Effect of Mixing Time and Overload on Concrete Produced by Stationary Mixers

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This paper covers tests made in conjunction with the Bureau of Public Roads on two concrete paving projects to determine the minimum time of mixing required by stationary mixers, used to mix concrete for agitating or non-agitating delivery, to prepare well-mixed and uniform concrete, and to determine the amount of overload that can be permitted.

Two mixers were used in the tests, one a 210 S, the other a 254 S. Mixing times were 150, 120, 90, 75 and 60 seconds, with no overload and with a 10 percent overload.

Tests were made to determine compressive and flexural strength, consistency, air content, unit weight and percentage of mortar in the mix (using washout).

Based on the results obtained, the Ohio Department of Highways has changed its specifications for central-mix concrete to 1½-min mixing time with an allowable 10 percent overload.

● IN THE SUMMER of 1958, the Ohio Department of Highways participated in a mixing time study of 34-E dual-drum pavers. This study, suggested by the Bureau of Public Roads and participated in by several highway departments was to determine the most desirable mixing time and the permissable overload, if any. As a result of Ohio participation in the paver study, considerable interest in optimum mixing times, not only for pavers, but also for stationary mixers used with central-mixed concrete paving operation was generated in the state.

Generally, a minimum mixing time of one minute for the first cu yd plus 15 sec for

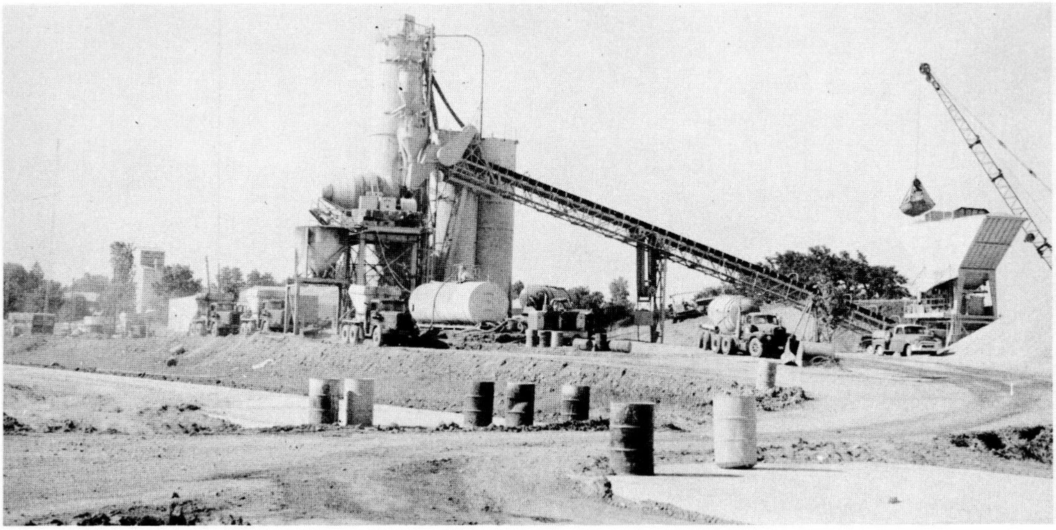


Figure 1.

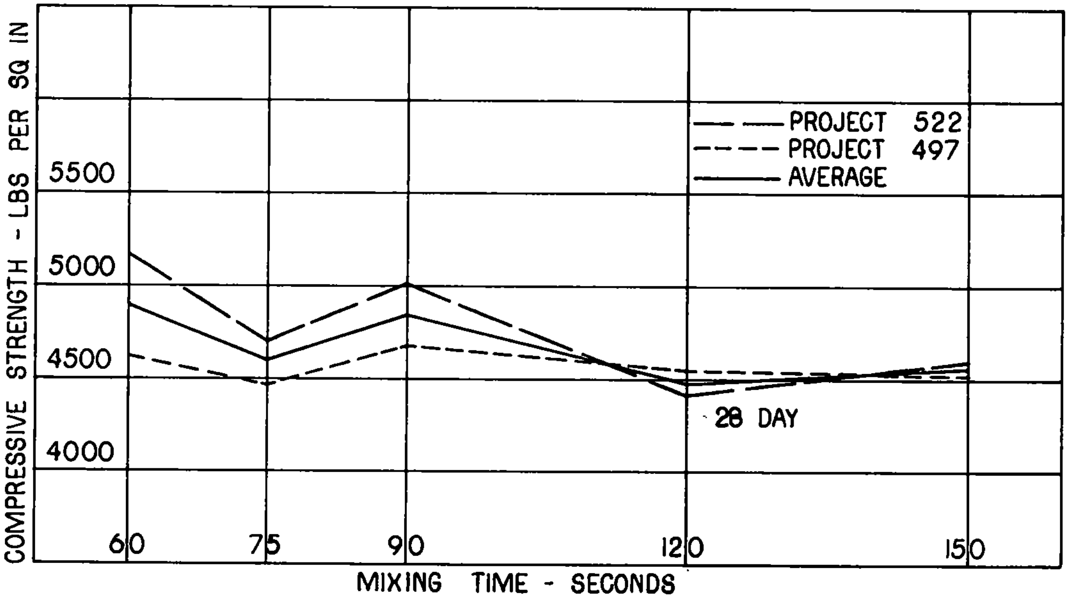
each additional yard or fraction thereof was specified for concrete completely mixed in a stationary mixer. Some concrete users, however, were of the opinion that the length of mixing time required was not dependent on the size of the mixer, but that any properly designed mixer, regardless of size, would mix concrete in approximately the same time.

