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16. ABSTRACT

Synopsis

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A test site was constructed using two cement contents and varying moisture percentages. Samples were prepared at the site and at the laboratory and tested for compressive strength and density. Results were compared with those from standard specimens fabricated with the same aggregate and cement. Abrasion resistance of the CTB was evaluated.

The slipformed (CTB) generally attained a compressive strength of 400 psi at 7 days which is needed for Class B (CTB). This was true even though the construction procedure led to a great reduction in compressive strength. It is probable that CTB placed in the conventional manner would attain this strength using one-half the cement required by the slipformed material. Abrasion resistance was superior in the slipformed material.

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HIGHWAY RESEARCH REPORT

EVALUATION OF CEMENT TREATED BASE PLACED WITH A SLIP-FORM PAVER

67-32

STATE OF CALIFORNIA

TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 643268

State of California
Department of Public Works
Division of Highways
Materials and Research Department

May 5, 1967

Exp. Auth. 643268

Mr. J. C. Womack
State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A

REPORT

ON

THE EVALUATION

OF

CEMENT TREATED BASE

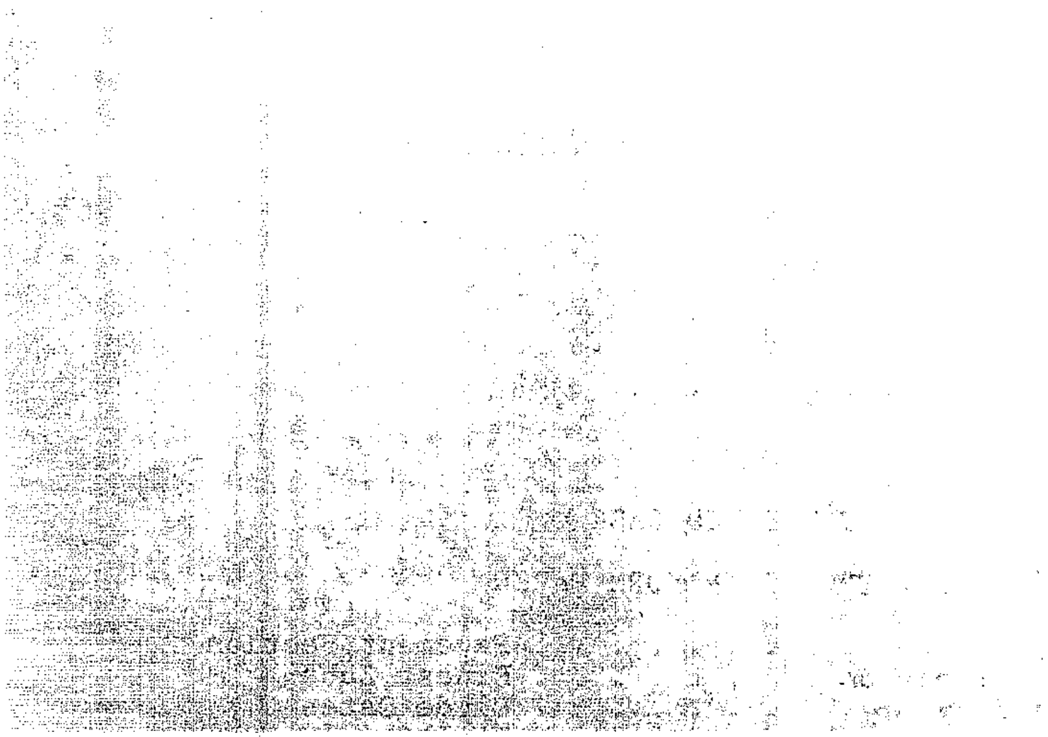
PLACED WITH A SLIP FORM PAVER

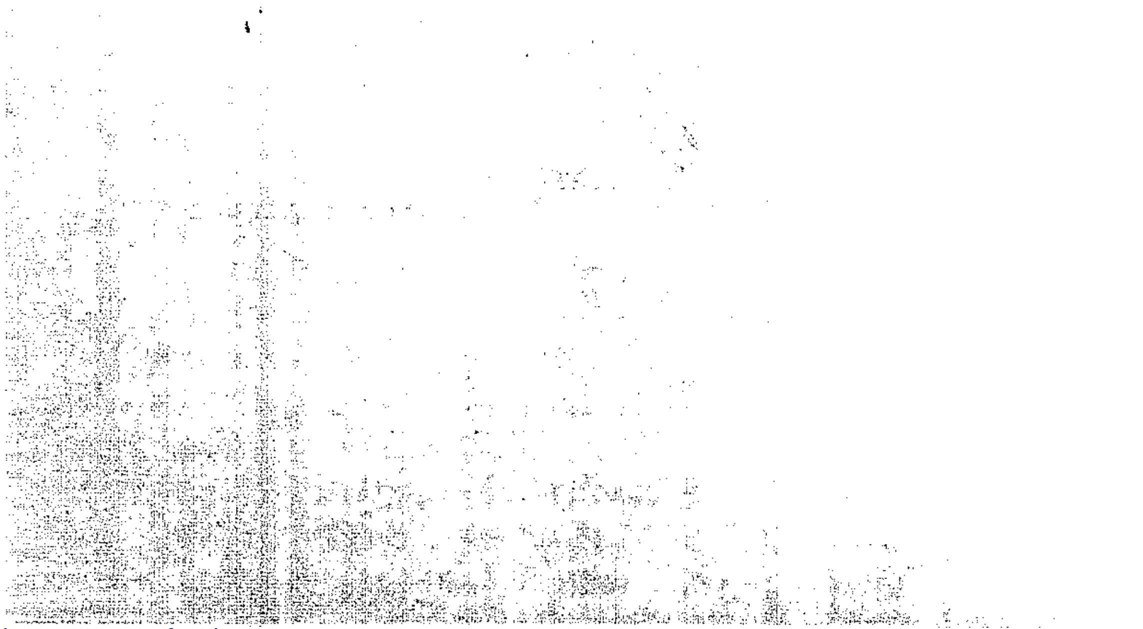
Study made by . . . . Pavement Section
Under general direction of . . . . . . Ernest Zube
Work supervised by . . . . Clyde Gates
Report prepared by . . . . Earl Shirley

