A STUDY OF TRANSIT MIXED CONCRETE

Final Report

by

HOLLIS B. RUSHING
CONCRETE RESEARCH ENGINEER

Research Report No. 30

Research Project No. 63-10C
Louisiana HPR 1 (6)

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research and Development Section
In Cooperation with
U. S. Department of Transportation
Federal Highway Administration
BUREAU OF PUBLIC ROADS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This report describes a research project in which various aspects of transit mixed concrete were studied. Phase I describes the work performed in evaluating the effects of extended retention of concrete in a transit mix truck for three hours. Four mixes were evaluated. These were (1) sand and gravel concrete with no admixtures, (2) sand and gravel concrete with admixtures, (3) lightweight coarse aggregate and sand with the moisture content of the coarse aggregate maintained at approximately 15 percent, and (4) the same mix with the moisture content of the coarse aggregate maintained at approximately 30 percent. Phase II describes the work performed in the field to determine yield, slump loss, loss of entrained air, water requirements and a comparison of field manufactured specimens to laboratory manufactured specimens. These tests were performed on concrete as was being used on construction projects throughout the State.

The conclusion reached from Phase I of this study were that sand and gravel concrete without admixtures is affected more by long retention in a transit mixed truck than is sand and gravel concrete with admixtures. If necessary as much as two hours retention could be tolerated without severly damaging the proporties of the concrete. Lightweight concrete with 15 percent moisture in the coarse aggregate performed better than lightweight concrete with 30 percent moisture in the coarse aggregate. Phase II indicated that slump loss, loss of entrained air and yield are not as large of a problem as has been indicated in the past.

Key Words: Admixtures, air content, compressive strength, freeze and thaw durability, lightweight aggregate, slump, transit mixed, yield.

INTRODUCTION

This study was undertaken in order to enhance the knowledge of transit mixed concrete in the highway construction field. There were several factors which influenced the decision to undertake a study of this nature. First is the fact that the use of transit mix concrete in highway construction has increased tremendously during the past several years. This increased use has created problems to which answers were badly needed. Secondly, the specifications now in use for transit mixed concrete were written at a time when transit mix concrete was the exception rather than the rule as it today. Thirdly, complaints from contractors were growing more numerous on such items as slump control, yield and haul time. For these major reasons it was determined that a full investigation into the properties of transit mixed concrete was badly needed.

SCOPE

This project was divided into two phases in order to investigate as fully as possible the properties of transit mixed concrete. Both phases will be discussed in this report.

Phase I consisted of a study of the effects of retaining concrete for extended periods in a transit mix truck. After stipulated intervals, a sufficient amount of concrete was removed from the truck for slump and air content tests and to make specimens for compressive strength, and durability (freeze and thaw) tests. The slump of the concrete was maintained at a constant level as close as possible by adding water if needed as the retention period continued. Four mixes were evaluated. These consisted of (1) a sand and gravel mix with a nominal cement content of 6.0 sacks/yard without admixtures and (2) a 5.5 sack/yard mix with an air entraining and a water reducing, set retarding admixture, (3) a mix with a nominal cement content of 5.75 sack/yard using lightweight coarse aggregate and natural sand with the moisture content of the lightweight aggregate maintained at approximately fifteen percent and (4) the same mix as number three with the moisture content of the lightweight coarse aggregate maintained at approximately thirty percent.

Phase II of the study consisted of a field investigation from a representative cross-section of ready mix concrete plants throughtout the state which furnish concrete to jobs being constructed for the Louisiana Department of Highways. Thirteen plants were visited and data accumulated as to the concrete yield, initial slump and slump loss in transit, actual cement content, actual water content, air content if applicable and compressive strength. In addition, a sufficient quantity of all materials used were obtained and brought to the concrete laboratory and the field mixes were duplicated for a comparison of results.

PHASE I
METHOD OF PROCEDURE

As previously stated, four concrete mixes were evaluated in this phase. In order to determine the effect of prolonged mixing in a transit mix truck, the following procedure was employed. The materials were batched into the truck and the drum rotated at mixing speed (approximately 14 r.p.m.) for 100 revolutions. A sufficient quantity of concrete was taken from the truck to make all necessary tests and specimens. The drum was rotated at agitating speed for approximately thirty minutes and then at mixing speed for approximately two minutes prior to discharging the second quantity of concrete for testing. This thirty minute cycle was then repeated. After concrete was discharged for the third series of tests and specimens, the agitating period was increased to one hour prior to obtaining the concrete for the fourth series of tests and specimens. The fifth series of tests and specimens were then taken one hour from the fourth making the total time in the truck approximately three hours. If slump loss began to occur during this three hour period, then water was added to the concrete just prior to discharge to restore the slump to the original state. When this procedure was used it was necessary to recompute the water/cement ratio for the concrete remaining in the truck. However, this presented no problem since a measured quantity of concrete was removed for each test series and the quantity remaining in the truck could be easily calculated.

All testing was performed on two occasions. The first series was performed during the month of February, 1966 and a duplicate series was performed during the month of August, 1966. This was done to determine the effect of ambient temperatures on the slump loss and other properties of the concrete mixes. However, since a very mild winter was experienced during this period, the ambient air temperatures were not as wide spread as had been hoped for.

Materials

The cement used in all concrete mixes was Type 1.

The lightweight coarse aggregate used was an expanded clay produced by the rotary kiln method. The aggregate is produced in Erwinville, Louisiana.

The sand and gravel aggregates used are natural uncrushed materials obtained from the Amite River in Louisiana. They are both predominantly siliceous materials.

The admixtures used in the study consisted of a water reducing, set retarding agent (calcium lignosulfonate) and an air entraining agent (neutralized vinsol resin). The set retarding admixture was used at the rate of four ounces per sack of cement in Series A and six ounces per sack of cement in Series B while the air entraining agent was used at the rate necessary to produce the required air content. This rate varied from 0.50 ounces to 1.5 ounces per sack of cement, depending on the mix being used.

Test Procedures

The following test procedures were followed for the materials and other concrete:

AASHO T27-60 Method of Test for Sieve Analysis of Fine and Coarse Aggregates.

AASHO T19-56 Method of Test for Unit Weight of Aggregate.

AASHO T152-57 Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method.

AASHO T119-60 Method of Test for Slump of Portland Cement Concrete.

AASHO T23-60 Method of Test for Making and Curing Concrete Compression and Flexure Test Specimens in the Field.

AASHO T-22-60 Method of Test for Compressive Strength of Molded Concrete Cylinder.

ASTM CZ91-61T Method of Test for Resistance of Concrete to Rapid Freezing in Air and Thawing in Water.

DISCUSSION OF RESULTS

Test Results of Aggregate

The gradation and unit weight of the aggregates used in this study are shown in Table 1.

TABLE 1

GRADATION AND UNIT WEIGHT OF AGGREGATES

Percentage Passing Sieve Indicated, By Weight				
U.S. Sieve	Lightweight Coarse Aggregate	Gravel	U.S. Sieve	Sand
1 1/2 in.		100	3/8	100
1 in.		93	No. 4	99
3/4 in.	100	81	No. 8	89
1/2 in.	92	44	No. 16	76
3/8 in.	75	23	No. 30	61
No. 4	7	8	No. 50	20
DRY UNIT WEIGHT - LBS./CU.FT.				
Loose	38	90		106
Rodded	43	96		113

Test Results of Concrete

When this study was originated, there was some doubt as to whether concrete taken from the rear portion of the concrete load would be representative of the remaining concrete in the truck. It was assumed that if the transit mix truck was in good condition, with mixing blades not worn, then the concrete should be a homogenous mixture throughout and a sample could be taken at any location in the load and be representative of the entire load. However, in order to substantiate this fact, an experiment was established whereby a sample of concrete taken at the very beginning of the discharge would be compared to samples taken at four other intervals throughtout the discharging of a five cubic yard load of concrete. Tests performed on each sample consisted of unit weight, air content, slump, and gradation of aggregate. In addition, standard cylinder were made for determining compressive strength. The results of these tests are shown in the Appendix and indicated that a representative sample would be obtained at the beginning of the discharge.