Figure 2.

Figure 3.

The Ohio Department of Highways specifications required a minimum mixing time of two minutes for stationary mixers.

The possibility of including stationary mixers in the paver study was reviewed with the Bureau of Public Roads and it was decided a more practical approach would be to conduct a separate study.



EFFECT OF MIXING TIME ON COMPRESSIVE STRENGTH
AVERAGE OF BOTH LOADINGS

Figure 4.

TABLE 1

MIXING TIME VERSUS COMPRESSIVE STRENGTH

Mixing Time (sec)	Overload (%)	Compressive Strength (psi): 250S Smith Project 522 (1958) Max	Min	Avg[a]	210S Burmeister Project 497 (1958) Max	Min	Avg[a]	Composite of 2 Projects Max	Min	Avg
		28-Day Break								
150	0	5180	3860	4614	5320	4600	5077	5320	3860	4846
150	10	5080	4140	4568	4570	3460	3973	5080	3460	4271
120	0	4950	3880	4510	4740	4140	4435	4950	3880	4473
120	10	4640	3930	4326	5020	4100	4663	5020	3930	4495
90	0	6030	4740	5306	5080	4170	4629	6030	4170	4968
90	10	5300	4030	4713	5230	4240	4730	5300	4030	4722
75	0	5530	3740	4619	5110	4210	4747	5530	3740	4683
75	10	5430	4300	4803	4850	3820	4210	5430	3820	4507
60	0	5620	4450	5022	5440	4100	4748	5620	4100	4885
60	10	5960	4710	5323	5060	3360	4511	5960	3360	4917

[a] Each average compressive strength represents 27 samples taken from 3 batches.

Accordingly, arrangements were made to make such a study on two Ohio highway projects in the summer of 1959.

A proposed program for the study was prepared and submitted to the Bureau of Public Roads for approval. Variables provided for in the program were mixing times of 150, 120, 90, 75 and 60 seconds, with 0 and 10 percent overloads. The tests were to be essentially the same as those used in the paver study which was reported by D.O. Woolf of the Bureau of Public Roads at the 1960 Highway Research Board meeting. Samples for tests were taken from each tenth batch of 90 consecutive batches. Three samples were taken from each batch sampled. Specimens were made for compression and flexure tests on certain batches. Tests were made for air content, slump and unit weight. Washout tests to determine percent of coarse aggregate were also made. Some modifications in the planned procedure were made as will be explained later.

Two projects were selected for the study. On one project, located on US 33, about 20 miles southeast of Columbus, designation Project 522(1958), Fairfield and Franklin Counties, the concrete was mixed in a 254-S (9.3 cu yd) Smith Mixer (Fig. 1). The weighted aggregates were fed to the mixer by belt, the charging times for a 10 percent overload being 23 sec. For the same size batch, charging time for the water was 26½ sec, and discharge time for the mixed concrete 15 sec. Inasmuch as the plant was completely interlocked only the mixing time was changed, the charging and discharge times remaining unchanged. This gave an additional mixing time of about 2 sec to all batches