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

Attach





FOREWORD

This study is concerned with quality aspects of cement treated base placed with a slipform paver. It resulted from an exchange of ideas between highway engineers and highway contractors. The investigation was begun in December 1965 at the request of the Construction Department of the California Division of Highways. Particular application for the product evaluated is in the growing field of automated highway construction.

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ACKNOWLEDGMENTS

The author wishes to express his appreciation to Mr. Frank Kinsman, of this department, for his assistance in making the field evaluation of the project, Mr. Harold Keeler of the Construction Department for his helpful comments, and personnel of the Peter Kiewit Sons Company for their unstinting cooperation.

SYNOPSIS

This study examines the feasibility, from a quality viewpoint, of a proposed change in construction technique for placing cement treated base (CTB). The proposed method uses a slipform paver and CTB with a high moisture content to facilitate placing. No compaction, other than vibration, is given the CTB.

A test site was constructed using two cement contents and varying moisture percentages. Samples were prepared at the site and at the laboratory and tested for compressive strength and density. Results were compared with those from standard specimens fabricated with the same aggregate and cement. Abrasion resistance of the CTB was evaluated.

The slipformed (CTB) generally attained a compressive strength of 400 psi at 7 days which is needed for Class B (CTB). This was true even though the construction procedure led to a great reduction in compressive strength. It is probable that CTB placed in the conventional manner would attain this strength using one-half the cement required by the slipformed material. Abrasion resistance was superior in the slipformed material.

INTRODUCTION

The placement of cement treated base (CTB) with slipform paving machines is a logical step in the development of construction techniques for the highway industry.

In 1965, the British Transport Ministry purchased a slipform paver for use with portland cement concrete pavement (PCC). They also tested it with the placement of a "wet-lean" concrete which conforms, in the most part, to California's cement treated base. The report on these tests has not yet been issued.

Hearing of the new use for slipform pavers, contractors in this country foresaw substantial savings in the use of this development. Modern specifications require tighter grade control and placement of CTB to a specified surface with very little subsequent handling. Use of the existing wire-guided paving machines would seem to obviate many difficulties while reducing labor costs.

Accordingly, in one of their regularly scheduled meetings with State Highway officials, the contractors representatives asked the Division of Highways to investigate and give an opinion on this new construction technique.

The purpose of this research project is to examine, from a quality viewpoint, the CTB placed by means of a slipform paver and to compare it with CTB placed in a manner conforming to our current Standard Specifications.

The means by which the evaluation was accomplished included an on-the-job appraisal of the technique used, sampling of the CTB being placed, field vibration of CTB specimens, coring of the cured layer, and testing with respect to density and compressive strength. At the same time, specimens were fabricated in the standard manner (1) using the same raw materials. Those specimens were also tested for density and compressive strength to afford a comparison with the slipformed material.

CONCLUSIONS

1) Cement treated base, made from the aggregate used in this study, with at least 4% cement, and placed by the slipform paver which was evaluated, attained a compressive strength of 400 psi at 7 days which is needed for Class B CTB. This same strength could have been attained with standard construction methods using only about one-half the amount of cement.

2) When this cement treated base was placed by the slipform paver, the compressive strength, compared with that of standard specimens (1), was substantially reduced. Reductions amounted to 1/2 or 3/4 of the strength of the standard specimen.

3) The abrasion resistance of the slipformed CTB was far superior to that of normally compacted CTB when measured by the surface water abrasion test. This may prove to be a very important property of this material.

4) Refinement of the slipformed CTB process could lead to a significant advance in highway construction technology.

RECOMMENDATIONS

1) It is believed that the procedure evaluated in this report has potential merit as an advanced construction technique and should be further analyzed.

2) Further analysis should be divided into four parts:

a) Economic benefits should be ascertained by contrasting the savings in labor with the increased cost of material. (This assumes an increase in cement content will be needed).

b) The effect on the combined structural strength of CTB and PCC should be studied with regard to the loss in CTB compressive strength.

c) Optimum aggregate gradations, aggregate types, moisture contents, and cement contents as well as vibration frequencies and intensities should be selected. Permeability of subgrades should also be evaluated in this phase.

d) Construction and evaluation of an actual test section embodying the refined techniques would develop the practical aspect of the process and allow further evaluation under actual traffic.

DISCUSSION

Peter Kiewit Sons Company arranged a trial run of slipformed CTB on December 15, 1965, and invited representatives from the Division of Highways to attend. The demonstration was held in their equipment yard adjacent to their aggregate plant on Stony Creek near Orland, California.