Table 2 shows the concrete mix designs used in the study. The water cement ratio shown is the design ratio before any water was withheld or added to maintain the slump as constant as possible. The mix numbers shown in the table identify the respective mixes in the following manner. 1A is a sand and gravel mix containing 6.0 sacks of cement per cubic yard with no admixtures. 1B is the duplicate mix that was tested to determine effect of air temperature. 2A is a sand and gravel mix containing 5.5 sacks of cement per cubic yard with admixtures. 2B is the duplicate mix. 3A is a mix containing lightweight coarse aggregate and sand with a 5.75 cement content, with admixtures and the lightweight coarse aggregate has a moisture content of approximately 15 percent. 3B is the duplicate mix. 4A is the same as 3A except the moisture content of the lightweight coarse aggregate was approximately 30 percent. 4B is the duplicate mix.

TABLE 2

CONCRETE MIX DATA

Mix Numbers	Cement Lbs.	Cement Aggregate Lbs.	Fine Aggregate Lbs.	Water Lbs.	Admixture Set Retarder Ozs.	Admixture Air Entraining Ozs.
1A	94	322	197	46		
1B	94	322	197	46		
2A	94	355	198	45	4	0.5
2B	94	355	198	45	6	0.5
3A	94	115	214	70	4	0.75
3B	94	123	228	72	6	1.0
4A	94	112	208	78	4	1.0
4B	94	125	232	75	6	1.0

Table 3 shows the results received from the concrete mixes when tested for slump and compressive strength. In addition the temperature of the air and concrete, and the water cement ratio of the concrete when sampled are given. The results of the freeze and thaw tests are given in Table 4. The results are the average of three, 3 inch x 4 inch x 16 inch test specimens.

Figure 1 is a plot of the compressive strength results for mixes 1A and 1B. The 7 and 28 day curves for each mix generally follow the same pattern, although there is a difference between the pattern of the two mixes. Mix 1A produced higher strengths at both ages, but there was a general loss of strength with time in the truck. Mix 1 B had lower strengths than mix 1A, but there was a definite increase in strength between the 100 rev. time period and the 35 minute time period, and then the strength began to decrease. The overall loss in strength for mix IA was 978 p.s.i. on the 7 day tests, and 1019 p.s.i. on the 28 day tests. On Mix IB the loss on 7 day tests was 537 p.s.i. while 218 p.s.i. loss was obtained on the 28 day tests.

Figure 2 shows the results received on mixes 2A and 2B. There was not much overall loss in strength on either mix, with mix 2A showing no loss on the 7 day tests and 35 p.s.i. loss on the 28 day tests. However, there was a rather pronounced drop in strength through the one hour time interval for mix 2B, but then a gain in strength occurred during the next two hours which offset the loss. Mix 2A exhibited very minor changes throughout the three hour period.

Figure 3 illustrates the results received from a lightweight concrete mix with the moisture content of the lightweight coarse aggregate maintained at approximaterly 15 percent. Mix 3A had a overall reduction in strength at 7 days of 789 p.s.i. for the three hour period, with a slight increase in strength occurring between the two and three hour intervals. The 28 day results gave an almost identical trend. Mix 3B exhibited a strength gain after the one hour period, then a sharp decrease after two hours and an increase after three hours with the resulting overall strength loss being 453 p.s.i. at 7 days and 277 p.s.i. at 28 days.

Figure 4 illustrates the results received from lightweight concrete with the lightweight coarse aggregate moisture content maintained at approximately 30 percent. Mix 4A exhibited a significant increase in strength between the one and two hour time interval, but also a rather severe decrease between the two and three hour time interval with an overall loss in strength at 7 days of 271 p.s.i. and an overall gain in strength at 28 days of 312 p.s.i. Mix 4B produced an almost steady decrease in strength throughout the three hour period. The overall loss being 948 p.s.i. at 7 days and 672 p.s.i. at 28 days.

The use of admixtures in the sand and gravel concrete appeared to be beneficial in maintaining the strength of the concrete throughout the three hour test period. The effect of varying the moisture content of the lightweight coarse aggregate was not really conclusive. A comparison of the results received from mix 3A which had 15 percent moisture and 4A which had 30 percent moisture showed that higher initial strength was obtained with 15 percent moisture, but there was a decrease in strength throughout the three hour period, whereas the 30 percent moisture produced a lower initial strength with an increase occurring through the two hour period and a decrease occurring during the two to three hour period. The overall strength loss was less for the mix containing 30 percent moisture. A comparison of mixes 3B and 4B reveals that the lower moisture content of 15 percent produced less strength loss than the mix containing the higher moisture content aggregate.