TABLE 2

MIXING TIME VERSUS TRANSVERSE STRENGTH

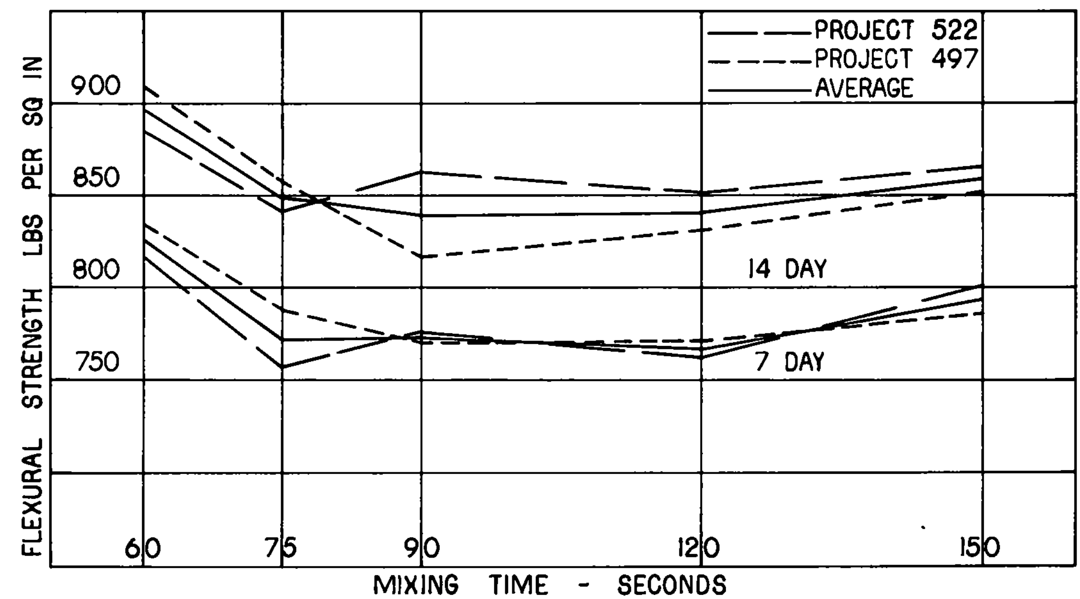
Mixing Time (sec)	Overload (%)	Transverse Strength (psi): 254S Smith Project 522 (1958) Max	Min	Avg[a]	210S Burmeister Project 497 (1958) Max	Min	Avg[a]	Composite of 2 Projects Max	Min	Avg
					7-Day Break					
150	0	940	720	807	950	660	811	950	660	809
150	10	920	670	796	900	680	761	920	670	779
120	0	880	590	758	950	700	799	950	590	779
120	10	870	650	766	880	650	744	880	650	755
90	0	880	670	778	910	580	796	910	580	787
90	10	890	650	775	920	660	747	920	650	761
75	0	890	680	774	940	710	813	940	680	793
75	10	880	640	739	840	650	764	880	640	752
60	0	930	720	804	920	780	831	930	720	818
60	10	900	760	832	920	650	837	920	650	834
					14-Day Break					
150	0	980	780	872[b]	950	780	861[b]	980	780	867
150	10	980	780	861	990	750	843	990	750	852
120	0	940	740	847	960	760	835	960	740	841
120	10	900	800	856	980	670	826	980	670	841
90	0	950	830	883	910	680	831	950	680	857
90	10	950	760	842	870	720	800	950	720	821
75	0	970	780	861	920	810	861	970	780	861
75	10	870	750	820	940	780	853	940	750	837
60	0	1050	780	904	980	830	904	1050	780	904
60	10	930	730	865	970	850	914	970	730	890

[a] Each average flexural strength represents 18 breaks of 9 beams from 3 batches.
[b] Each average flexural strength represents 9 breaks of 9 beams from 3 batches.

of zero percent overload. Batches of 0 and 10 percent overload with all five mixing times, as planned, were processed through this plant.

A 210-S Burmeister Mixer (Fig. 2) was used on the second project, which was located on US 35 about 15 miles southeast of Chillicothe, designation Project Number 497(1958), Jackson County. With this plant the weighted aggregates and cement were fed by a belt into a collecting hopper, from which they were discharged into the mixer. At this plant, also completely interlocked, the charging time for the aggregates was 44 sec, discharge time 25 sec and charging time for the water 52 sec. In this case, as in Project 522, only the mixing times were changed, so that the smaller batches had slightly longer mixing than did the overload batches. Because the capacity of the cement scales was only 5,000 lb, the complete 10 percent overload could not be used. The actual overload was 9.2 percent. Due to a misunderstanding the 0 overload was not 0 but 2.8 percent. For tabulation of test results and analysis these overloads are considered to be 0 and 10 percent, not 2.8 and 9.2 percent as they actually were.

As the study was originally planned it was intended to take a 100-lb sample from the first third, second third, and last third of the test batch as discharged from the mixer.



EFFECT OF MIXING TIME ON FLEXURAL STRENGTH - AVERAGE OF BOTH LOADINGS

Figure 5.

