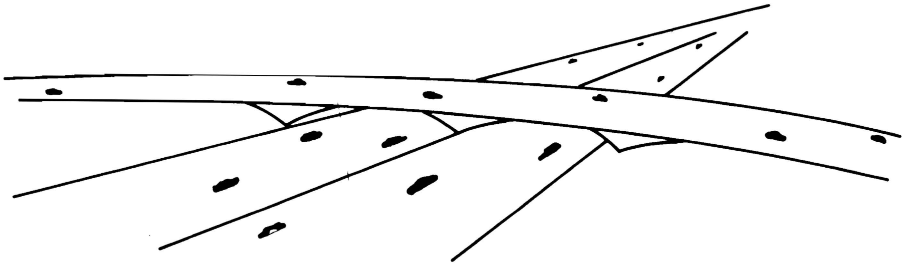
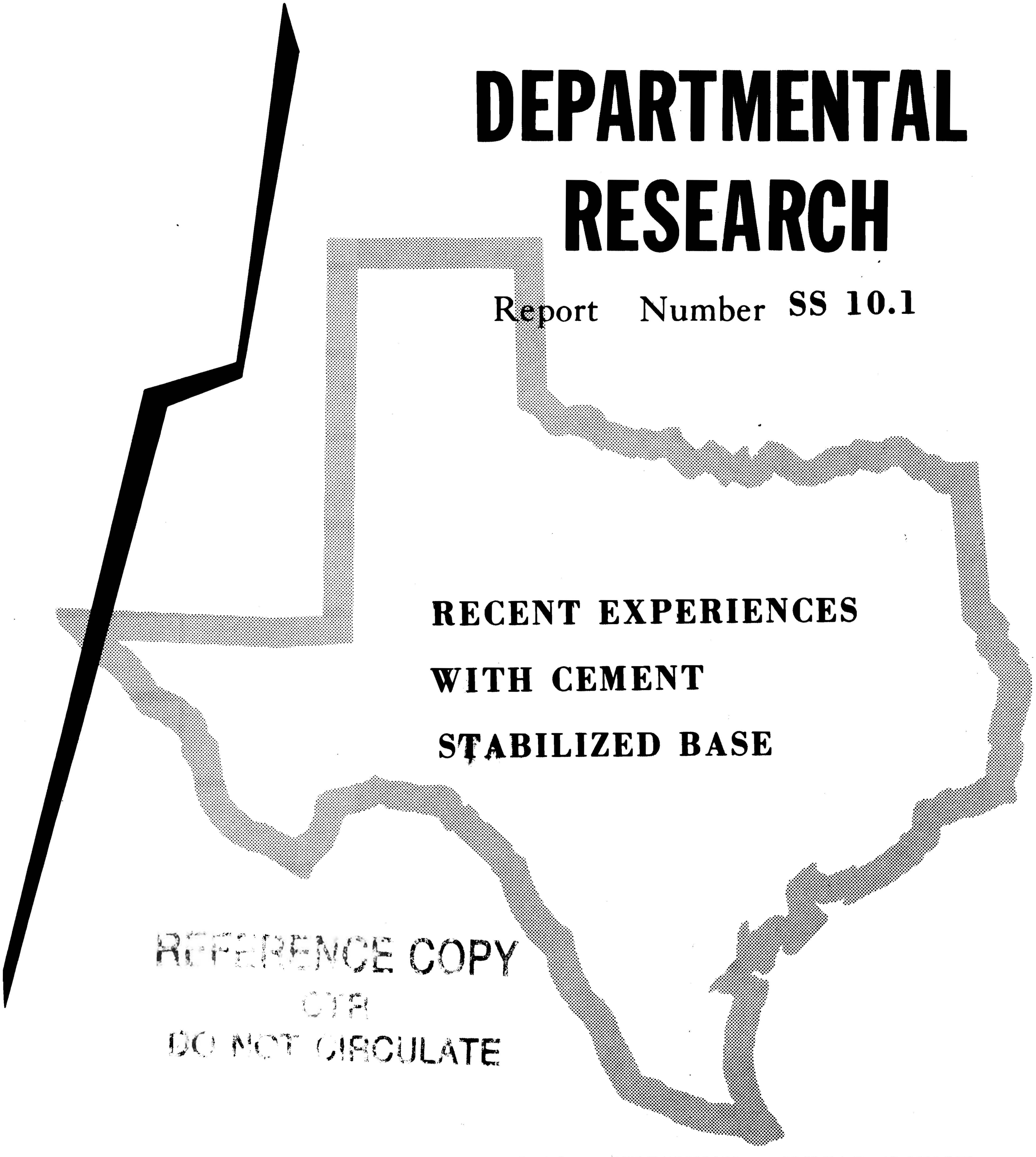