Field Observations

A Blaw-Knox paving machine, normally used to slipform portland cement concrete pavement (PCCP) 24 feet wide and eight to nine inches in thickness, was used to slipform a four-inch layer of CTB. The paver is a track layer and is guided, both in line and grade, by pre-established piano wire reference lines.

The machine was totally unmodified for this experiment and still carried eight-inch side forms. To accommodate the eight-inch side forms, a four-inch layer of subgrade material had been built up in the test section. Figure 1 illustrates the final cross-section.

Paving operations were the same as for PCC pavement except spreader boxes were not used to distribute the concrete along the grade in front of the paver. In this trial section, the trucks dumped the CTB in piles directly in front of the paver; one pile on each side of the center of the paver. PCC is normally sufficiently plastic (two-inch slump) to flow under the influence of vibration. The drier CTB, however, tended to stay where it was placed and the corners of the paver were, at times, "starved" for material.

The only compaction given the CTB was vibration of the material by the paver. This was accomplished by two vibratory systems. The first consisted of "stinger" type vibrators placed at two-foot intervals across the front of the machine. These were arranged such that the longitudinal axis of the vibrator was both horizontal and parallel to the direction of movement of the paver. These vibrators were submerged in the CTB layer. The second system of vibration consisted of a transverse pipe vibrating a couple of inches above the "stingers". This vibrator affected only the top portion of the layer and tended to operate as a "strike off" screed.

The material used for the CTB aggregate came from Stony Creek near Orland, California, and is the end product of a closed cycle crusher plant. It is a 3/4" maximum aggregate and meets the grading requirements for Class 1 and 2 aggregate base as well as the grading requirements for Class A and B CTB. Table 8 gives the grading analysis and sand equivalent of the aggregate.

Batching and mixing the CTB was done in a Noble PCC batch plant. Two batches of three cubic yards each were pulled and fed together into an eight cubic yard mixing drum. The mixing time was approximately 45 seconds.

The mixed material was hauled by dump trucks to the test site. Two trucks, each carrying a six cubic yard batch, deposited their loads immediately in front of the paver. One truck went to the left of center and the other to the right of center.

Two test sections were constructed. Each section consisted of six truck loads (36 cubic yards) of material deposited and spread in a ribbon four inches deep, 24 feet wide and about 100 feet long. The first section contained four percent cement and had a varying amount of added moisture. The diagram in Figure 2 shows the variation in added moisture for the first test section. Actual moisture content in this section varied between 7.2 and 9.2%. by weight of the dry aggregate. The second test section contained six percent cement and had added water in the amount of 120 gallons of water for each six cubic yard batch of CTB. Actual moisture content in the second section was a little over 9% by weight of the dry aggregate.

Portions of the first test section (A,B,D, and F in Figure 2) appeared dry and had a coarse and open surface texture. Other portions (C and E in Figure 2) had a slight laitance on the surface and generally resembled concrete in appearance. No problems were found with the edges of the layer except in places where the mix was obviously too dry. In the drier parts of the test run, the stinger vibrators parted the mix and left grooves which did not flow together and heal.

The second test section presented a uniform appearance and could easily be mistaken for PCC pavement except for a few transverse depressions left by the screed.

In both sections the paver tracks lost traction under the load and caused the paver to slew somewhat. This spinning of the tracks was attributed to the soft soil on which the trials were conducted.

Upon completion of the trial runs, Hunt's Seal was used as a curing membrane.

Field Sampling

Test samples were taken from three portions of each of the two test sections. Both moisture samples and samples for compressive strength and density were selected from double truck loads constituting the beginning, middle, and end portions of each test section.

Samples for density and compressive strength were consolidated by holding the CTB mold liner, filled with CTB, against the transverse vibrator on the slipform paver. This was done to provide approximately the same compactive effort as was being applied in the field operation.

Samples of the CTB aggregate were obtained as was a sample of the cement used on the job.

Field Coring

The two test sections were sampled with coring equipment approximately seven weeks after the CTB was placed. Cores were taken in line with the grooves left by the vibrating "stingers" and in the areas in between these grooves (Figure 2). The cores from the first test section, which used four percent cement, tended to be crumbly (Figure 3) and they eroded from the water flow during the coring operation. The cores from the test section using six percent cement held up well during coring operations. No apparent difference was noted between cores taken in line with the "stinger" groove and those taken between grooves.

A section of CTB on project 02-Teh-5-0.0/9.3 contained CTB, from the same source, placed in a conventional manner according to specifications. This CTB contained 3.5% cement and was placed on December 14, 1965. An attempt to recover cores in this area met with limited success as the cement content was too low for good coring conditions.

Laboratory Testing

Specimens taken at the test site and fabricated as described under "Field Sampling" were tested for moisture, compressive strength, and density. Cored specimens underwent the same tests. Results are exhibited in Tables 1 and 2, respectively.

Aggregate and cement used on the job were brought to the laboratory and used to fabricate test specimens in three different ways. Compressive strengths and densities were determined for these specimens. The first set of specimens (results in Table 3) had the same two percentages of cement as used on the test site, but the % moisture used and the compaction were performed in the standard manner (1). Another set of specimens (results in Table 4) repeated the cement contents, but utilized vibratory compaction* and the moisture content which was used in Field Test Section II. The third set of specimens (results in Table 5) conformed to the second set, but the specimens were vibrated and cured over a 4"

*Compaction was accomplished by placing the moldliner on a Syntron Vibratory Table (Style 1456). This table is 11"x11" and the surface was covered with a solid 1" Neoprene pad. Vibration was accomplished at 60 cps. using maximum amplitude and continuing until the surface of the specimen was covered with a fines and water slurry resembling that obtained with field equipment.

deep silty sand base contained in a capped extension of the circular mold liner. This was an attempt to simulate field conditions.