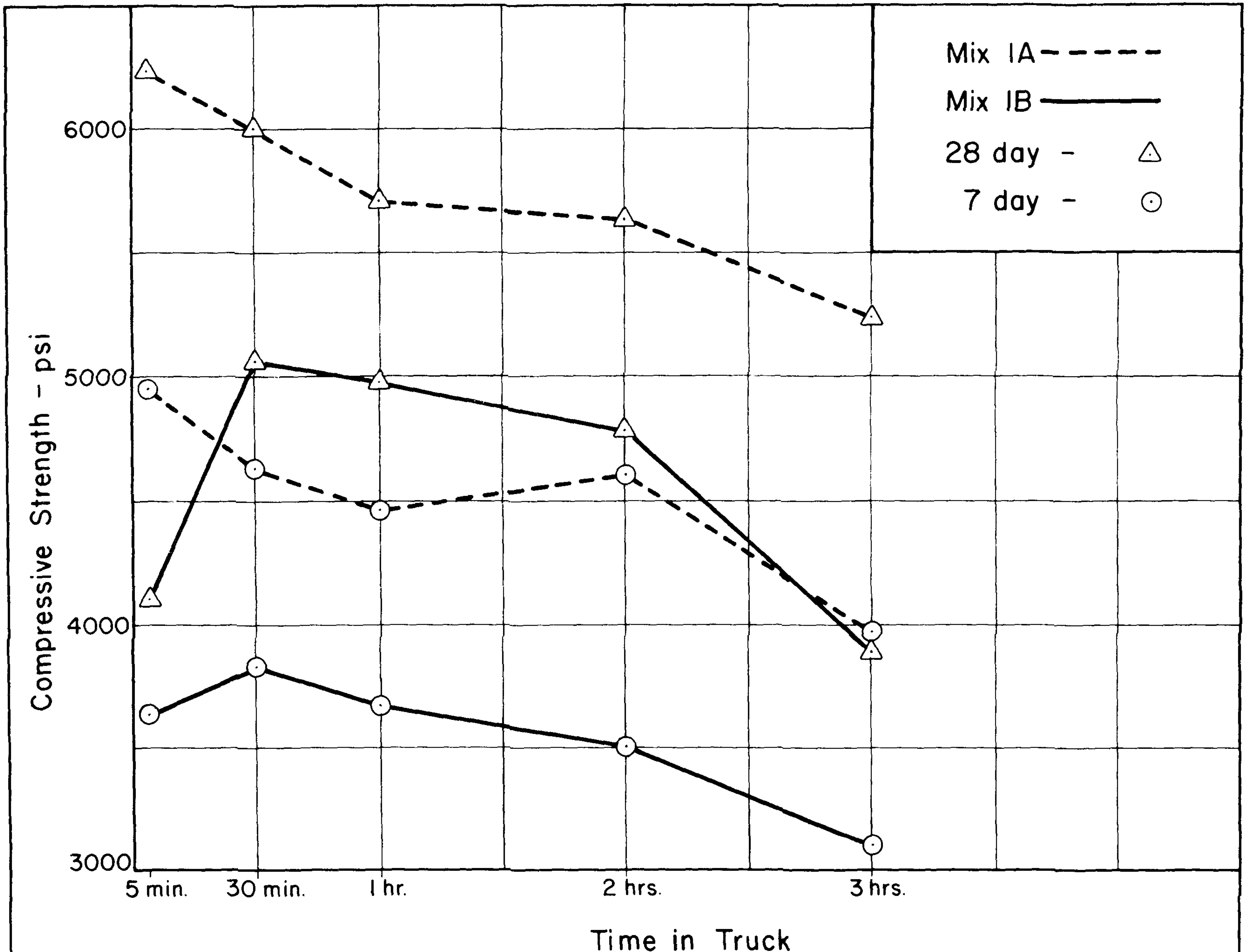

Figure 1 Compressive Strength vs. Retention Time

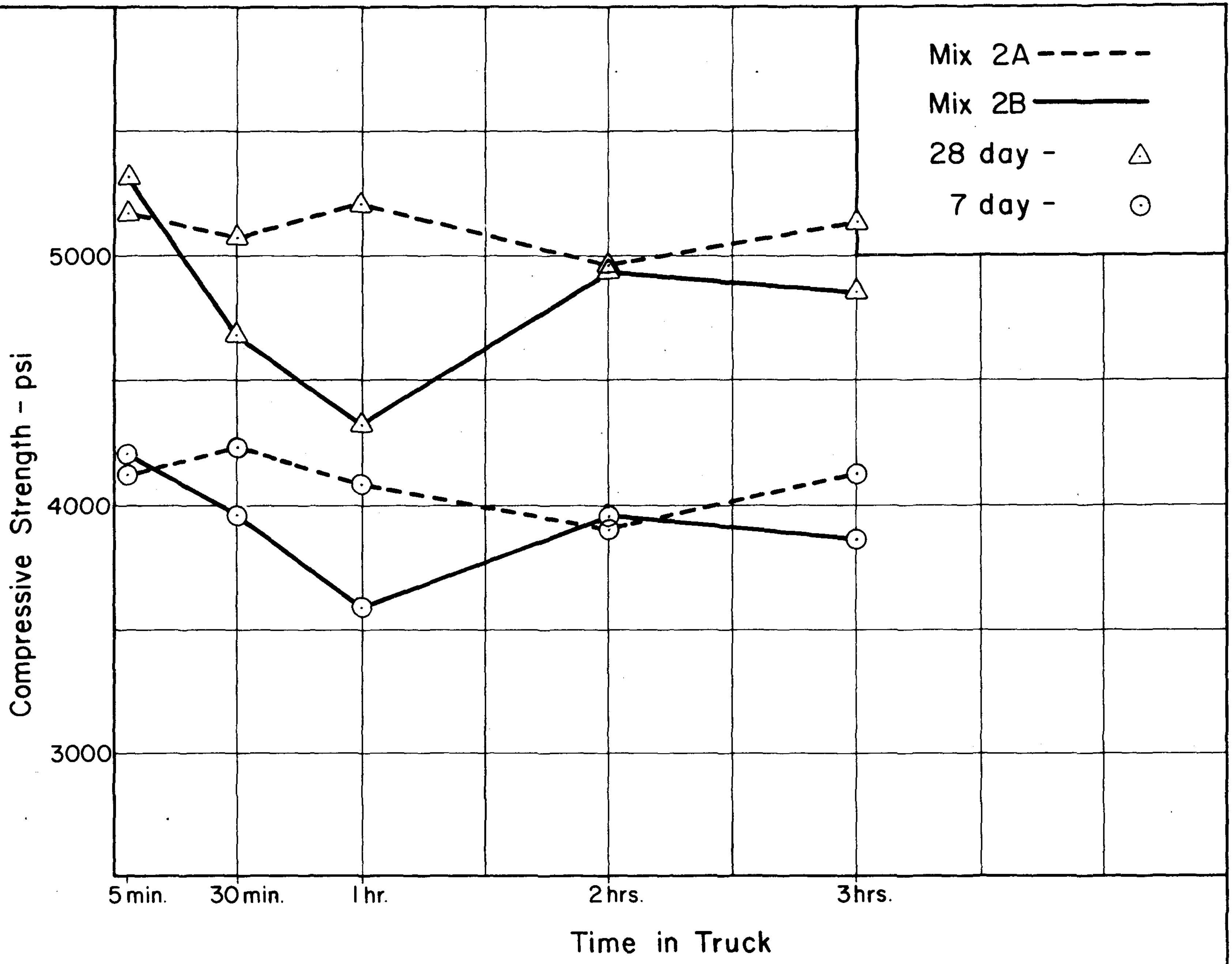

Figure 2 Compressive Strength vs. Retention Time

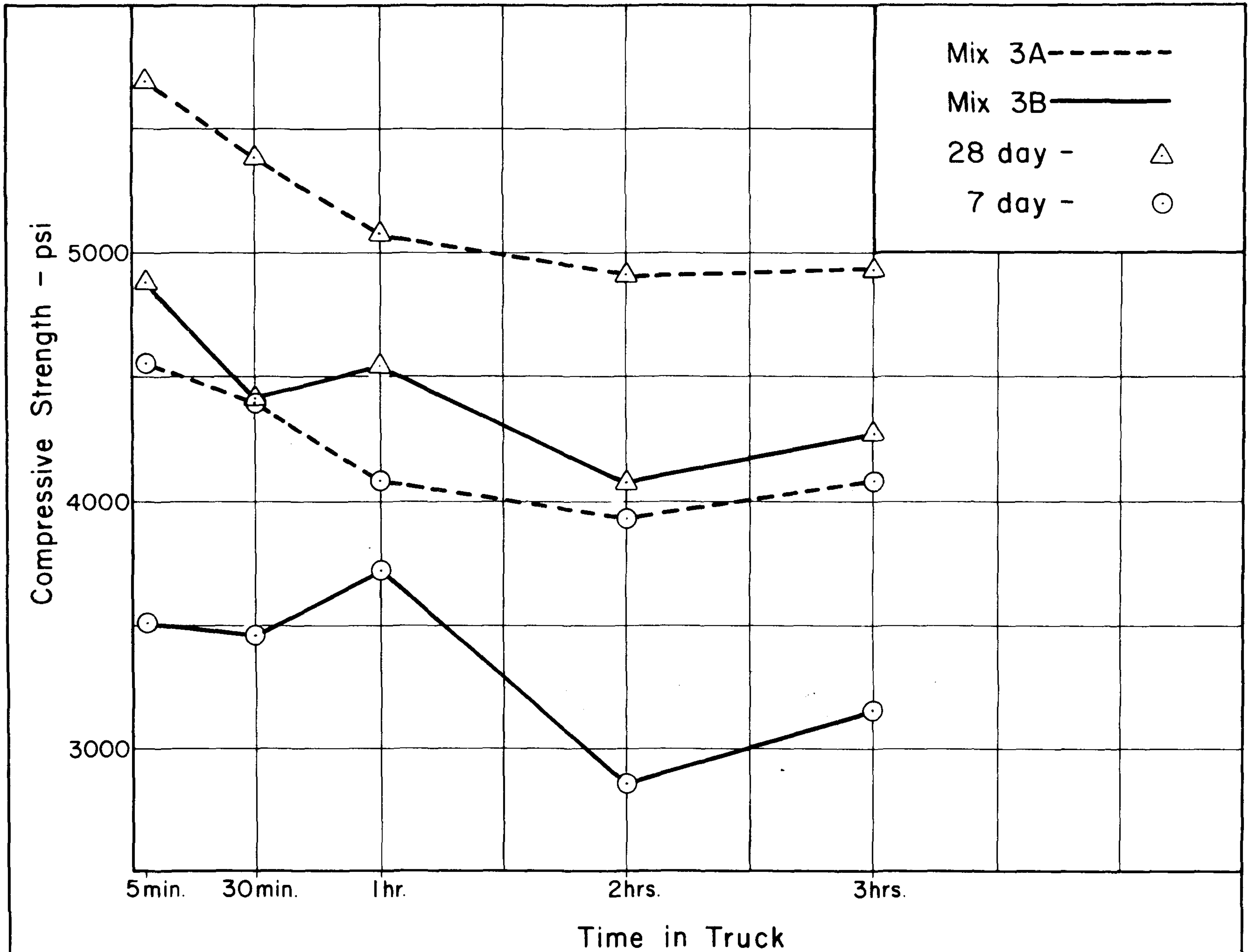

Figure 3 Compressive Strength vs. Retention Time

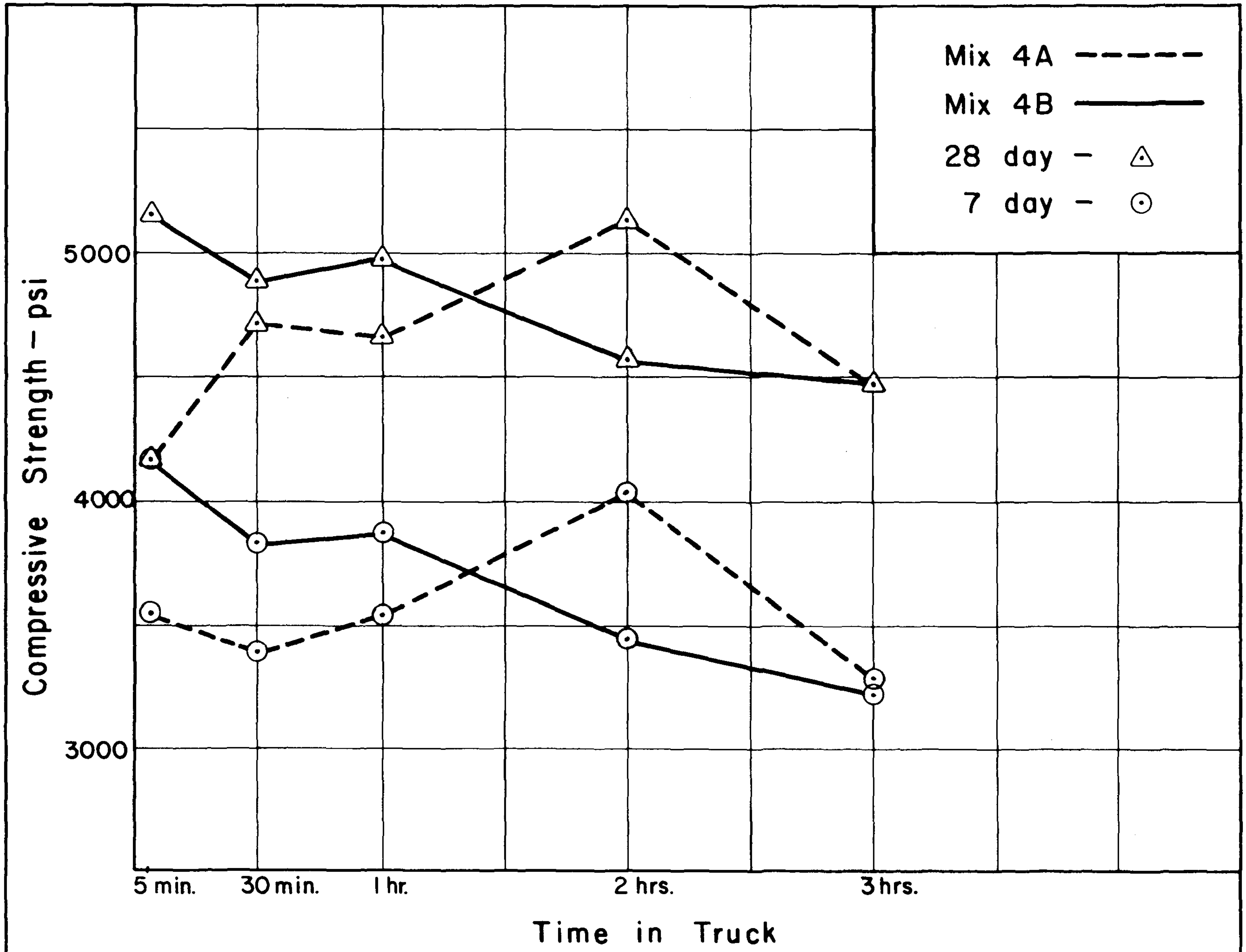

Figure 4 Compressive Strength vs. Retention Time

The results of the freeze and thaw durability tests shown in Table 4 indicate that Mix 1A had a reduction in D. F. of eight percent after one hour, 58 percent after two hours and 65 percent after three hours. Mix 1B had a higher initial D. F. than Mix 1A and the D. F. of Mix 1B never dropped below the initial results during the three hour period with a net gain of two percent occurring on the three hour specimens. Apparently the lower water cement ratio for Mix 1B during the two hour retention period was the reason for the better performance. Although the concrete sampled after three hours had a 6.15 gals/sack water cement ratio, this concrete was in the truck for only 25 revolutions at this high ratio and apparently was unaffected by the additional water.

A comparison of the results of mixes 2A and 2B revealed that the two mixes performed in a somewhat similiar manner during the one hour retention period, but at the two and three hour interval, Mix 2A outperformed Mix 2B. At the end of two hours Mix 2A had retained 76 percent of its original D. F. while 2B had retained only 60 percent. At three hours Mix 2A had 61 percent of its original D. F. while Mix 2B had only 19 percent of its original D. F. Once again it appears that the dominating factor was water cement ratio with Mix 2B requiring more added water to maintain the slump than Mix 2A plus the initial water cement ratio for Mix 2B was higher than Mix 2A.

A comparison of the results of mixes 1A and 1B with no admixtures against mixes 2A and 2B with admixtures definitely shows a benefit in using admixtures to improve the durability of the concrete whether the mix is retained for long periods or not in a ready mix truck.

A comparison of the results of the lightweight concrete mixes indicate that the durability is not reduced by extended retention time to any degree that would be cause for concern, but rather is nomally increased to provide a more durable mix. The results would indicate that the lower initial moisture content of approximately 15 percent produces more durable concrete than the 30 percent initial moisture content.

PHASE II
METHOD OF PROCEDURE