DEPARTMENTAL RESEARCH

Report Number **SS 10.1**



RECENT EXPERIENCES WITH CEMENT STABILIZED BASE

TEXAS HIGHWAY DEPARTMENT

"RECENT EXPERIENCES WITH CEMENT STABILIZED BASE"

by

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SPECIAL STUDY REPORT SS 10.1

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ABSTRACT

Evaluation of field experiences with cement stabilized base on a recent Texas Highway Department project in San Antonio provides interesting data and guidelines for future construction economies. Various techniques and approaches were used, measured and considered. Higher densities were achieved that initially believed feasible. The passage of time with proper curing and maintenance resulted in increased density readings. Considerable variation in amount of cement spread by conventional road dispersing equipment was recorded. This seemed to have a questionable effect on densities. Finished surfaces and surface durability may relate to binder content and effect density results. Trade association engineers are helpful in this construction phase as they well might be in other areas. Review of construction data should lead to better engineering tomorrows.

RECENT CONSTRUCTION EXPERIENCES WITH CEMENT STABILIZED BASE[a]

Malcolm L. Steinberg,* M.ASCE

INTRODUCTION

The value of science and technology to society lies largely in the area of doing something useful and in a manner better than its been done in the past. Engineering aims for a steady evolution to an improved, more economical product. In a specialized area, cement stabilization has proven itself over a fifty year period a valuable engineering material. Recent construction experiences with cement stabilized base will look at some of the field problems, involved, resolved and unresolved. Sometimes it seems to the construction engineer that with so much experience in dealing with a material and a procedure, few questions and problems should remain. The most feasible should be known. Sometimes out on the project the engineer finds that like that old song, 'it ain't necessarily so'.

Or maybe this is just a communication problem. In that case, some more communicating will be done here. This project covered a six mile urban expressway contract on the west side of San Antonio.

[a] Presented at the Friday October 10, 1969 Texas Section Meeting held at Lubbock, Texas

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[1] Numerals in parenthesis refer to corresponding items in the Appendix-References

INTRODUCTION

(Continuation)

The plans and construction supervision for this facility were prepared and handled by the Texas Highway Department. The first question that seemed to arise was whether the 98% of optimum density could be met. As answers to one question came in, others arose. What happens with the passage of time? What are the problems of nonuniformity? Some answers developed as the work progressed, while others led only to more searching. The immediate needs are fulfilled, but further studies and probing seem called for. This is especially true if further economies in construction operations are to be reached.

