57

MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

A STUDY OF TRANSIT-MIXED CONCRETE IN RELATION TO A PROPOSED CHANGE IN BATCH QUANTITIES ON CONSTRUCTION PROJECT 9-8, C5

E. A. Finney

RESEARCH LABORATORY
TESTING AND RESEARCH DIVISION
AUGUST 5, 1944

A STUDY OF TRANSIT-MIXED CONCRETE IN RELATION TO A PROPOSED CHANGE IN BATCH QUANTITIES

This report pertains to a recent request of the Anderson Sand and Gravel Company of Saginaw for permission from the Department to increase the charge in their truck mixers from 4 cubic yards to 5 cubic yards in connection with their contract to furnish concrete for patch work on Project 9-8, CS, M 20, Bay City west.

Since their truck mixers were designed for 4 cubic yards, it was held desirable to conduct comparative tests to determine the relative efficiency of mixing in both 4 and 5 cubic yard batches before granting such permission.

On July 21, 25, 26 and 27 a study was made including a survey of plant and operating conditions and an analysis of several batches of concrete by the Dunagan method.

Proposed Tests:

It was decided that pertinent information should include (1) efficiency of dispersion of the cement, (2) efficiency of dispersion of the various sizes of aggregate, and (3) studies of such concomitant data as unit weight, slump, strength, mixing time, distance of haul, number of revolutions of the mixer and workability.

Test Procedure:

Blank Dunagan extractions were performed on representative samples of the aggregates for the purpose of determining the sand-clay-silt factor. The following percentages of each bone dry aggregate passed the No. 100 sieve: -

FA	0.77 %
4A	0.074%
10A	0.158%
Total	1.002%

For all practical purposes, therefore, the sand-clay-silt factor was taken as 1%.

It was decided to sample the concrete at five different points in each batch. These points were (1) immediately after the initial discharge of the mixer, (2) after approximately 25% of the batch had been discharged, (3) after 50%, (4) after 75%, and (5) after about 95%. As soon as possible after taking the last sample, all samples were weighed and the cement extracted. The aggregates were dried and taken to the Research Laboratory at East Lansing for grading. Other data such as slump, unit weight, revolutions, etc. were secured at the paving site.

A set of five such tests was run on an experimental 5 cubic yard batch on the afternoon of July 21, 1944. A set of ten tests, on duplicate samples taken at five points, was conducted on the regular 4 cubic yard mix on the afternoon of July 25. Another set of ten tests on duplicate samples was run during the forenoon of July 26, also on a 4 yard batch. A set of five tests on a 5 yard batch was conducted in the morning of July 27, and another set on a second 5 yard batch that afternoon.

Transit Mix Operations:

The fine aggregate, course aggregate and water are added to the transit mixer simultaneously while the drum is revolving at approximately 10 R.P.M. It requires about three minutes to charge the drum with these materials. After the drum has received its full charge of aggregates and water, the drum is stopped and the vehicle moved to the cement hopper where the charge of cement is allowed to flow in on top of the aggregate and water and no further mixing is done at the plant. The time element for moving vehicle and adding cement is about one minute.

Upon leaving the plant the drum remains stationary until the vehicle reaches the Bay County Line which takes approximately thirty to forty minutes.

TABLE I
ANALYSIS OF READY MIX CONCRETE, PROJECT S-8, CS
4 Cubic Yard Batch
M20, Bay City Rest

Trial No. 1

Material	Specific Gravity	Batch Weight Total	Batch Weight %	PERCENT OF WHOLE CONCRETE - ACTUAL (DUNAGAN) 1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B	5 A	5 B	Average A	Average B
Cement	3.14	2852	16.20	15.22	16.52	17.20	16.97	19.05	17.81	15.75	16.12	15.52	14.52	(16.65) 16.70	16.55
Water		650	3.97												
FA	2.62	4085	25.14	21.61	24.40	25.45	24.48	24.96	24.96	25.12	25.25	22.77	20.25	(23.72) 25.58	23.56
4A	2.71	4598	27.08	25.45	25.96	22.88	22.80	21.15	21.95	24.65	22.71	22.77	25.10	(23.54) 23.56	23.52
10A	2.66	4484	27.61	25.45	25.96	22.88	22.80	21.15	21.95	24.65	22.71	22.77	25.10	(23.54) 23.56	23.52

Trial No. 2

Material	Specific Gravity	Batch Weight Total	Batch Weight %	PERCENT OF WHOLE CONCRETE - ACTUAL (DUNAGAN) 1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B	5 A	5 B	Average A	Average B
Cement	2.14	2852	16.20	15.82	16.51	15.74	16.65	16.10	17.50	16.61	16.28	17.41	18.50	(16.12) 15.94	16.29
Water		650	3.97												
FA	2.62	4085	24.14	17.24	19.29	20.35	20.87	25.18	24.28	22.68	22.50	25.44	26.22	(22.08) 21.77	22.59
4A	2.71	4598	27.08	28.86	29.44	26.60	25.69	25.82	22.98	24.60	24.45	22.00	20.87	(24.94) 25.18	24.69
10A	2.66	4484	27.61	28.86	29.44	26.80	25.69	25.82	22.98	24.60	24.45	22.00	20.87	(24.94) 25.18	24.69