As decribed in the introduction, this phase of the project was to study the physical properties of transit mixed concrete from a representative cross section of ready mix concrete plants throughout the state in order to determine what range of values were being received on compressive strength, yield, slump, cement content, water content and air content where applicable. In addition, samples of all materials used where brought to the laboratory and the field mixes were duplicated to compare the laboratory results with the field results.

A total of thirteen ready mix plants were visited during this study.

The procedure at each plant would consist of obtaining the batch weights that were being used from the inspector on the job and recording this in a dairy. Next, the truck that would be used for our study would be selected. Normally the third or fourth truck would be used in order to allow the inspector sufficient time to get the plant operating properly. When the truck that was selected for use was under the hopper being loaded, a sample of sand and gravel was obtained from the material entering the truck for determination of moisture content. These moisture results were then used to compute the actual water content of the mix and this was compared to the figures being recorded for the project files. After the truck was charged, the required mixing was performed at the plant site, and sufficient concrete was removed from the truck to check unit weight for yield, air content and slump. When the concrete arrived at the job site, all tests except the unit weight were performed again and cylinders were made for seven and 28 day tests.

The materials used in the concrete were sampled and sufficient quantities of each were brought to the laboratory for the purpose of duplicating the field mixes. The laboratory procedure consisted of using the same mix design as was used in the field and to control the slump of the concrete as close as possible to the initial slump recorded in the field. The amount of water required was then recorded for comparing with the amount of water used in the field. In addition specimens were made to compare compressive strength of the laboratory mixes with the compressive strength of the field mixes.

Materials

All materials used in this phase of the project was the same as was being used on the construction project at the time of our visit to the concrete plant. No attempt was made to check the materials for specification requirements, since the Project Engineer had sampled and approved all materials.

Test Procedures

All applicable test procedures used were the same as described under Phase I.