One additional specimen with six percent cement from the first set of specimens and one with six percent cement from the third set were subjected to the surface water abrasion test*. This test is rather severe and was used in this instance to demonstrate what might happen to CTB under a rocking PCC slab in the presence of water and heavy truck traffic. Figure 4 illustrates the results of this test.

Results of Tests

Vibrated Samples

Specimens compacted in the field by vibration after sampling from the CTB placed in the test sections, gave compressive strengths and densities dependent upon the moisture content. When the moisture contents were between 7% and 8%, the material was too dry for use with the paver, but the density and compressive strength were relatively high. Higher moisture contents, which were more suitable for use with the slipform paver, gave lower strengths and densities (Table I). It can be seen that the compressive strengths were averaging over 400 psi and that the densities, when compared with the standard densities (1) in Table 3, gave relative compactions of 95% or better.

Cored Samples

Cores of the same material, taken from the test slabs, gave compressive strengths (see Table 2) similar to those specimens compacted at the site. Densities of the cores were slightly higher. This difference is caused either by a change in vibration mode and intensity or by the change in environment (i.e. The difference between a capped tin mold and the slab environment). Thus, the test slab met the compressive strength level currently used as a Class B CTB design criterion.

Standard Laboratory Samples

Control values were established by subjecting the CTB mixture to the standard method for optimum moisture (1), maximum density, and compressive strength. These tests (Table 3) indicate that a very high quality CTB can be made from this material.

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*Briefly, this test consists of agitating a 4" diameter specimen with a vertical motion while allowing 4--1-1/8" diameter rubber balls, in a water medium, to wear away the top surface of the specimen. For a full description of the method see Reference 2.

Vibrated Laboratory Samples

Specimens of CTB, compacted in the laboratory with vibration by a syntron table and the high moisture content necessary for slipform paver operation, performed almost as well as did the field specimens. In this case, however, strengths of the 4% CTB were below 400 psi and the relative compaction of the 6% material, compared with the normally compacted 6% specimen, was only 94% (See Table 4).

Laboratory Samples Vibrated Over Sand

Use of the sand base beneath laboratory vibrated specimens allowed excess water to escape during and after vibration. Strengths of these specimens (See Table 5) are close to the other laboratory vibrated specimens, but the densities are substantially lower. The low densities can probably be attributed to the fact that the escape of water from the CTB into the sand did not allow proper vibration of the CTB. Considering the low densities, the strengths were high. This is no doubt due to the lower water-cement ratio occasioned by the escape of excess water.

Comparison of Compaction Methods

Tables 6 and 7 present a comparison of compaction methods in terms of moisture, compressive strength and density for the 4% and 6% cement specimens, respectively. The percent relative compaction is also shown in these tables and is based upon the density attained in the standard method being equal to 100%.

Surface Water Abrasion Test

Results of the surface water abrasion test are shown pictorially in Figure 4. In terms of actual weight of material lost, the vibrated specimen showed a weight reduction, due to the test, of 1.0 gram while the standard specimen lost 10.7 grams.

Previous results (3) of this test, when it was used on CTB specimens, show that the vibrated CTB from this study would rank with the best performing 6% cement specimens previously tested while the standard specimen from this study ranks with the worst specimens in the previous study.

The apparent advantage of the vibrated CTB, in this respect, is probably the formation of a cement-rich crust which forms during vibration, as the coarser particles sink through the cement-water-fines matrix.

The overall results of this study, as outlined on the previous pages, indicate that CTB placed by slipform pavers might be satisfactory and have added merit as a construction technique.

Further work is needed and it is thought that economic benefits should be analyzed carefully prior to final acceptance of this as an alternate procedure.

REFERENCES

1. California Division of Highways, Materials and Research Department, "Test Method No. Calif. 312", Materials Manual Vol. 1, Sacramento, California.

2. Skog, J. and Zube, E., "New Test Methods for Studying The Effect of Water Action on Bituminous Mixtures", (Paper presented at the Asphalt Paving Technologists Meeting, San Francisco, California, February 1963.)

3. Skog, J., "Progress Report #3A on the Development of a Test Method for Measuring the Resistance of Cement Treated Bases to Surface Abrasion Loss by Water Action", Unpublished, November 1961.

4. Zube, E., "California's Experience with Cement Treated Bases Under Asphaltic Concrete and Portland Cement Concrete Pavements", (Paper presented at the 10th International Conference for Civil Engineers, Bad Meinberg, West Germany, February 1964.)

TABLE 1

COMPRESSIVE STRENGTHS AND DENSITIES
OF FIELD FABRICATED SAMPLES

Location	Percent Cement	Percent Moisture	7-day Compressive Strength(PSI)	Density(PCf)
Test Strip #1				
North	4	7.2	882	141
Middle	4	7.9	738	140
South	4	9.2	414	136
Test Strip #2				
North	6	9.6	242	136
Middle	6	8.7	468	138
South	6	9.7	563	137

These samples were compacted by holding the CTB mold liner, filled with CTB, against the transverse vibrator on the slipform paver.