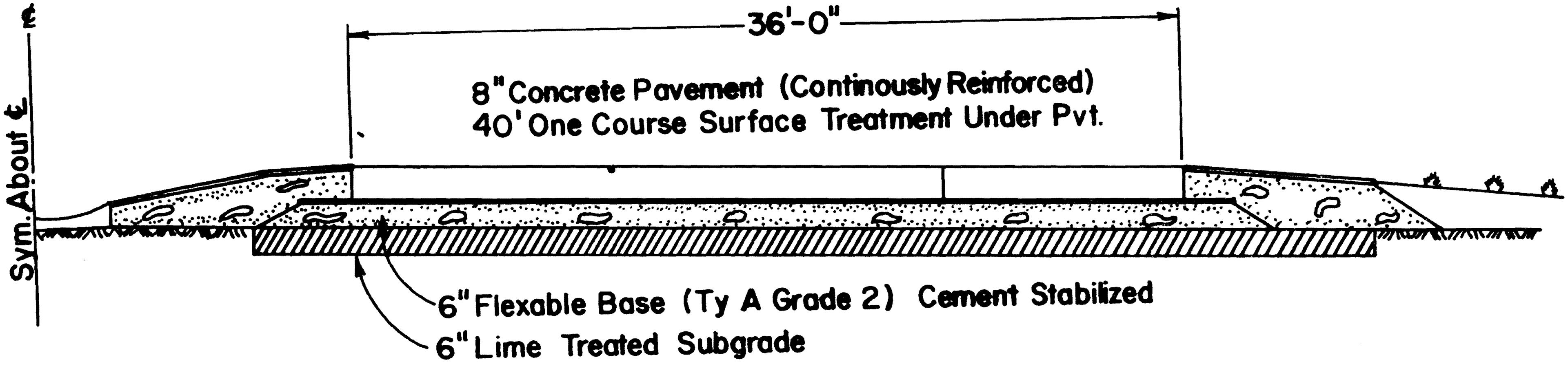
THE GENERAL SCENE:

The work described here took place on Project U 459(13), part of the U. S. Highway 90 Urban Expressway in the west side of San Antonio, Texas. This project was also the source of that earlier paper entitled 'Underdrains in Heavy Clay Soils'.(8) It is 6.2 miles long, extending from Cupples Road on the east to Interstate Loop 410 on the west. To the south of the project are Kelly and Lackland Air Force Bases, and Wilford Hall Air Force Hospital, sometimes referred to as the largest industrial complex west of the Mississippi. The Killian-House Company was the successful low bidder and was awarded the contract by the Texas Highway Department in August of 1966. Construction was supervised by highway department personnel, and in late December of 1967, cement stabilization work began.

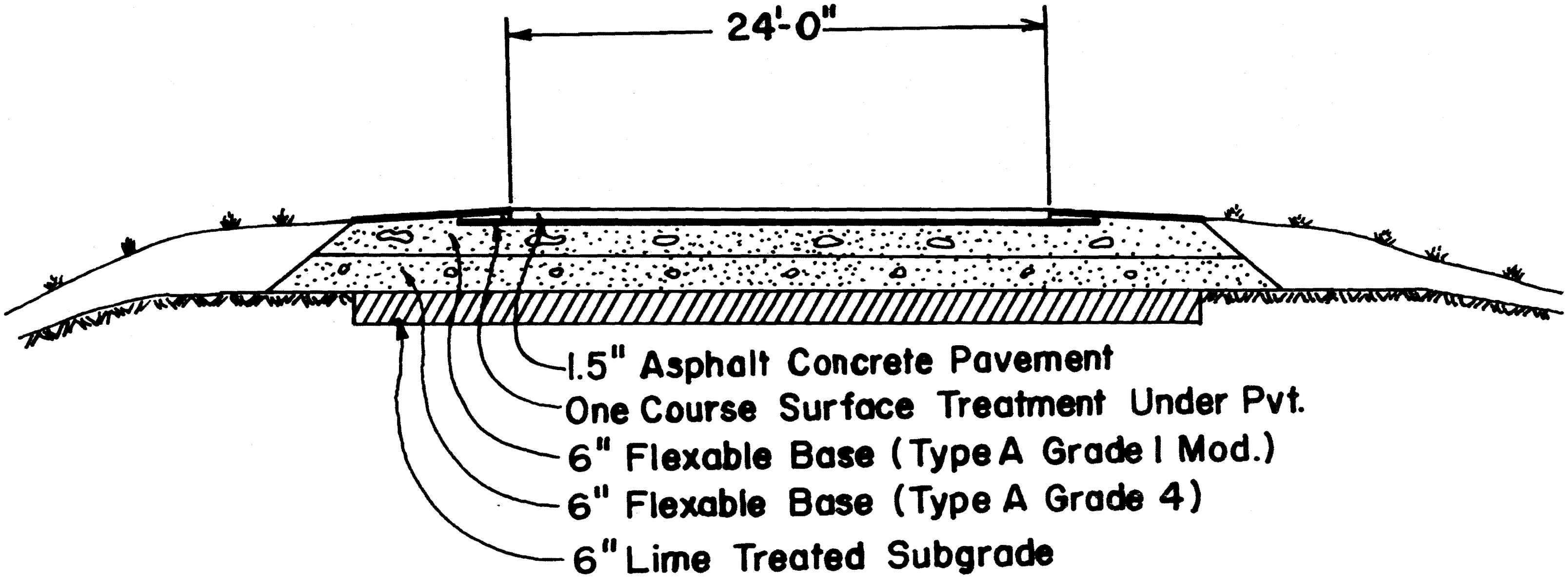
The contract called for cement stabilization of six inches of Flexible Base, Type A-Grade 2 (Appendix II). This work was to be done on main-lane sections, varying in width from 31 to 43 feet. The base was placed on 6 inches of lime stabilized subgrade; stabilized with portland cement spread at a rate of 150 pounds a cubic yard, approximate 4% by weight, and had a 98% density requirement. It received a one course surface treatment. Later an 8 inch continuously reinforced concrete pavement was placed over it. The embankment on the project as well as the lime stabilization work was also density controlled. (Fig. 1)