DISCUSSION OF RESULTS

The main objectives for this phase of the study were, (1) to determine the actual water in gallons per sack being used to compare with the amount being reported, (2) to determine the slump loss being encountered during transporting of the concrete, (3) to determine the change in air content from the plant to the job site, (4) to determine the actual yield being obtained, (5) to compare results of field specimens with laboratory specimens. E ch of these factors will be discussed separately.

Comparison of Mixing Water Used

The comparison of the amount of mixing water being used was conducted to determine if due to variation in stockpile aggregate moisture contents, the plant inspector's reported amount of water might be lower or higher than actual water required. The amount being reported by the inspector was recorded, and compared to computation made on a randomly selected truck. The actual water being used was computed by sampling the materials as they were being loaded into the selected truck and performing moisture tests to determine correct free moisture. From this moisture content, the actual water could be calculated. Figure 5 shows the comparison between reported and actual water used. In most cases the reported water was lower than what was actually being used. On the average, the reported water was approximately 0.4 gallons per bag of cement below the actual being used.

Slump Loss

Slump loss has become a major problem in the use of transit mix concrete. The problem is particularly acute during the summer months when high temperature tend to dry out the concrete rapidly with a subsequent low in slump being reported. In order to determine the extent of slump loss being experienced, samples of concrete were obtained at the plant after the completion of the required mixing, and again at the job site as the truck was being unloaded. Figure 6 shows the results of this part of the study. In all but four instances, slump loss was experienced. In the case of Plant No. 10, slump loss was experienced but water was added before we could obtain our samples and this is why an increase in slump is shown on Figure 6. The slump loss was on the average approximately one inch. There was no particular trend between time of haul and slump loss. The average time was 50 minutes with the maximum