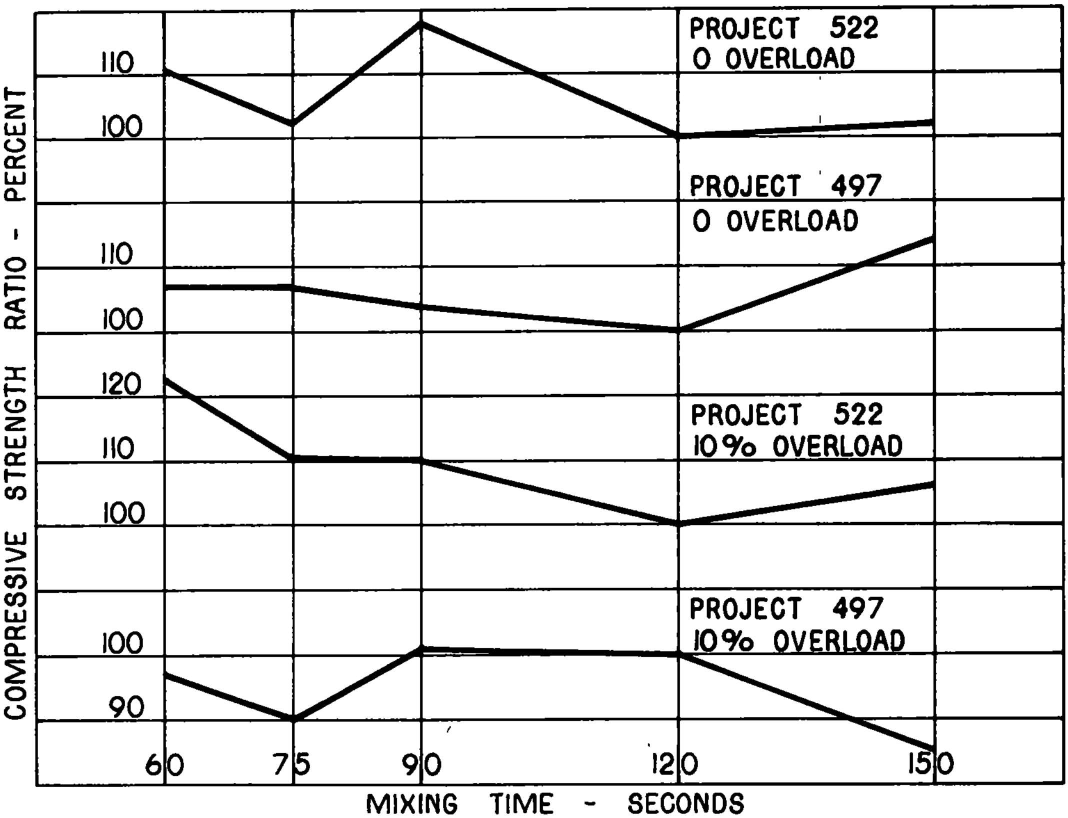
TABLE 3

EFFECT OF MIXING TIME AND OVERLOAD ON COMPRESSIVE STRENGTH AT 28 DAYS

		Unit Compressive Strength (psi)					Ratio to Strength for 120-Sec Mixing Time (%)				
		Mixing Time									
Project No	Overload (%)	60 Sec	75 Sec	90 Sec	120 Sec	150 Sec	60 Sec.	75 Sec.	90 Sec	120 Sec	150 Sec
522(58)	0	5022	4619	5306	4510	4614	111	102	118	100	102
497(58)	0	4748	4747	4629	4435	5077	107	107	104	100	114
522(58)	10	5323	4803	4713	4326	4568	123	111	109	100	106
497(58)	10	4511	4210	4730	4663	3973	97	90	101	100	85
Average		4901	4595	4844	4484	4558	109	102	108	100	102

However, on closer analysis this seemed to be hazardous as well as impractical. Because each plant was equipped with a holding hopper, it was then decided to divide the batches into thirds as they were discharged from the holding hopper. The procedure used was as follows:

1. Immediately prior to discharge of a test batch all concrete in the holding hopper was withdrawn.
2. The test batch was then discharged into the holding hopper.
3. The test batch was then discharged by thirds into three dumpcrete trucks and transported to the casting and testing area.



EFFECT OF MIXING TIME ON COMPRESSIVE STRENGTH AGE 28 DAYS

Figure 6.