Plan quantities involved initially were 18,133 barrels of cement used in the stabilization work and 45,454 cubic yards of Flexible Base (Type A-Grade2). Before any of the cement stabilization work began, it became apparent that the frontage road areas and turnarounds in the low water crossings of the Leon Creek seemed to need the same protection.

A field change was duly executed and this area actually became the site of the first project work on this item. About this time, word began drifting back to the project engineer that the contractor's personnel were asking some of the state inspection forces about the details of the stabilization work. They would have been happy to help them out, but unfortunately none had experiences in this work beyond small driveway stabilization. In an effort to keep the proverbial blind from leading the blind, the local Portland Cement Association field engineer was contacted. He presented a film and slide look at the operation for state and contractors personnel. It helped. Although this contractor had supervisors on other projects, that had done heavy volumes of this work, there was little passing of all but the most elementary information. His presenttation made everybody a little less uncomfortable in any event.



TYPICAL SECTION MAINLANE



TYPICAL SECTION FRONTAGE ROAD

FIG. 1

PROCEDURE

The Frontage Roads and the turn arounds in the Leon Creek area were the first sections cement stabilized on the project. A six-inch lift of a Type A-Grade 4 base was rough graded to finish blue top elevations with a maintainer. A Bros, self-propelled master mixer made a single pass thru the base to make it more receptive to the cement. Transport trucks then drove thru the land, unloading and spreading the cement thru a three holed bar attached to the truck, using an air blown vacuum pump to pull the cement out. The Bros and Rex D-8 tractor-drawn pulvimixer were used in an effort to meet the six hour specified deadline for completing the work. Each mixer made two passes, followed by the maintainer blading the material into three windrows, one down the middle and one down each crown line. The cement admixed base was pulled in and laid in one to two inch lifts. A Hyster compactor, a vibratory, and twenty-five ton pneumatic roller accompanied the blade and water truck in regular base laying operations. Final blue-tops were set and the blade, accompanied by a ten ton flat wheel roller and a water truck, finished the surface to line and grade.

A sample of mixed base and cement was taken in a water tight container to the Residency Laboratory. While finishing operations were being completed, the lab was running the moisture density curves and determining our density limits. Field density tests were then taken by personnel from the District Laboratory with a Nuclear Chicago Density Machine. This Nuclear Machine was checked and correlated with the Rainhart Standard Volumeter. All field densities were taken in the same location to reduce error.

The lands were water cured for several days, and where needed, the surface was maintained by blading and rolling, and density tests repeated. A one course surface treatment was then applied to the cement stabilized base.

