.0	2.25	2.5	4.7	4.3	141.3	141.9	75.8	81.3	2160	2210	5.02	4.95
	39	70.0	2.75	2.75	2.9	3.5	140.4	140.2	88.2	80.5	1820	2260	4.92	5.18
	61	69.5	2.5	2.5	4.8	4.2	140.2	140.6	75.3	83.6	2000	2050	4.85	4.88
	80	70.0	3.0	2.75	3.9	3.8	140.3	141.2	76.6	82.7	2080	2010	4.70	4.60
	Average	69.9	2.6	2.6	4.1	4.0	140.6	141.0	79.0	82.0	2020	2130	4.87	4.90

*Numerals 1 and 4 refer to first and last quarters of batch.

Table 6
Averages of Variation Between First and Last Portions of Individual Batches

1. Slump, inches
2. Air Content, percentage points
3. Unit weight of air-free mortar, lbs. per cu. ft.
4. Weight of coarse aggregate, lbs. per cu. ft. of concrete
5. Compressive strength, lbs. per sq. in.
6. Cement content, sacks per cu. yd.

Nominal Mixing Time Seconds	Size of Batch, cu. ft.							
	34.0		37.4		40.8		Average	
30	1	0.1	1	0.4	1	0.3	1	0.3
	2	0.2	2	0.5	2	0.3	2	0.3
	3	1.1	3	0.8	3	2.1	3	1.3
	4	3.9	4	3.1	4	6.9	4	4.6
	5	20	5	80	5	170	5	90
	6	0.19	6	0.21	6	0.27	6	0.22
50	1	0.8	1	0.2	1	0.6	1	0.5
	2	0.3	2	0.2	2	0.1	2	0.2
	3	1.1	3	1.6	3	1.3	3	1.3
	4	4.7	4	4.5	4	4.5	4	4.6
	5	120	5	90	5	80	5	90
	6	0.18	6	0.22	6	0.15	6	0.18
70	1	0.4	1	0.3	1	0.1	1	0.3
	2	0.4	2	0.1	2	0.4	2	0.3
	3	0.6	3	1.3	3	0.5	3	0.8
	4	1.9	4	4.5	4	6.9	4	4.4
	5	140	5	190	5	150	5	160
	6	0.27	6	0.19	6	0.12	6	0.19
Average	1	0.4	1	0.3	1	0.3	1	0.4
	2	0.3	2	0.4	2	0.3	2	0.3
	3	0.9	3	1.2	3	1.3	3	1.2
	4	3.5	4	4.0	4	6.1	4	4.5
	5	90	5	120	5	130	5	110
	6	0.21	6	0.21	6	0.18	6	0.20

Table 7
Average Relationships for Variations as Affected by Mixing Time and Size of Batch

	Mixing Time		Size of Batch	
1. Slump, inches	30 sec. 50 sec. 70 sec.	0.3 0.5 0.3	34.0 cu.ft. 37.4 cu.ft. 40.8 cu.ft.	0.4 0.3 0.3
2. Air Content, percentage points	30 sec. 50 sec. 70 sec.	0.3 0.2 0.3	34.0 cu.ft. 37.4 cu.ft. 40.8 cu.ft.	0.3 0.4 0.3
3. Unit Weight of Air-free mortar, lbs.per cu. ft.	30 sec. 50 sec. 70 sec.	1.3 1.3 0.8	34.0 cu.ft. 37.4 cu.ft. 40.8 cu.ft.	0.9 1.2 1.3
4. Weight of Coarse Aggregate per cu.ft. of Concrete, lbs.	30 sec. 50 sec. 70 sec.	4.6 4.6 4.4	34.0 cu.ft. 37.4 cu.ft. 40.8 cu.ft.	3.5 4.0 6.1
5. Compressive Strength, psi	30 sec. 50 sec. 70 sec.	90 90 160	34.0 cu.ft. 37.4 cu.ft. 40.8 cu.ft.	90 120 130
6. Cement factor sacks per cu.yd.	30 sec. 50 sec. 70 sec.	0.22 0.18 0.19	34.0 cu.ft. 37.4 cu.ft. 40.8 cu.ft.	0.21 0.21 0.18

Table 8
Effect of Size of Batch and Mixing Time on Compressive Strength of Concrete