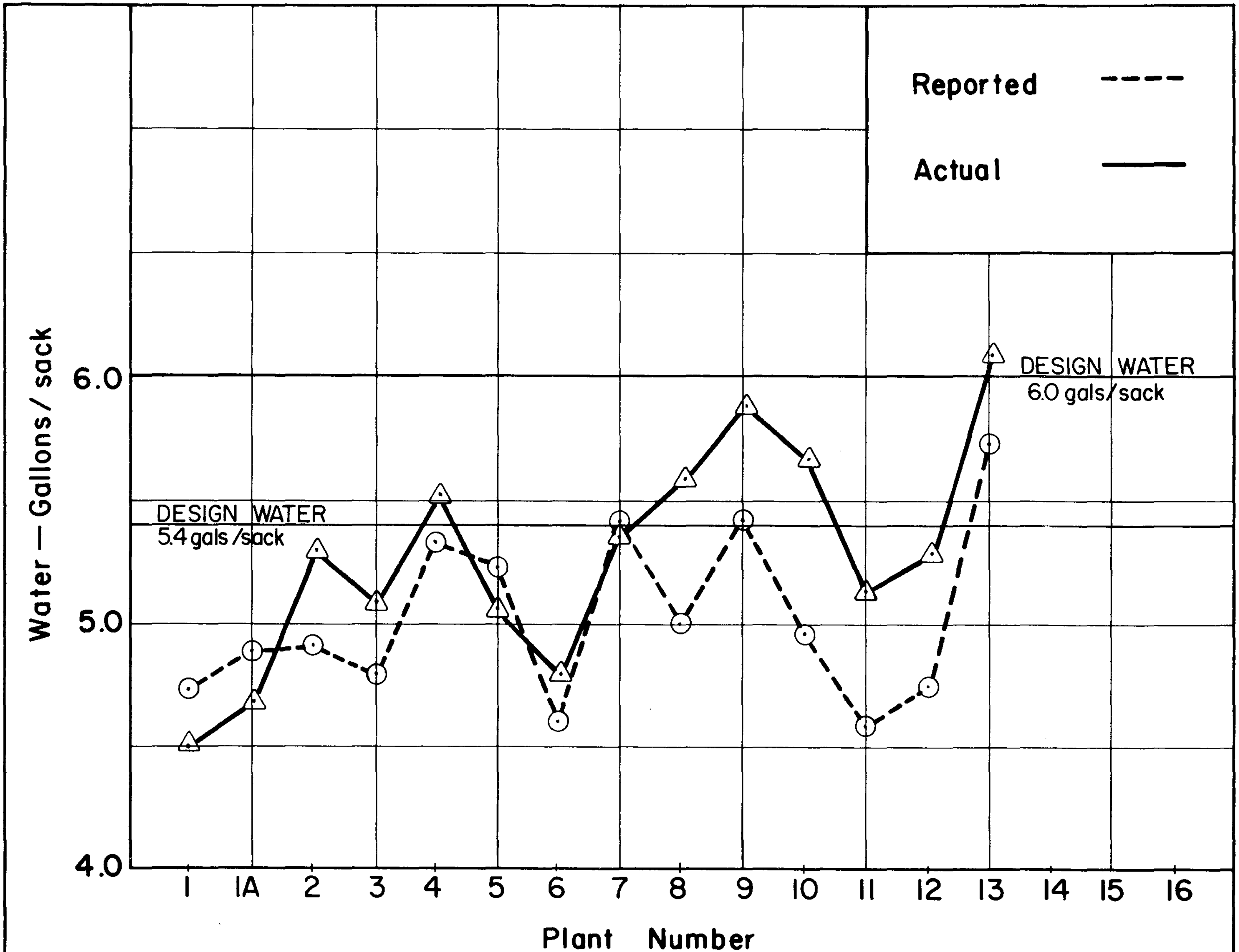

Figure 5 Comparison of Water Reported vs. Actual Water Used

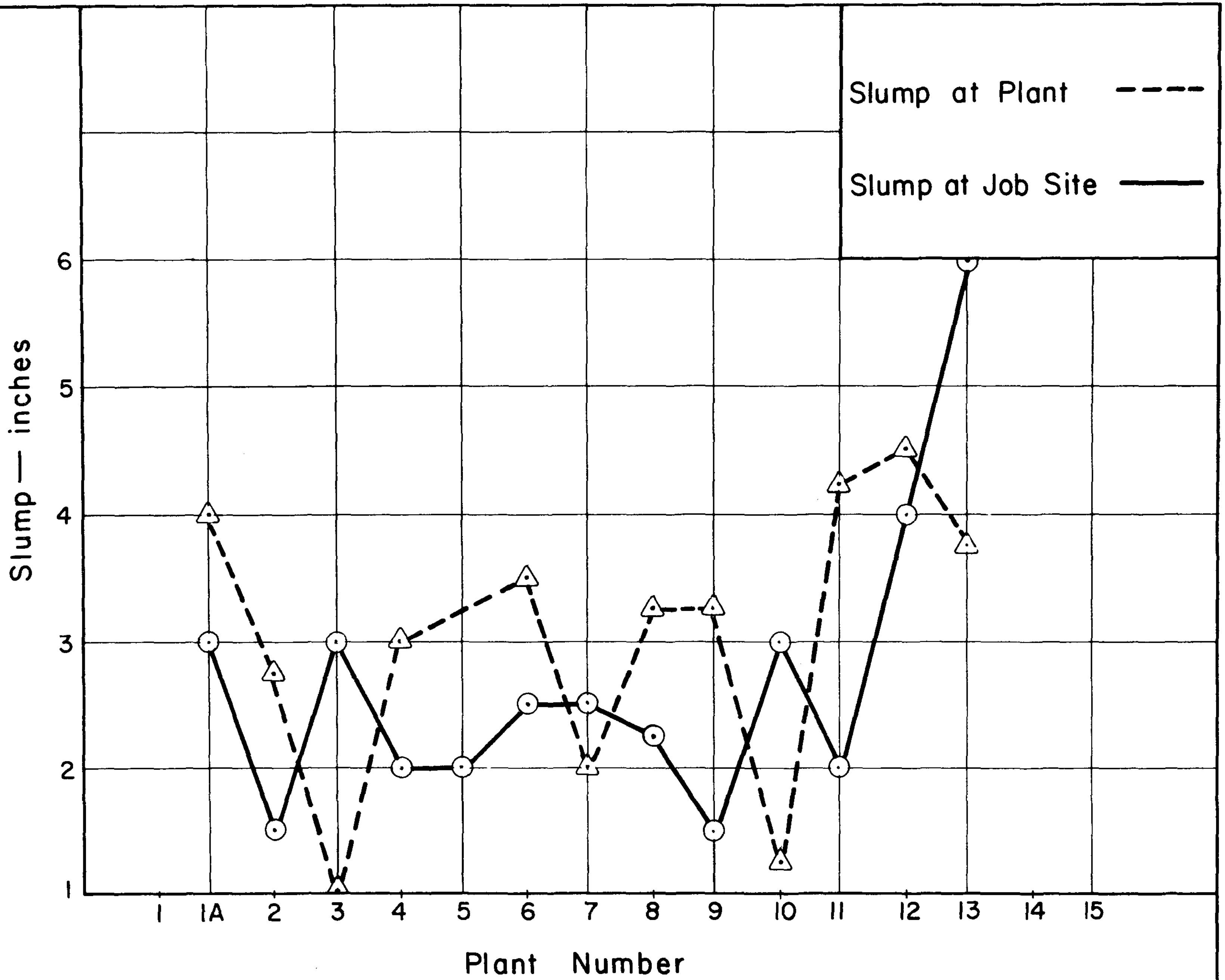

Figure 6 Comparison of Slump of Concrete

being one hour and 15 minutes and the minimum being 30 minutes. The temperature range of the concrete was from 88°F to 98°F.

Change in Air Content

This part of the study was conducted the same way as the slump loss. Samples were taken at the plant site after the required mixing and again at the job site. A roll-o-meter was used to check the air content at both locations. Figure 7 shows the results received from this part of the investigation. From these results, it appears that loss of entrained air in transit is not a serious problem. The highest loss encountered was one percent with this occurring three times. However, in all three instances the initial air content was relatively high as compared to the other readings. In one, case, the air content increased by two and one-forth percent. There was no real explanation for this. On the whole, the air content tended to remain relatively stable.

Yield Determination

Computation of yield was made on all jobs to determine if yield loss was indeed as serious a problem as was being reported. The fresh unit weight of the concrete was measured at the plant after the required mixing, and the actual yield was computed from this. A comparison of the actual vs. the theoretical is shown in Table 5. The lowest yield received was 96.5 percent of theoretical, and the highest was 101.4 percent of theoretical. An average yield of the 14 plants was 99.0 percent of theoretical. On seven of the 14 plants, the actual yield was within ± one percent of the theoretical. Eleven plants were within two percent of theoretical, with only three plants falling below the two percent level. This variation from theoretical was due to two factors. The most pronounced was that the total water used was below the design water. Secondary, was the fact that the mix was designed for four percent air and in some cases less air was obtained in the mix. The problem of using less than the design water is something that has plagued concrete production for some time. The only way that this problem could be overcome would be to change the mix design each day to meet all changes that have occurred due to temperature, aggregates, humidity, etc. This is not practical at the present time due to lack of trained concrete technicians in the field. Until the practice of requiring a concrete technician for each batch plant can be put into practice, this problem will remain with us. However, it should be pointed out that the yield loss found in this study does not remotely approach the figure that is sometimes reported by contractors.

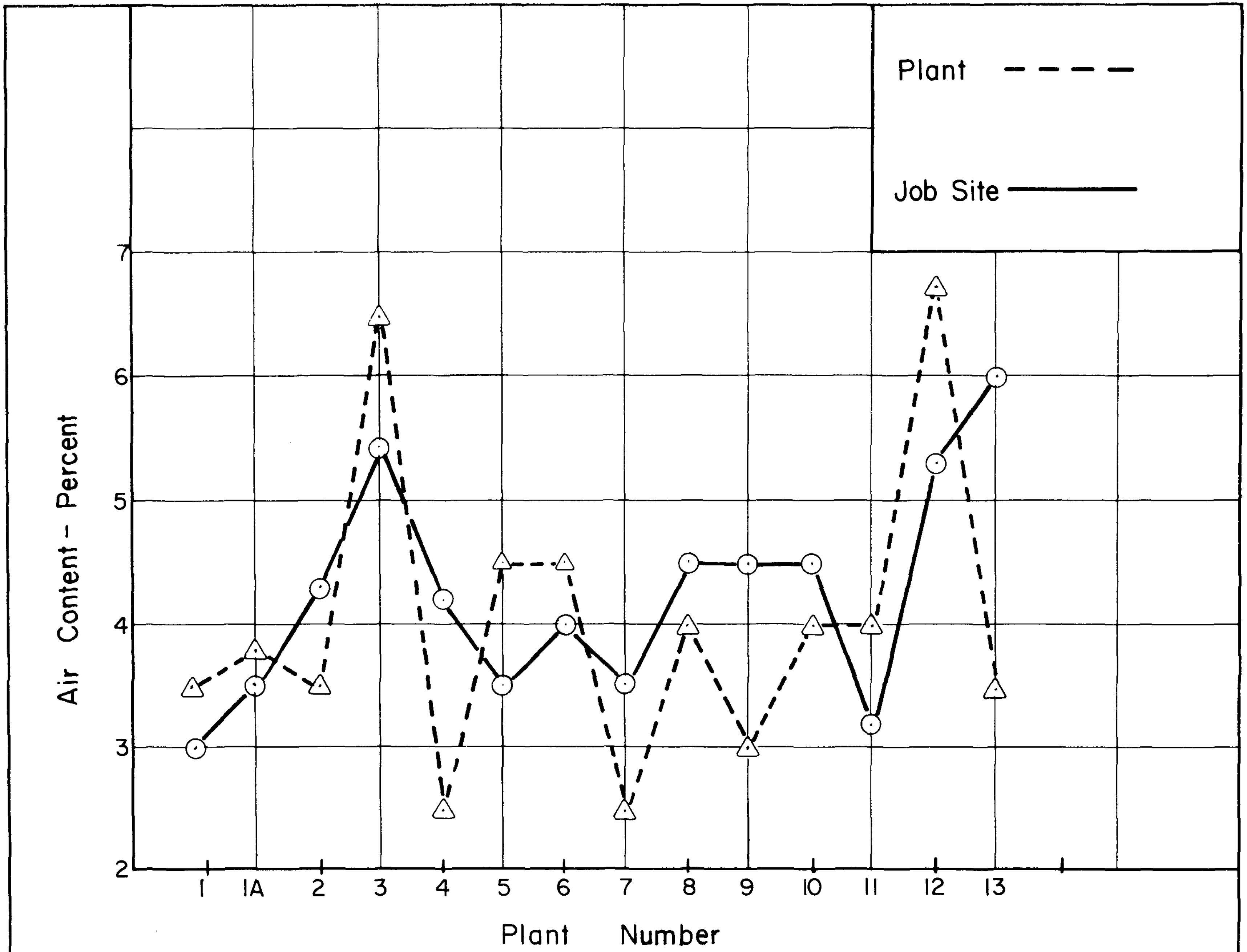

Figure 7 Comparison of Air Contents

TABLE 5

CONCRETE YIELD RESULTS

Plant No.	Batch Weight Lbs.	Unit Weight Concrete lbs/cu.ft.	Total Cu.Ft. Per Batch	Theoretical cu.ft. Per Batch	Percent Theoretical Yield
1	25,001	146.4	170.8	175.5	97.3
1A	23,121	145.4	159.0	162.0	98.1
2	27,066	145.6	185.9	189.0	98.4
3	26,834	144.4	185.8	189.0	98.3
4	27,198	147.6	184.3	189.0	97.5
5	12,649	145.2	87.1	87.8	99.2
6	27,298	144.9	188.4	189.0	99.7
7	19,499	145.6	133.9	135.0	99.2
8	15,478	141.4	109.5	108.0	101.4
9	23,333	143.6	162.6	162.5	100.3
10	27,049	144.6	187.1	189.0	99.0
11	19,844	144.6	130.3	135.0	96.5
12	26,840	140.6	190.9	189.0	101.0
13	23,650	145.2	162.9	162.0	100.6