TABLE 2

COMPRESSIVE STRENGTHS AND DENSITIES OF CORED SAMPLES

Core No.	Location	Percent Cement	Compressive Strength(PSI) *	**	Density pcf
	Test Strip #1				
1	South	4	---	---	141
2	"	4	413	743	144
3	"	4	---	---	142
	Test Strip #2				
6	North	6	390	703	139
7	"	6	429	772	140
4	Middle	6	496	893	140
8	"	6	452	813	140
5	South	6	416	748	141

* Values corrected to 7-day curing time using relationships shown in Ref. 4 (Fig. 12 and 13)

**Uncorrected Values (7 week cure)

These samples were cored from the test strips constructed by the slipform paver which used only vibration for compaction.

TABLE 3

COMPRESSIVE STRENGTHS AND DENSITIES OF LABORATORY SAMPLES COMPACTED NORMALLY

Percent Cement	7-day Compressive Strength(PSI)	Density (PCF)	Percent Moisture
4	1250	142	6.1
4	1310	143	"
6	1880	146	"
6	1610	144	"

These samples were fabricated according to Test Method No. Calif. 312.

TABLE 4

COMPRESSIVE STRENGTHS AND DENSITIES OF LABORATORY SAMPLES COMPACTED WITH VIBRATION

Percent Cement	7-day Compressive Strength(PSI)	Density (PCF)	Percent Moisture
4	335	136	9.5
4	330	136	"
6	550	137	"
6	500	136	"

Compaction was accomplished by placing the moldliner on a Syntron Vibratory Table (Style 1456). This table is 11"x11" and the surface was covered with a solid 1" neoprene pad. Vibration was accomplished at 60 cps. using maximum amplitude and continuing until the surface of the specimen was covered with a fines and water slurry resembling that obtained with field equipment.

TABLE 5

COMPRESSIVE STRENGTHS AND DENSITIES OF LABORATORY SAMPLES COMPACTED WITH VIBRATION OVER A SAND BASE

Percent Cement	7-day Compressive Strength(PSI	Density (PCF)	Percent Moisture
4	320	132	9.5
4	340	131	"
6	430	131	"
6	460	133	"

Compaction was accomplished by placing a double length moldliner, the lower half of which was filled with sand, on a Syntron Vibratory Table (Style 1456). This table is 11"x11" and the surface was covered with a solid 1" neoprene pad. Vibration was accomplished at 60 cps. using maximum amplitude and continuing until the surface of the specimen was covered with a fines and water slurry resembl-- that obtained with field equipment.

TABLE 6

A COMPARISON OF COMPACTION METHODS
IN TERMS OF % MOISTURE
COMPRESSIVE STRENGTH, & DENSITY
(4% Cement Used)

Compaction Method	% Moisture	Average Compressive Strength (psi)	Average Density (pcf)	% Relative Compaction
Standard (TM Calif.312)	6.1	1280	142.5	100
Vibration (By hand-at paver)	9.2	414	136.0	96
Vibration (Paving Machine)	*	413	142.3	100
Vibration (Laboratory)	9.5	333	136.0	96
Vibration (Lab-over sand)	9.5	330	131.5	92

* These samples were cored from an area which originally had about 9.2% moisture.

TABLE 7

A COMPARISON OF COMPACTION METHODS
IN TERMS OF % MOISTURE,
COMPRESSIVE STRENGTH, & DENSITY
(6% Cement Used)

Compaction Method	% Moisture	Average Compressive Strength (PSI)	Average Density (pcf)	% Relative Compaction
Standard (TM Calif.312)	6.1	1745	145	100
Vibration (By hand-at paver)	9.3	424	137	95
Vibration (Paving Machine)	*	437	140	97
Vibration (Laboratory)	9.5	525	136.5	94
Vibration (Lab-over sand)	9.5	445	132	91

* These samples were cored from an area which originally had about 9.5% moisture.