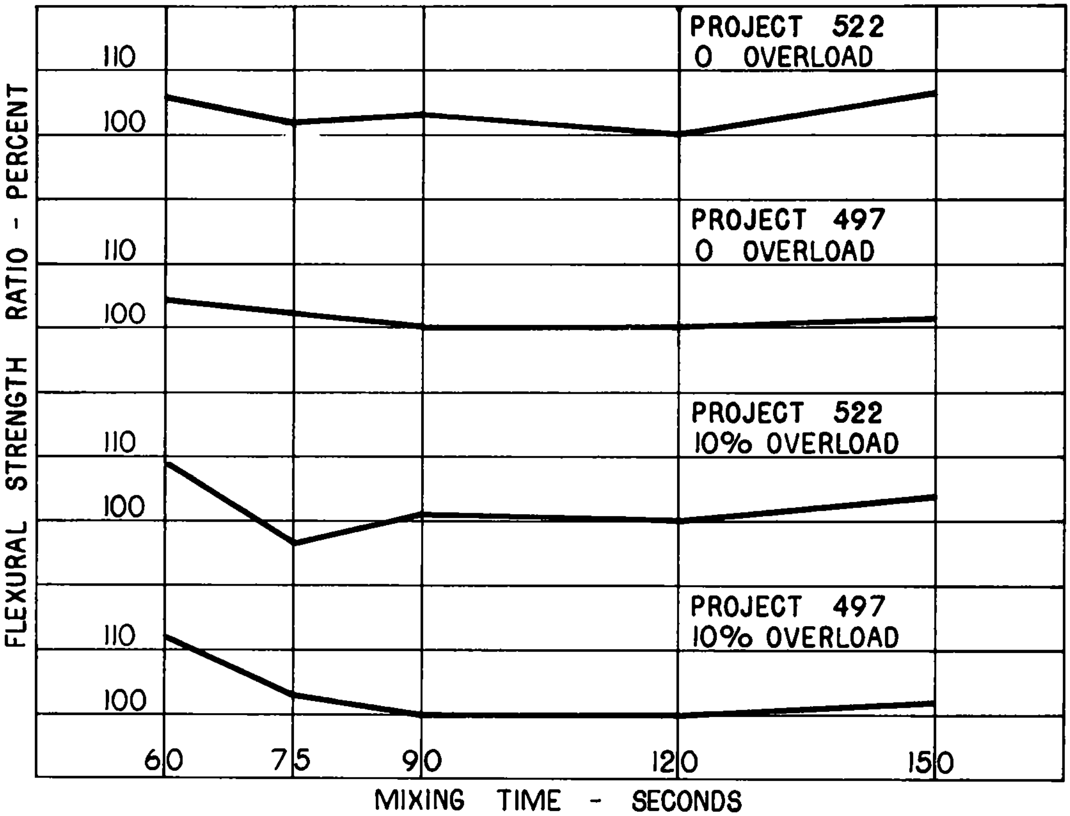
TABLE 4
EFFECT OF MIXING TIME AND OVERLOAD ON FLEXURAL STRENGTH AT 7 DAYS

		Unit Flexural Strength (psi)					Ratio to Strength for 120-Sec. Mixing Time (%)				
		Mixing Time									
Project No	Overload (%)	60 Sec.	75 Sec.	90 Sec	120 Sec.	150 Sec.	60 Sec.	75 Sec.	90 Sec.	120 Sec.	150 Sec.
522(58)	0	804	774	778	758	807	106	102	103	100	106
497(58)	0	831	813	796	799	811	104	102	100	100	101
522(58)	10	832	739	775	766	796	109	96	101	100	104
497(58)	10	837	764	747	744	761	112	103	100	100	102
Average		826	773	774	767	794	108	101	101	100	103

4. At the casting area a test sample of concrete was discharged from each truck into pans (Fig. 3) and designated First, Second and Third samples.

Three 6- by 12-in. cylinders were cast from each third sample of three test batches. These were cured overnight at the casting site and transported to the testing laboratory on the following day where they were stored in the moist room until tested at 28 days. The average results obtained from these tests are given in Table 1. A review of these data shows that the average compressive strength of the 10 percent overload concrete is approximately 4 percent less than that with no overload.

Similarly, 6- by 6- by 40-in. beams were cast for testing. These were handled in the same manner as the cylinders. The beams were tested at the laboratory in a center



EFFECT OF MIXING TIME ON FLEXURAL STRENGTH AGE 7 DAYS

Figure 7.

TABLE 5

EFFECT OF MIXING TIME AND OVERLOAD ON FLEXURAL STRENGTH AT 14 DAYS

		Unit Flexural Strength					Ratio to Strength for 120-Sec. Mixing Time (%)				
		Mixing Time									
Project No	Overload (%)	60 Sec	75 Sec	90 Sec	120 Sec.	150 Sec	60 Sec	75 Sec.	90 Sec	120 Sec.	150 Sec
522(58)	0	904	861	883	847	872	107	102	104	100	103
497(58)	0	904	861	831	835	861	108	103	100	100	103
522(58)	10	865	820	842	856	861	101	96	98	100	101
497(58)	10	914	853	800	826	843	111	103	97	100	102
Average		897	849	839	841	859	107	101	100	100	102

loading device, two breaks being made at seven days and one at 14 days from each specimen. The data obtained from these tests are given in Table 2. A review of these data shows that the concrete with no overload averaged 3 percent higher at seven days and 2 percent higher at 14 days than the concrete with the 10 percent overload.

Inasmuch as the overload had no significant effect on either the compressive or flexural strength it may be assumed that a 10 percent overload, at least so far as