The bulk of the cement stabilization work took place on the East and West Bound Main Lanes. Generally 1200' was the length of a working land and 360 barrels of cement was used per land. A CMI Autograder with electronically controlled grader arms,operating from string lines along each crown line, was used to make a preliminary base distribution. Due to the machines requirements, this was done about .02 above grade. The CMI then preloosened the base and the base was prewatered. Initially,the operation remained the same as it was on the frontage roads, except the CMI substituted for the blade. After treating a few lands using this method, and not getting the density results we had hoped for, a consultation was held with the contractor's men and the Portland Cement Association area engineer. Following this conference the pattern was modified. A sheepsfoot roller was introduced, following mixing and lab sampling. When the sheepsfoot started to walk out, a maintainer shaped the section and a twenty-five ton self-propelled pneumatic roller began its compactive efforts. A vibratory roller then made a single pass over the land. The CMI then cut the section to line and grade,the water truck watered, while the pneumatic kept rolling. Use of the CMI permitted omission of separating the base into several windrows, and accelerated the work. A final pass with a ten ton flat wheel roller was made to reduce any surface tire marks before density tests were made.

A word about the density tests. Usually they were first taken on the day of mixing. There was no rigidity about this. Subsequent tests were taken as needed. The fact that they were non-destructive tests, where results could be read immediately on a dial counter, was very important for a wide variety of reasons; they were quick, there was no further loss of time and money awaiting results were among the most important. Laboratory density testing was in accordance with THD test method 113 modified. A word about the advice. Unfortunately, not all the suggestions were followed. A push type, sheepsfoot roller was suggested to avoid the tearing action that accompanies turning the roller around at the end of the land. This roller was not secured, and a pull type sheepsfoot had to suffice making its turn off the base on the subgrade slopes. The push type idea seemed like an excellent one. It would have been less destructive and faster.

FIRST QUESTION FIRST....CAN THE 98% DENSITY REQUIREMENT BE MET?

The problem that seemed most important at first was the achievement of the 98% density requirement. The attached summary indicates we had nothing to fear here. Of the sixty-five test sites, passing densities were recorded at fifty-seven locations. In four of the eight failures the test results were within a pound of the required value. Therefore, in significant values failure occurred in only four of sixty-five tests. While not perfect, this would represent passing result on almost 94% of all test locations. (See Table 1)

It is interesting to note that had the density requirement been set at 95% of maximum, failure would have occurred in only two locations... sixty-three passing in sixty-five tests. Contrasted to these figures is the fact that in fifteen tests,results were above the 100% density value. This apparent phenomena was similarly reflected in five of seventeen South Carolina tests.(1) Obviously there's comething more at work here than compaction. Several of these factors are discussed subsequently.

In any event, when failure does occur with cement stabilized base, you cannot rework the land. Water curing and surface care can work wonders and frequently a review of techniques being used are a big help too.

TABLE 1

DENSITY RESULTS OF CEMENT STABILIZED BASE

CAN 98% DENSITY BE ACHIEVED?