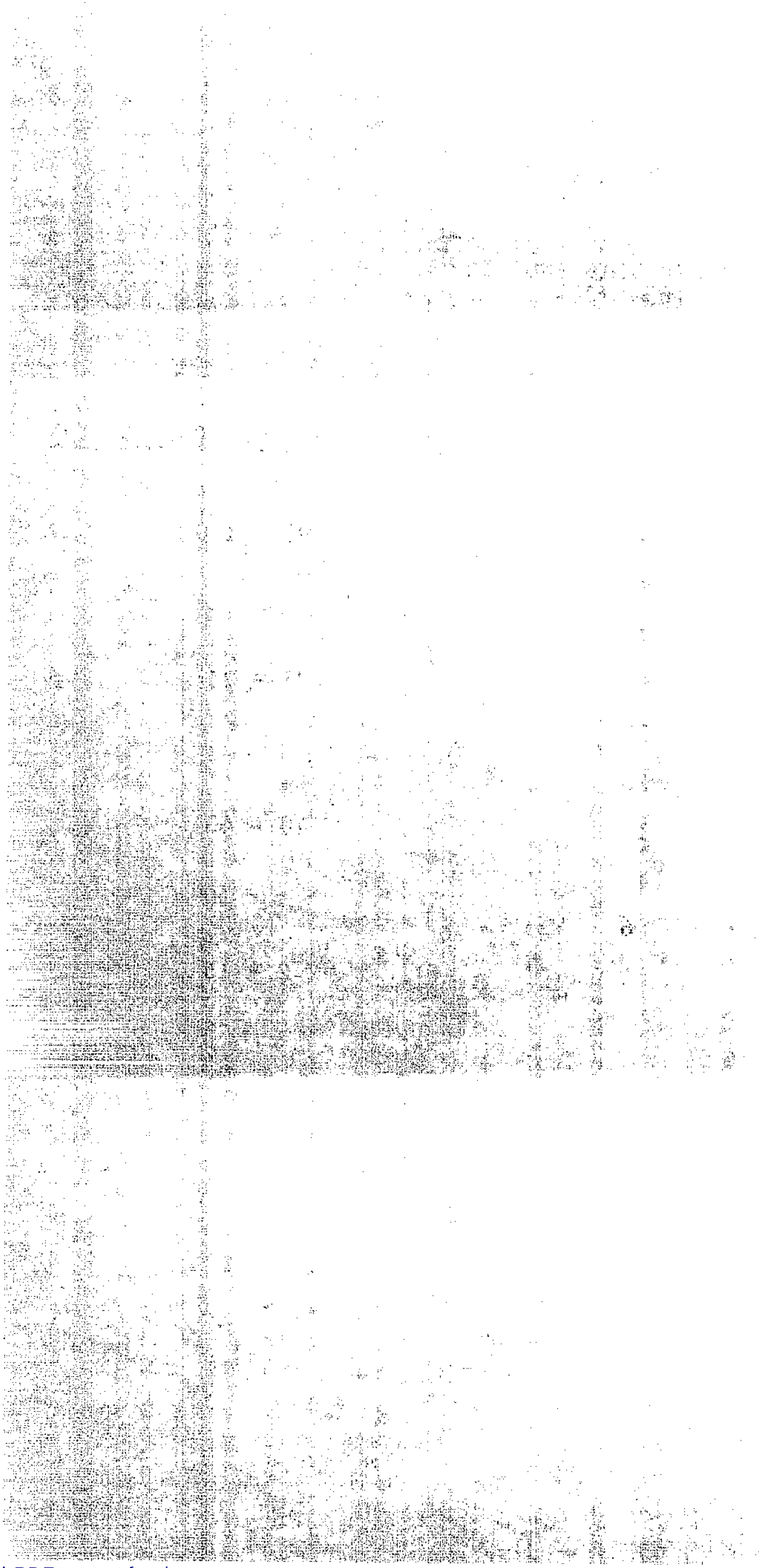
TABLE 8

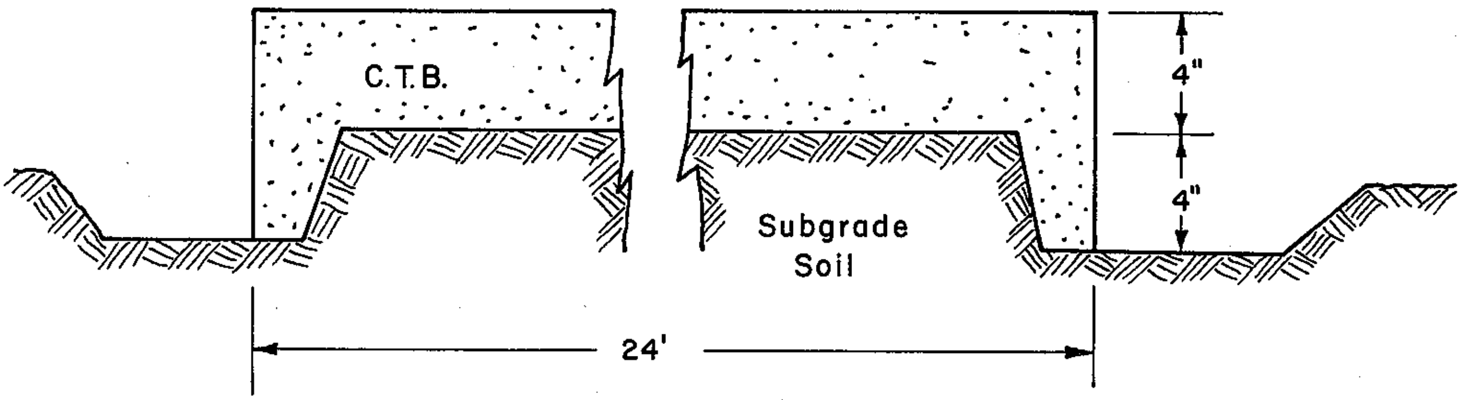
TEST RESULTS ON AGGREGATE
USED IN THIS PROJECT
(65-4726)

Grading Analysis

Sieve	% Passing As Received	% Passing As Used	Specifications (Cl. B CTB)
1"	100		100
3/4	98	100	90 - 100
1/2	82	84	
3/8	70	71	
#4	50	51	35 - 75
#8	38	39	
#16	27	28	
#30	19	19	10 - 40
#50	11	11	
#100	6	6	
#200	5	5	2 - 15