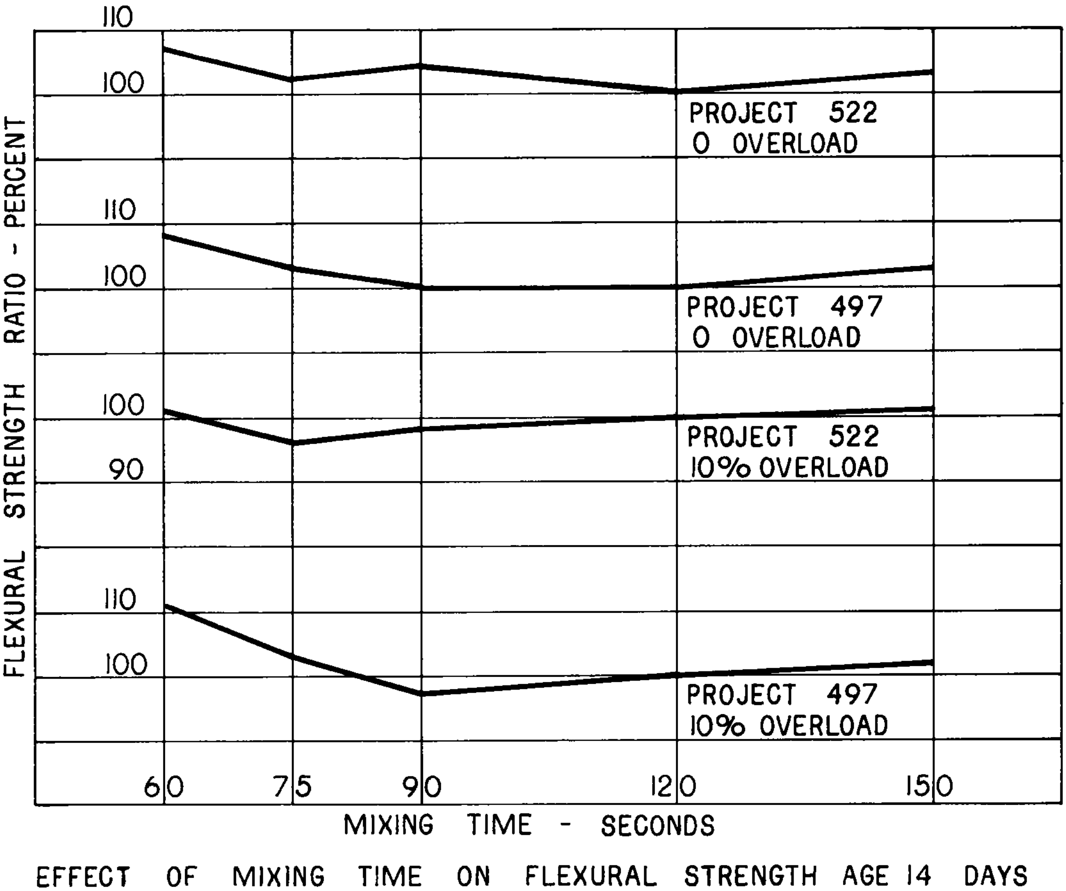


Figure 8.

TABLE 6

AIR CONTENTS OF SELECTED SAMPLES

Specimen No.	Mixing Time (Sec.)	Average[a] Air Volume (%)	Average[a] Number Voids per Traverse (In.)	Average Air Volume Field Tests (%)	Average Slump Field Tests (In.)
10-2-2	60	4.41	7.41	4.2	2
8-5-2	75	4.84	7.46	4.2	2 ½
6-8-2	90	3.83	5.25	4.2	2 ¼
4-2-3	120	3.62	7.13	4.4	2 ¼
2-8-1	150	3.75	7.05	4.2	2 ¾

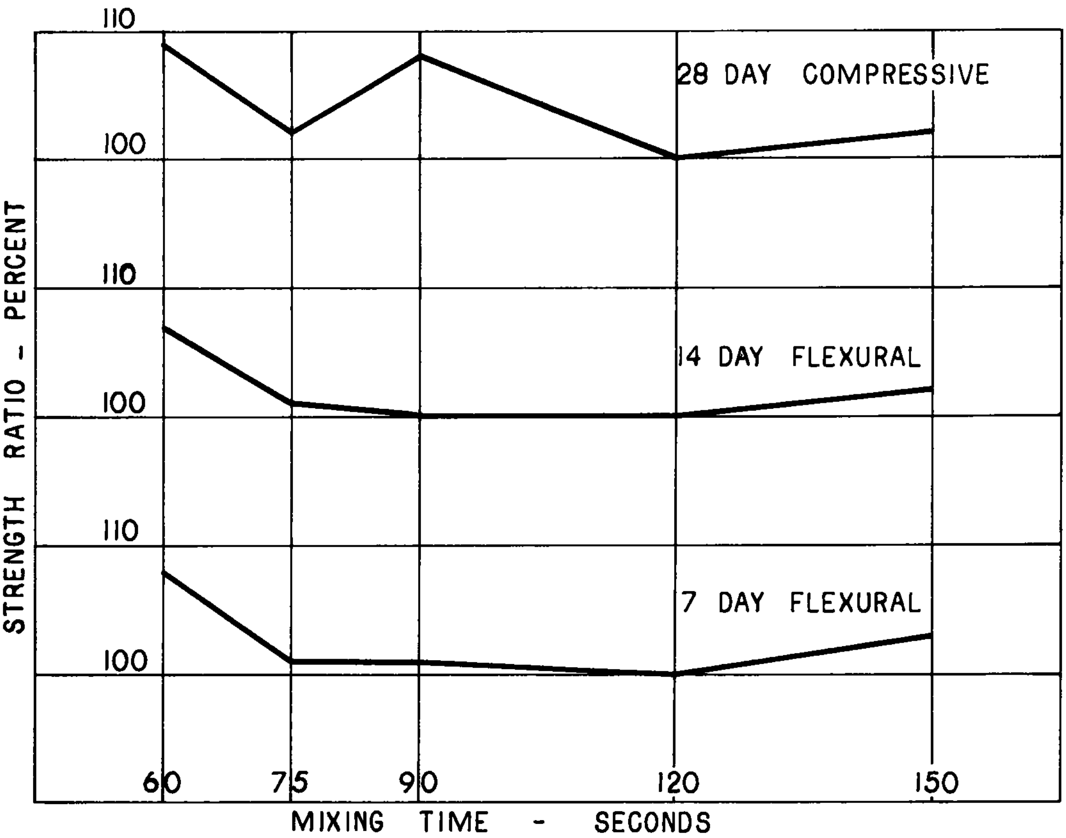
Note: — All specimens tested represent 10 percent overloads.
[a] Average of two sections cut from each beam.

strength is concerned, may be permitted because this will produce 10 percent more concrete of essentially the same strength.

The effect of mixing time on compressive and flexural strength using the average of both loadings for each project is shown in Figures 4 and 5. Comparisons were also made to show the effect in percent that variation of the mixing time had on both compression and flexural strength. In these comparisons, the strength obtained with 120 sec of mixing was considered to be 100 percent. Table 3 and Figure 6 give this information on 28-day compressive strength. The 7-day and 14-day flexural strengths are compared in Tables 4 and 5 and in Figures 7 and 8.