TABLE II
ANALYSIS OF READY MIX CONCRETE, PROJECT 9-8, C3
5 Cubic Yard Batch
M20, Bay City West

Trial No. 1	Material	Specific Gravity	Batch Weight Total	Batch Weight %	PERCENT OF WHOLE CONCRETE - ACTUAL (EUNAGAR) 1	2	3	4	5	Average
	Cement	3.14	3290	16.76	14.50	15.10	16.42	15.30	11.89	14.84
	Water		808	4.14						
	FA	2.62	4780	24.24	21.78	22.68	24.61	22.81	17.88	21.81
	4A	2.71	4305	21.92	21.18	19.91	19.25	19.89	24.40	20.89
	10A	2.66	6475	32.95	31.77	29.90	29.91	29.48	36.68	31.95
	Cement	3.14	3290	16.19	14.96	15.70	16.45	15.58	15.97	15.71
Trial	Water		917							
No.	FA	2.62	5045	25.28	21.81	25.24	30.68	24.40	28.17	25.66
2	4A	2.71	5524	27.17	25.02	24.80	22.87	24.50	24.55	24.49
	10A	2.66	5557	27.33	25.02	24.80	22.87	24.50	24.55	24.49
	Cement	3.14	3290	16.24	15.40	16.27	15.57	16.30	16.30	15.97
Trial	Water		799							
No.	FA	2.62	5095	25.12	19.94	24.06	22.61	26.50	29.55	24.53
3	4A	2.71	5514	27.20	22.60	25.91	25.61	22.94	19.92	22.99
	10A	2.66	5557	27.44	22.60	25.91	25.61	22.94	19.92	22.99

TABLE III
SUMMARY OF DUNCAN ANALYSIS

Batch	Trial	Design Batch Weight in %			Duncan Values in %			Deviation From Design in %		
		C	FA	CA	C	FA	CA	C	FA	CA
4 cu.yd.	1	16.20	25.14	27.54	16.65	25.72	25.54	+0.45	-1.42	-4.00
4 cu.yd.	2	16.20	24.14	27.54	16.12	22.08	24.94	-0.08	-2.06	-2.60
				AVERAGE				+0.17	-1.74	-3.20
5 cu.yd.	2	16.19	25.28	27.25	15.71	25.66	24.49	-0.48	+0.38	-2.76
5 cu.yd.	3	16.24	25.12	27.52	15.97	24.53	22.99	-0.27	-0.59	-4.53
				AVERAGE				-0.37	-0.10	-3.64

Mean Variation from Actual Design

	4 cu.yd. Batch	5 cu.yd. Batch
Cement	+0.17	-0.37
Fine Aggregate	-1.74	-0.10
Coarse Aggregate	-3.20	-3.64

At the county line the operator starts the drum rotating at the rate of 8 revolutions per minute. This mixing is continued during the final fifteen to twenty minutes of the drive from the county line to the project. By this method the concrete mixture receives 140 to 150 revolutions of the drum, which is the top limit for Department specifications.

On the project it is generally necessary to add about 5 to 10 gallons additional water to the batch in order to facilitate discharge of the concrete from the mixer. This is to be expected since research has shown that the slump will drop considerably with length of haul, operating methods, temperature and materials.

Result of Tests:

The results from the Dunagan tests are presented in Tables I and II. For the sake of better comparison the values in Table I and II have been further summarized in Table III which presents the average mean variation of the cement, fine and coarse aggregates from the design values. The results from this work apparently indicate that there is very little difference between the two concretes. However, from the studies on the Michigan Test Road in which the Dunagan method was used to analyse fresh concrete from the pavement slab, it was learned that a large number of tests is necessary to obtain data from which definite conclusions can be drawn.

In a general way the data indicate that a better dispersion of the cement was obtained in the 4 yard batch. The dispersion of the aggregates varied considerably and seemed to be in practically all cases under design requirements. This condition may be due largely to the small size of sample (2000 grams) which is required for the Dunagan test.

During the test additional data was obtained relative to slump, drop in weight and modulus of rupture strength. These values are presented in Table IV. It is to be noted that the 4 cubic yard batches had a fairly uniform drop in weight although it was on the high side, whereas the examination of one 5 cubic yard batch showed an 11 pound drop. This would indicate that mixing conditions would have to be studied and revised in the case of the 5 cubic yard batch.

Strength values for modulus of rupture at 3 days on beams representing one 4 cubic yard batch averaged 418 pounds per square inch. The 3 day beam strengths from one 5 cubic yard batch averaged 440 pounds per square inch. These values are exceedingly low for supposedly high early strength concrete.