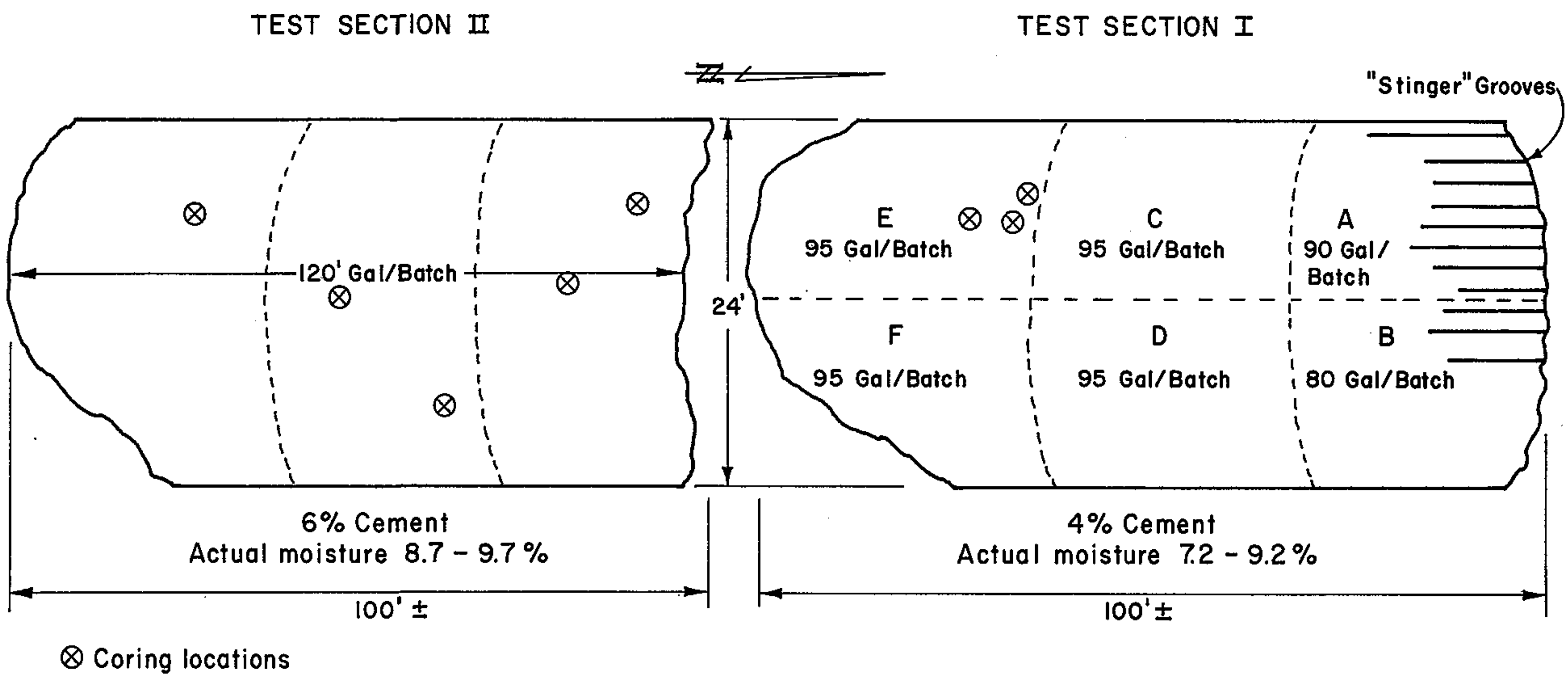
Sand Equivalent = 40





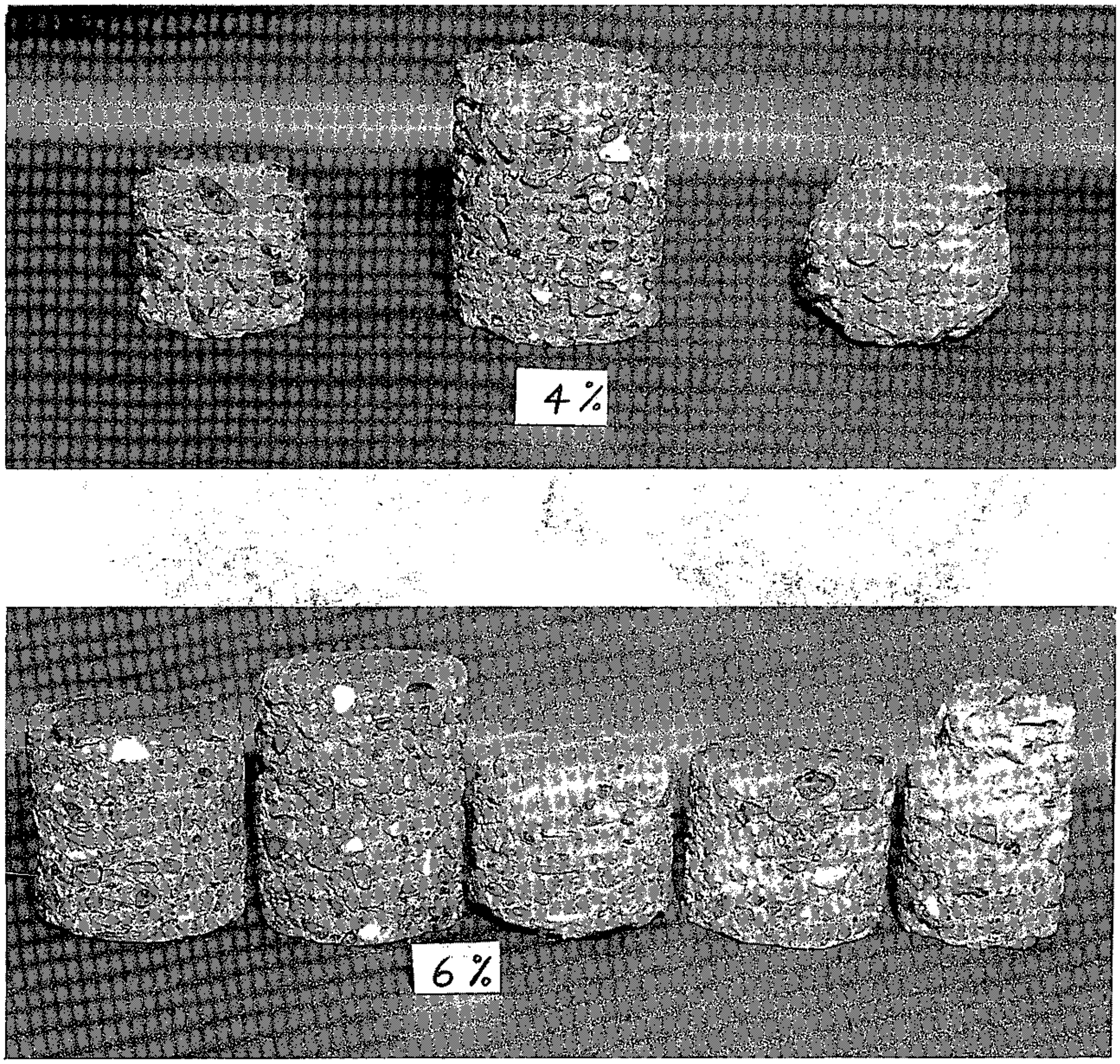
Sketch showing adjustment of subgrade to allow a slip-form paver, with 8-inch side-forms, to place a 4-inch slab of cement treated base.