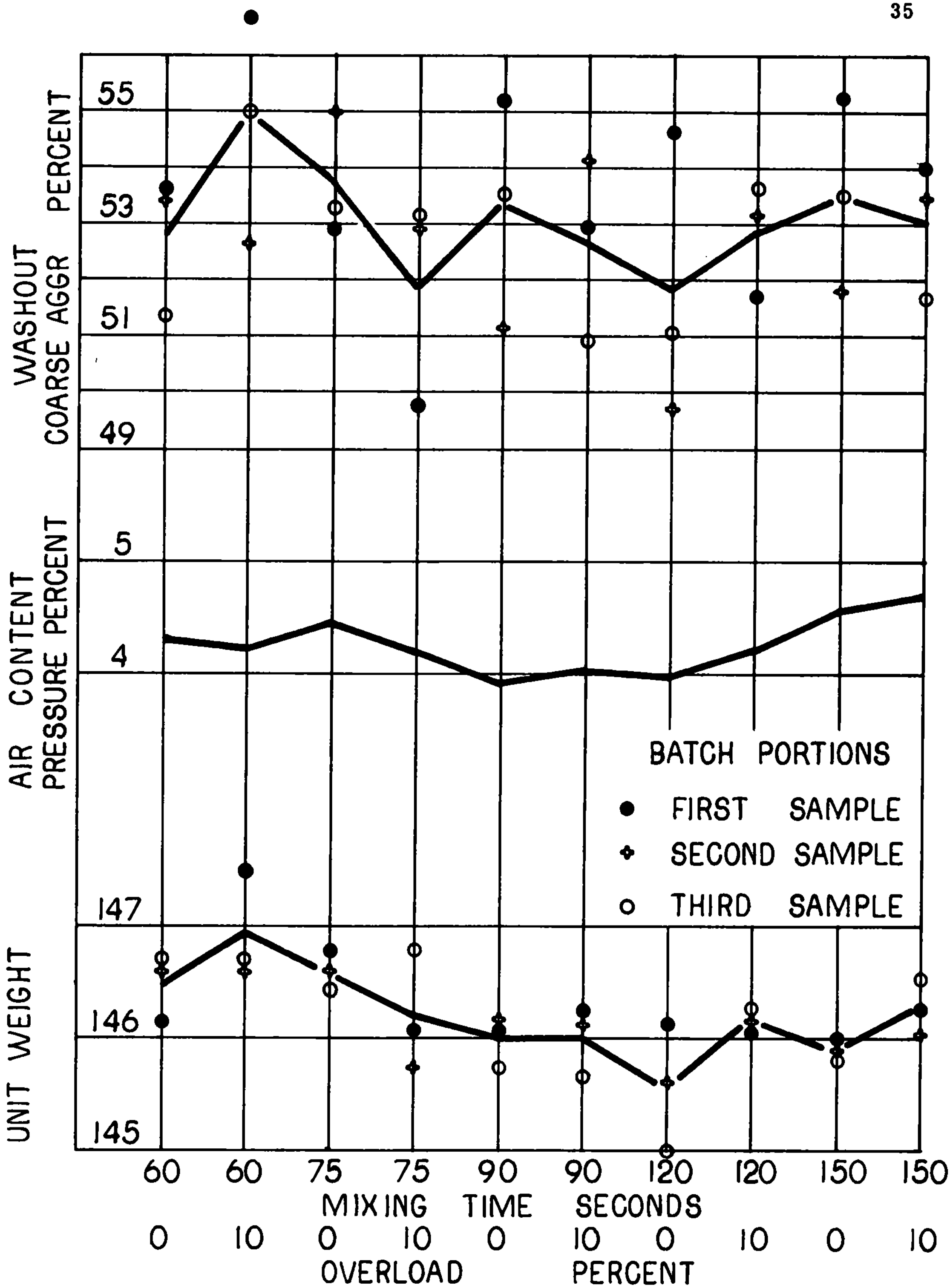
The composite effect of variation in mixing time is shown in Figure 9. Here 0 and 10 percent overload test results are combined using the 120-sec average as 100. A study of the data in Figure 9 shows that both compressive and flexural strengths are greatest with 60-sec mixing. The compressive strength, except for a peak at 90 sec, decreases slowly with additional mixing with some slight recovery at 150 sec. The flexural strength also decreases with more than 60 sec of mixing and here again some recovery is shown with 150 sec. In neither case do the data indicate that mixing more than 60 sec is conducive to higher strengths.