Comparison of Field Specimens and Laboratory Specimens

This part of the study was conducted to determine the comparison between concrete cylinders cast in the field and sent to the District Laboratories for testing and concrete cylinders made in the laboratory using the same materials, but with very strict fabricating, curing, capping and testing procedures used. Figure 8 shows the results of this investigation. On the whole, the results could be considered very comparable. In most cases the laboratory specimens were slightly higher in strength, but there were some exceptions to this. There were only two mixes that showed what could be considered major differences between field and laboratory results. Plant 7 produced a seven day strength of 5025 p.s.i. and a 28 day strength of 5975 p.s.i. as compared to laboratory tests at seven days of 4260 p.s.i. and 28 days of 5225 p.s.i. Also, Plant 13 produced field results at seven and 28 days of 3025 p.s.i. and 4325 p.s.i. as compared to laboratory results at seven and 28 days of 4125 p.s.i. and 5530 p.s.i. It would appear from these results that on the average, field specimens produce very representative results for the concrete under tests.

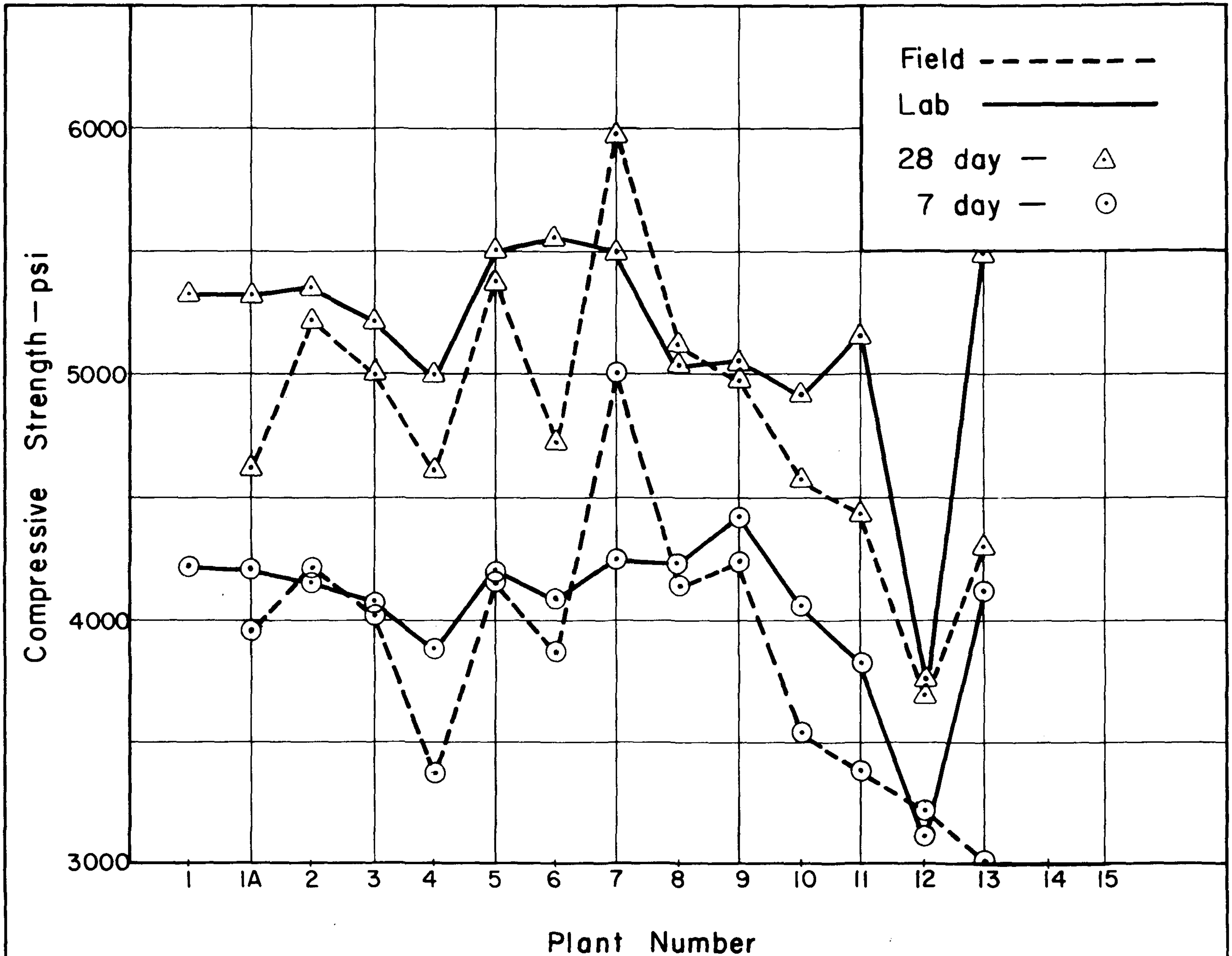

Figure 8 Comparison of Concrete Cylinder Results

SUMMARY OF RESULTS

Phase I -

(1) Extended retention of sand and gravel concrete in a transit mix truck up to three hours tends to reduce the compressive strength at seven and 28 days and the freeze and thaw durability with the largest change occurring between the two and three hour interval.

(2) The use of admixture (set retarding and air entraining) showed a very beneficial effect for the sand and gravel concrete, particularly in increasing durability and in maintaining the compressive strength loss at a minor level throughout the three hour test period.

(3) Lightweight concrete (lightweight coarse aggregate and natural sand) with the moisture content of coarse aggregate maintained at approximately 15 percent gave better overall results than lightweight concrete with the higher moisture content.

(4) The analysis of effect of temperature on the concrete properties was inconclusive due to the mild winter temperature experienced during the testing period.

Phase II -

(1) The amount of mixing water being reported is generally less than the actual quantity being used due to change in moisture content of aggregates and errors in performing the moisture tests.

(2) The loss of slump is not a very significant factor as long as the concrete is not held in the trucks for extended periods of time.

(3) The loss of entrained air is generally in the rnage of one to one and one-quarter percent while in transit to the job site.

(4) Actual yield being obtained averages 99 percent of theoretical with a low of 96.5 percent and a high of 101.4 percent.

(5) The test specimens made in the field are very reliable and corresponds very closely to specimens made in the laboratory.

RECOMMENDATIONS

The purpose of this research was to gain additional knowledge concerning the performance and physical properties of transit mixed concrete. The study of prolonged mixing, up to three hours retention in the truck, was not to change the existing specifications, but to determine if in fact a longer time in transit would greatly affect the properties of the concrete mix. The results of this study would indicate that periods of up to two hours could probably be tolerated without sacrificing the performance of the concrete. However, until such time as it may be absolutely necessary to allow this much time in transit, it is not recommended that this practice be allowed.

If such an occasion does arrive, whereas conditions might warrant the allowing of up to two hours, then very close control should be used to insure that high quality concrete will be produced.

The only recommendation forthcoming from the field study would be that if it is desired to improve upon the actual yield vs. theoretical yield being obtained, then a program should be established whereby concrete designs can be adjusted in the field to compensate for changes in conditions that will affect the yield. This will require a capable concrete technician at each plant or in some cases one for several plants to make these adjustments in the proper manner to insure high quality concrete.

APPENDIX

REPORT OF SAMPLING PROCEDURE FOR READY MIXED CONCRETE
LOUISIANA PROJECT NO. 63-10C
HPR 1 (3)

In accordance with Mr. Lyman G. Youngs' letter of September 17, 1963, a test was conducted to evaluate the sampling procedure anticipated for use in this project.