Figure 1



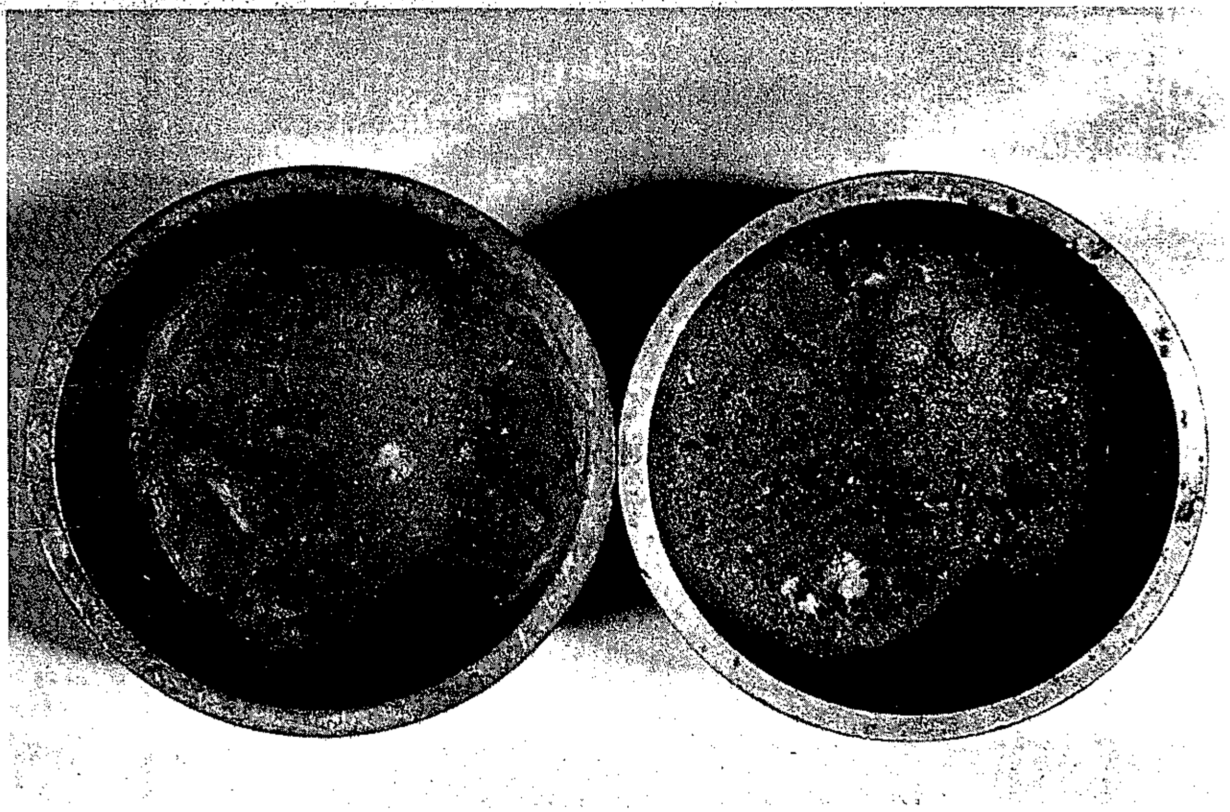
PLAN VIEW OF TEST SITE

Figure 2



EFFECT OF CEMENT CONTENT ON EROSION DURING CORING

Figure 3



Vibratory Compaction

Normal Compaction

SURFACE OF SPECIMENS AFTER THE SURFACE WATER ABRASION TEST.

Figure 4