Mixing Time Seconds	Compressive Strength, psi Average of all batch sizes	
30	2250	
50	2250	
70	2170	
Size of Batch Cubic Feet	Compressive Strength Average of all Mixing Times	
	psi	relative
34.0	2300	100
37.4	2240	97
40.8	2130	93

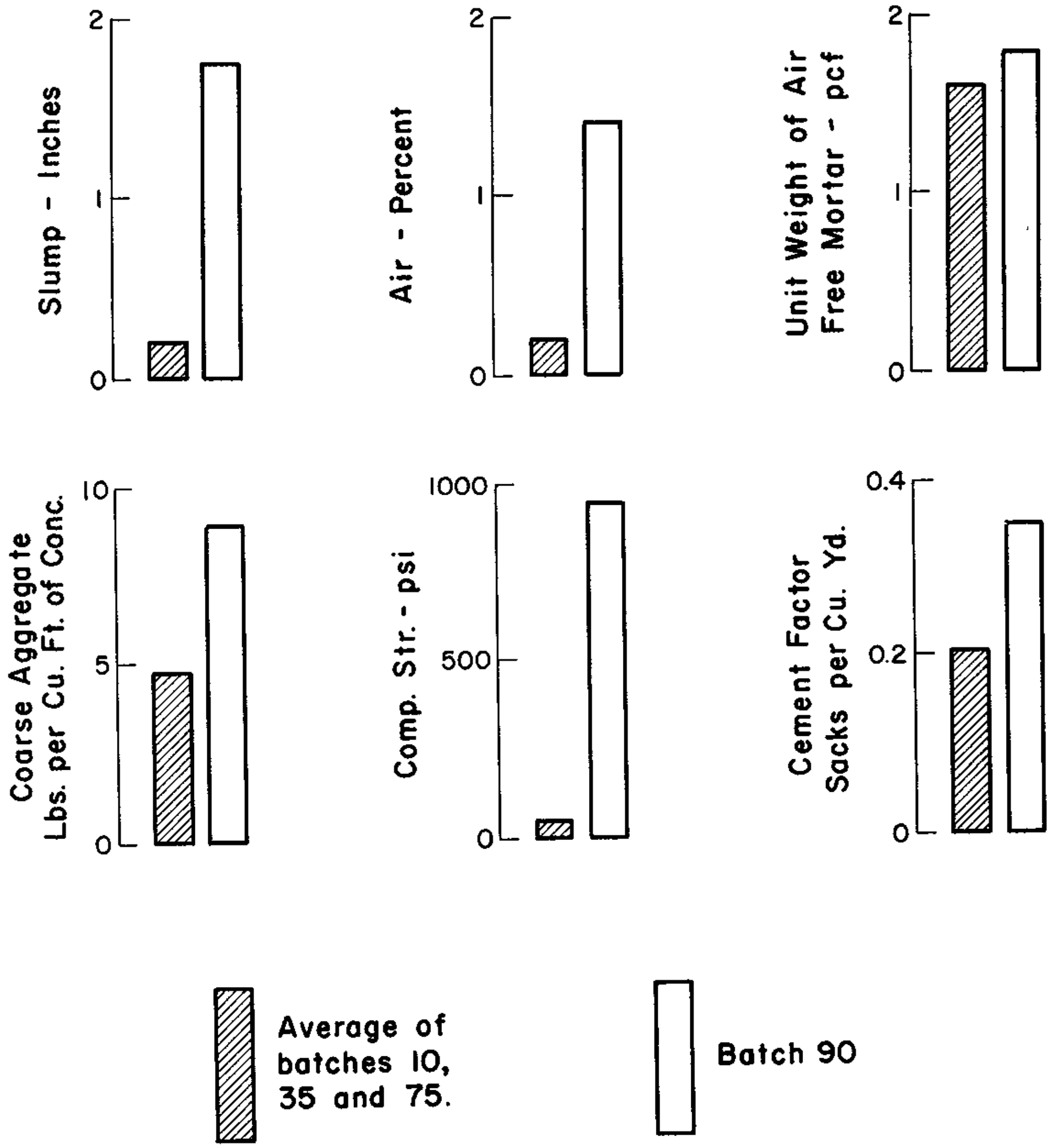

FIGURE 1

VARIATIONS WITHIN BATCHES

37.4 Cubic Feet, Mixed 50 Seconds