LANE	STATION	LABORATORY DENSITY 100%	98%	FIELD DENSITY	DATES MIXING	FIELD READING
		(In pounds per cubic foot)				
Westbound Main Lane	192	133.5	130.8	134.7	2-8-68	2-12-68
	202	135.7	133.0	135.9	2-7-68	2-9-68
	212	134.3	131.6	134.3	2-6-68	2-8-68
	224	133.1	130.4	132.9	2-5-68	2-8-68
	235	133.4	130.7	131.8	2-5-68	2-8-68
	247	138.7	136.0	135.1	2-1-68	2-16-68
	257	134.8	132.1	136.0	2-1-68	2-7-68
	260	138.75	135.9	136.0	2-1-68	2-7-68
	269	137.5	134.8	134.5	1-31-68	2-1-68
	280	135.9	133.2	135.7	1-30-68	2-1-68
	292	139.7	136.9	138.1	1-26-68	1-31-68
	303	141.4	138.6	138.5	1-25-68	1-31-68
	321	137.6	134.9	138.4	3-1-68	3-7-68
	329	134.2	131.5	139.2	3-4-68	3-7-68
	342	138.6	135.8	139.6	3-4-68	3-7-68
	355	136.1	133.4	138.7	3-5-68	3-7-68
	366	135.4	132.6	135.8	3-18-68	3-21-68
	377	138.1	135.3	135.6	3-19-68	3-21-68
	400	138.1	135.3	138.4		3-25-68
	389	139.5	136.7	138.1	3-20-68	3-26-68
	410	141.1	138.3	138.5		3-26-68
	421	135.9	133.2	134.1		3-26-68
	431	139.5	136.7	138.1		3-26-68
	493	140.7	137.9	138.6		4-3-68
	444	139.4	136.6	133.3		4-5-68
	457	136.9	134.2	137.6		3-28-68
	484	136.8	134.1	136.0		4-8-68
	504	139.7	136.9	137.5		4-10-68
	467	138.1	135.3	136.4		6-11-68
	477	136.5	133.8	134.8		6-11-68
Eastbound Main Lane	193	138.6	135.8	137.3	2-8-68	2-16-68
	205	136.5	133.8	134.3	2-9-68	2-16-68
	216	136.0	133.3	133.7	2-12-68	2-22-68
	228	141.5	138.9	133.2		2-22-68
	238	138.1	135.3	135.7	2-16-68	2-26-68
	250	140.9	138.0	132.0	2-21-68	2-26-68
	262	134.9	132.2	133.9	2-26-68	3-5-68
	273	133.1	130.4	134.5	2-26-68	3-5-68
	285	133.4	130.7	134.5	2-27-68	3-5-68
	296	134.8	131.9	135.8	2-27-68	3-6-68
	306	137.8	135.0	136.6	2-28-68	3-6-68
	320	136.3	133.6	141.4	2-29-68	3-7-68
	330	140.6	137.8	138.9	3-1-68	3-8-68
	341	139.9	137.2	139.2	3-5-68	3-7-68
	351	140.4	137.6	135.4	3-6-68	3-13-68

TABLE 1 (CONT'D)

		LABORATORY DENSITY		FIELD	DATES	
LANE	STATION	100%	98%	DENSITY	MIXING	FIELD READING
		(In pounds per cubic foot)				
Eastbound Main Lane (Continued)	365	135.4	132.7	134.2	3-7-68	3-13-68
	376	137.6	134.8	135.7	3-8-68	3-14-68
	388	136.7	134.0	137.7	3-8-68	3-14-68
	395+75	137.2	134.5	135.4	3-13-68	3-15-68
	399	137.2	134.5	137.1	3-13-68	3-18-68
	411	138.5	135.7	136.6	3-14-68	3-18-68
	420	140.7	137.9	138.0	3-14-68	3-26-68
	427	140.9	137.9	138.0	3-14-68	3-22-68
	430	140.9	137.9	138.2	3-15-68	3-22-68
	445	140.01	137.2	137.2	3-15-68	3-22-68
	456	139.1	136.3	136.9		4-10-68
	476	137.7	134.9	137.1		6-11-68
	486	138.2	135.4	135.4		4-10-68
	494	137.1	134.4	134.6		4-5-68
	505	140.4	137.6	138.0		4-11-68
	466	137.2	134.5	135.0		5-31-68
Eastbound Frontage Road	308	137.3	134.5	137.2	12-24-68	3-13-68
Westbound Frontage Road	313	139.3	136.5	137.9	1-17-68	1-26-68
Leon Cr. W. Turnaround	97	142.5	139.6	138.9	1-16-68	1-23-68
Leon Cr. E. Turnaround	97	142.5	139.6	140.3	1-16-68	1-23-68

NEXT QUESTION PLEASE:

If the passing percentage was that good, what's all the writing about? The construction problem arose from the fact that we did not get the passing tests with any clock-like regularity. This situation creates delay, consternation, and tends to get expensive. In the first six mixing lands (table 2), we had four density sites that were within a pound of passing first time around. The remaining two lands led to sixteen density tests. Thank goodness for the nondestructive test. Thank goodness for the nuclear density machine. It took from eight days to three weeks to get a passing density on these lands. They were watered, roller, and bladed to maintain the surface, while the effect of the passage of time was carefully watched to see what good might be obtained. Meanwhile, the local Portland Cement Association area engineer was contacted and literature was read and reread. One of the suggestions offered was the use of the sheepsfoot roller. Following its use, 66% of the tests passed the first time around, while those lands where it was not used passed only 33% of their first tests. The CMI 'lands' had the same percentages. Interestingly enough, they all passed. (table 2)

So time heals these wounds, too.