Unit weight determinations and washouts were made to determine uniformity within the batches. These were made on each third of three test batches of each combination of mixing time and overload on both projects. Because different aggregates were used in the two projects, no effort was made to combine the results obtained. The three test samples were combined for each batch and the air content determined using a pressure meter; slump tests and Kelly Ball tests were also made. In addition, air checks



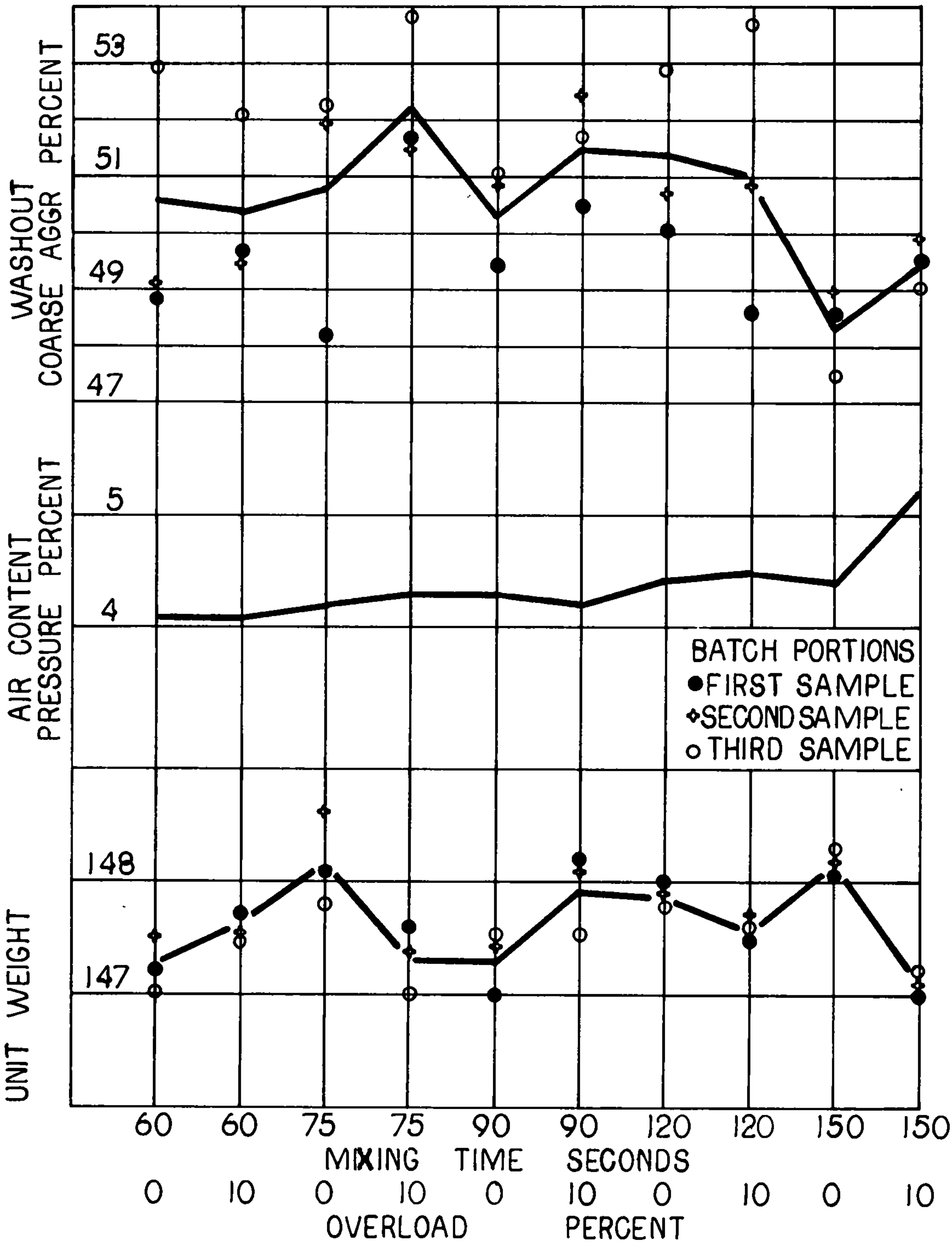
COMPOSITE EFFECT OF MIXING TIME ON STRENGTHS

Figure 9.



UNIFORMITY OF CONCRETE PROJECT 522

Figure 10.



UNIFORMITY OF CONCRETE PROJECT 497

Figure 11.

were made of the individual batch portions using the Chase Air Indicator. These varied considerably and were not used for comparison.

The results of the washout tests, expressed in percent of coarse aggregate and of the unit weights of the concrete for Project 522 (254-S Smith) are shown in Figure 10. No significant variation was obtained indicating that the concrete was mixed to essentially the same uniformity regardless of mixing time or overload used. Similar information for Project 497 (210-S Burmeister) is shown in Figure 11. Again no significant variation is found.

Based on a preliminary review of the data obtained in this study it was decided by the Ohio Department of Highways to reduce the specified mixing time for concrete mixed in stationary mixers from 2 to 1½ min. This mixing time has been permitted by proposal note since December 1959.

It was previously pointed out that the strengths obtained with the 60-sec mix were on the average higher than those obtained at any other mixing time (Fig. 9). This raised the question as to whether the air entrained at this mixing time was of the proper size and distribution. Through the courtesy of the Portland Cement Association, a limited number of air determinations were made (early in 1960) at their laboratory on sections of 5 test beams from Project 522, (254-S Smith). The results obtained by these determinations, together with related field data, are given in Table 6. This shows that based on the data available, the 60-sec mixed concrete had an air content comparable to or greater than that obtained at longer mixing periods.

It is the present intention to make further tests before reducing the required mixing time below the 1½-min minimum now specified. The charging times for aggregates used in this study, 23 and 44 sec, permit some mixing before the actual mixing period is started. This may have some bearing on the actual mixing time required.

ACKNOWLEDGMENTS

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