Shrink Mix Operations:

The equipment used for transporting and mixing the concrete is rated at 4 cubic yards as a truck mixer, 5.4 cubic yards as a shrink-mixer and 5 cubic yards as an agitator. The drum has a total volume of 208 cubic feet. It is understood that the request for the 5 cubic yard batch is based to a large extent on the fact that the batch is subjected to a certain amount of shrink-mixing at the plant.

According to the definition of shrink-mixed concrete, it is understood that the concrete batch must be partially mixed in a central mixing plant before placing in the truck mixer. Complete mixing of a 5 cubic yard batch at a central mixing plant requires about 2 1/4 minutes in a mixer having a ratio of gross drum volume to volume of batch of approximately four. For shrink mixing the required time in such a mixer may be reduced to a minimum of 30 seconds after all materials have been placed in the drum. In the case of the truck mixer there exists only a ratio of 1.5 between volume of drum

TABLE IV
MISCELLANEOUS CONCRETE DATA

Cubic Yard	Batch No.	Revolutions in Transit	Slump in Inches	Drop in Weight, Lbs. Trial 1	Trial 2
4	1	142	3	5.6	4.8
4	2	158	2 1/2	6.5	4.8
4	3	150	3	5.2	5.8
5	1	152	- -	- -	- -
5	2*	119	3 1/4	10.8	11.0
5	3	141	4	- -	- -

STRENGTH TESTS

Date Cast	Batch	Slump in Inches	Modulus of Rupture Trial 1	Trial 2	Age
7-24-44	4 cu. yd.	3 1/2	405	451	3 days
7-27-44	5 cu. yd.*	3 1/4	440	440	3 days

* Batch No. 2.

to volume of a 5 yard charge. It is apparent then that the truck mixer is not designed for rapid mixing of concrete and it would seem undesirable as a shrink mix unit unless ample study is made of all factors involved. Furthermore, shrink mixing requires that all ingredients of the concrete mixture shall be mixed into a mass before transferring to truck mixer or agitator. It may be concluded from these facts that the method now employed to charge the truck mixers for project 9-8, 03 would not produce results analogous to shrink-mixed concrete.

Conclusion:

The scope and duration of the study were insufficient to gather complete information on all phases of the problem; however, it is believed that the results obtained justify the following conclusions.

1. The average three-day beam strengths of 413 and 440 pounds per square inch for both the 4 and 5 cubic yard batches respectively were decidedly lower than the strengths which should be expected for normal 7-sack Vinsol resin concrete (minimum 550). This matter should be thoroughly investigated.

2. The average drop in unit weight for the 4 cubic yard batches is 5.8 pounds per cubic foot, which approaches the maximum value now considered satisfactory for air-entrained concrete.

3. The drop in unit weight for the 5 cubic yard batch was considerably in excess of specification requirements and nearly double that of recommended practice.

4. The results from the Dunagan tests indicate in general better dispersion of the cement in the 4 cubic yard batch than in the 5 cubic yard batch under similar handling conditions.

5. The concrete batch is not shrink-mixed at the plant. Further, it is not mixed as well as it would be if the drum were rotated during the complete charging operation, which is the general practice for local hauls.

6. It was observed that there was quite a variation in moisture content of the aggregates during the day. Such a condition will naturally affect the consistency between different batches and thereby influence the uniformity and quality of the mixture at delivery and throughout the pavement.

7. Under the summary of ready-mixed concrete data in Table V the vendor may increase at the will of the Department, the volume of the batch to 4.4 cubic yards and still comply with the capacity rating of the truck mixer. An increase above this value calls for shrink mixing as the term applies.

8. Finally the study brings out quite vividly the fact that the degree of success that the Department may expect from ready-mixed concrete is dependent to a large extent upon the control exercised during the mixing and transporting operations as well as to the condition of aggregates and type of cement employed in the mixture. Until such time as we can control these factors with the confidence that we will obtain what we want in ready-mixed concrete, we believe that it would be unwise for the Department to venture outside of accepted practice. Therefore, in view of the facts set forth above, we recommend that the request of the Anderson Sand and Gravel Company of Saginaw should not be granted.

TABLE V
SUMMARY OF MIXING REQUIREMENTS

Method Employed	Cubic Yards Maximum	Volume cu.ft.	% of Mixer Capacity 208 cu.ft.
Present Batch	4.0	108.0	51.9
Truck Mixer	4.4	118.8	57.5*
Proposed Batch	5.0	135.0	65.0
Shrink Mixer	5.4	145.8	70.0*
Agitator	6.0	166.4	80.0*

* A.S.T.M. Recommendations

ACKNOWLEDGEMENT

The field and laboratory work in connection with the Dungan study was done by B. W. Pocock and A. M. Burke of the Research Laboratory, unit weights, slump and beam strengths were furnished by Roy Fulton of the Construction Division. Data on general operating conditions were obtained by the above personnel and the author.