The procedure followed was to purchase five yards of concrete from a local concrete supplier and make the necessary test. Samples were taken from the truck at five different locations throughout the discharging of the concrete. Each sample was approximately seven cubic feet in size. The sequence of obtaining the sample was as follows:

Sample No. 1 - This sample consisted of the first seven cubic feet discharged from the truck.
Sample No. 2 - This sample was taken after discharging approximately 32 cubic feet of concrete and consisted of 7 cubic feet.
Sample No. 3 - This sample was taken after discharging approximately 64 cubic feet of concrete and consisted of 7 cubic feet.
Sample No. 4 - This sample was taken after discharging approximately 96 cubic feet of concrete and consisted of 7 cubic feet.
Sample No. 5 - This sample was taken after discharging approximately 125 cubic feet of concrete and consisted of 7 cubic feet.

The tests performed on each sample consisted of slump, air content unit weight and gradation. In addition, 6 in x 12 in. cylinders were made for testing compressive strength at 7 and 28 days. The gradation test was performed by taking a sample of fresh concrete of approximately 50 lbs, placing it in a large pan and washing the cement out. After washing, the sample was dried and separated on a No. 4 sieve. A gradation analysis was then performed on the samples.

Table 1 shows the results on unit weight, air content, slump and compressive strength for each sample. Table II shows the gradation analysis for each sample.

After analyzing all results of these tests, it appears that the concrete taken at the beginning would be representative of the remainder of the concrete left in the truck if the slump was the same throughout the truck. It was anticipated that slump loss would occur during the discharging because of the time consuming operation required to measure the concrete rather carefully. For this reason,

TABLE I

	Sample Number 1	2	3	4	5
Unit Weight, lbs/cu ft	145.8	145.4	146.2	146.2	146.2
Air Content, %	2.2	2.3	1.7	2.3	2.4
Slump, inches	7	6	3 3/4	3	2 1/4
Compressive Strength, p.s.i.					
7 days	3035	3070	3769	3844	3927
28 days	4197	4162	4805	5024	4840

TABLE II

	Sample Number 1	2	3	4	5
Coarse Aggregate Gradation					
U. S. Sieve	Per Cent Passing				
1 1/2 inch	100	100	100	100	100
1 inch	93	94	93	96	97
3/4 inch	78	83	78	81	80
1/2 inch	47	48	48	49	52
No. 4	0	0	0	0	0
Fine Aggregate Gradation					
U. S. Sieve	Per Cent Passing				
No. 4	100	100	100	100	100
No. 8	86	87	86	86	86
No. 16	75	78	76	76	75
No. 30	58	62	57	59	57
No. 50	20	30	20	26	20
No. 100	3	2	2	2	2

the concrete was mixed with sufficient slump to insure that the last portion of the load would not become too stiff to handle. We did not want to alter the concrete in any way throughout the discharge.

The only significant difference observed in the five samples was compressive strength. This difference was obviously due to the difference in slump of the concrete used to prepare the specimens. The first two samples produced close results, and the last three samples produced close results. This indicated that if the slump had been constant throughout the truck, all five concrete samples would have produced comparable compressive strength.

Since the slump will be controlled throughout the prolonged mixing planned for this study, the method originally planned, whereby samples of concrete will be taken from the beginning of the discharge, should prove satisfactory.

RESEARCH PUBLICATIONS

1. Concrete Pavement Research. H. L. Lehmann and C. M. Watson, Part I (1956). Part II (1958).

2. Use of Self-Prepelled Pneumatic-Tired Rollers in Bituminous Construction and Recommended Procedures. A Special Report, 1968.

3. Use of Expanded Clay Aggregate in Bituminous Construction. H. L. Lehmann and Verdi Adam, 1959.

4. Application of Marshall Method in Hot Mix Design. Verdi Adam, 1959.

5. Effect of Viscosity in Bituminous Construction, Verdi Adam, 1961.

6. Slab Breaking and Seating on Wet Subgrades with Pneumatic Roller. J. W. Lyon, Jr.,January, 1963.

7. Lightweight Aggregate Abrasion Study. Hollis B. Rushing, Research Project No. 61-7C, February, 1963.

8. Texas Triaxial R-Value Correlation. Harry L. Roland, Jr., Research Project No. 61-1S, March, 1963.

9. Asphaltic Concrete Pavement Survey. S. C. Shah, Research Project No. 61-1B, April, 1963.

10. Compaction of Asphaltic Concrete Pavement with High Intensity Pneumatic Roller, Part I. Verdi Adam, S. C. Shah and P. J. Arena, Jr., Research Project No. 61-7B, July, 1963.

11. A Rapid Method of Soil Cement Design. Harry L. Roland, Jr., Ali S. Kemahlioglu, Research Project No. 61-8S, March, 1964.

12. Correlation of the Manual Compaction Hammer with Mechanical Hammers for the Marshall Method of Design for Asphaltic Concrete. P. J. Arena, Jr., Research Project No. 63-1B, September, 1964.

13. Nuclear Method for Determining Soil Moisture and Density. Harry L. Roland, Jr., Research Project No. 62-1S, November, 1964.

14. Service Temperature Study for Asphaltic Concrete. P. J. Arena, Jr., Research Project No. 61-3B, October, 1964.

15. Quality Control Analysis, Part I - Asphaltic Concrete. S. C. Shah, Research Project No. 63-IG, November, 1964.

16. Typical Moisture - Density Curves. C. M. Higgins, Research Project No. 61-11S, May, 1965.

17. High Pressure Lime Injection. C. M. Higgins, Research Project No. 63-7S, August, 1965.

18. Durability of Lightweight Concrete-phase 3. Hollis B. Rushing, Research Project No. 61-8C, August, 1965.

19. Compaction of Asphaltic Concrete Pavement with High Intensity Pneumatic Roller, Part II-Densification Due to Traffic. S. C. Shah, Research Project No. 61-7B, October, 1965.

20. A Rapid Method for Soil Cement Design - Louisiana Slope Value Method, Part II - Evaluation. C. M. Higgins, A. S. Kenahlioglu, Verdi Adam, Research Project No. 6I-8S, May, 1966.

21. Typical Moisture - Density Curves, Part II - Lime Treated Soils. C. M. Higgins, Research Project No. 61-11S, May, 1966.

22. Nuclear Moisture-Density Evaluation, Part II. C. M. Higgins, Research Project No. 62-1SB, May, 1966.

23. Quality Control Analysis, Part II-Soil and Aggregate Base Course, S. C. Shah, Research Project No. 63-1G, May, 1966.

24. Quality Control Analysis, Part III-Concrete and Concrete Aggregate. S. C. Shah, Research Project No. 63-1G, November, 1966.

25. Shell Concrete Pavement. Hollis B. Rushing, Research Project No. 62-IC, October, 1966.

26. Evaluation of the Gyratory Compactor for use in Designing Asphaltic Concrete Mixture. Philip J. Arena, Research Project No. 61-2B, December, 1966.

27. Nuclear Density Evaluation on Asphaltic Concrete. Philip J. Arena, Research Project No. 62-1SB, April, 1967.

28. Solid Rubber Tire Roller Study. Philip J. Arena, Jr., Research Project No. 63-4B,June, 1968.

29. Correlation of Rapid Hydrometer Analysis for Select Materials to Existing Procedure LDH-TR-407-66. George W. Bass, Jr. and Marrion M. Cryer, Jr., Research Project No, 67-1S, May, 1968.

30. A study of Transit Mixed Concrete, Hollis B. Rushing, Research Project No. 63-10C, October, 1968.

31. Pressuremeter Correlation Study, C.M. Higgins, Research Project No. 66-25, October, 1968.

32. Skid Resistance Study, Hollis B. Rushing, Research Project No. 66-1G, October, 1968.

33. Durability of Lightweight Concrete, Hollis B. Rushing, Research Project No. 61-8C, Phase I.

34. Concrete Wear Study, Hollis B. Rushing, Research Project No. 63-8C.

35. Paint Study, David G. Azar, Research Project No. 63-1CH, December, 1968.