TABLE 2

THE NEXT QUESTION----THE EARLY TESTS

DATE STABILIZED	LAND (STATIONS)	LIMITS	DENSITY 98%	DENSITY FIELD	DATE	LOCATION
			(In pounds per cubic foot)			
12-23-67	93 + 40	T. Arnd	137.5#	136.0#	12-29-67	ET 101
	101 + 60	E&W FR		136.3		ET 101
				136.7		WT 99
				133.8		WT 101
				134.4	1-10-68	WT 99
				133.4		WT 101
				138.9	1-23-68	WT 101
				140.3		ET 101
12-24-67	307	EBFR	136.4(315)	134.5	1-24-68	(308)
	317		135.5(310)	133.7		(315)
				134.2	1-25-68	(308)
				130.0		(313)
				133.7	1-26-68	(313)
				134.3		(308)
				137.2	2-2-68	(308)
				136.7		(313)
1-29-68	307	WBFR	135.5	136.2	1-29-68	
	317					
1-16-68	93	WTARND	139.6	138.9	1-23-68	
	101					
1-16-68	93	WTARND	139.6	140.3	1-16-68	
	101					
1-17-68	307	WBFR	136.5	139.1	1-23-68	310
	317			136.9	1-24-68	308
				136.4	1-25-68	308
				137.9	1-26-68	308

THE PATTERN OF THE REPETITIVE TESTS

For a variety of reasons, we became committed to the repetitive test. On thirty-three lands we received a passing density result on our first test. Fortunately, our corollary pattern developed. Density tended to increase with the passage of time. Here, the construction pattern again duplicated the laboratory experience. These results were outlined in 'The Strength and Elastic properties of Compacted Soil Cement Mixtures' by Earl Felt and Melvin Abrams.(2) In repeated testing the trend was up. In forty-five cases out of fifty-eight repetitive tests the density results increased with the passage of time. This is particularly significant in view of the problem of keeping construction traffic off the land. This movement of heavy machinery created a raveling of the base material that caused difficulties in getting a smooth surface the density machine requires for accurate testing. Despite this difficulty, with continued water curing, occasional rolling and blading for surface maintenance, the increased density trend remained. Keep with it, keep it moist with a smooth surface and you'll probably get your density. (table 3)

TABLE 3

DENSITIES AND THE PASSAGE OF TIME

Lane	Sta	Date	Density (In pounds per cubic foot)	Lane	Sta	Date	Density (In pounds per cubic foot)
WBFR	313	12-29-68	136.2	WBL	215	2-7	136.2
Leon Cr T.Arnd W.	99	12-29	136.7	WBL *		2-8	134.3
		1-10	134.4	WBL	202	2-7	135.5
West	101	12-29	135.8	WBL		2-8	136.1
		1-10	133.4	WBL		2-10	135.9
		1-23	138.9	WBL	192	2-8	134.7
Leon Cr T.Arnd E.	101	12-29	136.3	WBL *		2-10	135.0
		1-23	140.3	WBL		2-12	134.7
WBFR	313	1-23	139.1	EBL	194	2-10	134.1
		1-24	136.9	EBL		2-12	135.6
		1-25	136.4	EBL		2-16	137.3
		1-26	137.9	EBL	205	2-10	132.9
EBFR	308	1-24	134.5	EBL		2-12	134.8
		1-25	134.2	EBL		2-26	133.9
		1-26	134.3	EBL	216	2-16	132.3
		2-2	137.2	EBL		2-26	133.8
EBFR	313	1-24	133.7	EBL	228	2-21	133.2
		1-25	130.0	EBL		2-26	135.2
		1-26	133.7	EBL	238	2-21	135.4
		2-2	136.7	EBL		2-26	135.7
EBFR	313	3-8	138.9	EBL	249	2-26	132.0
WFR	315	12-29	136.2	EBL		2-27	131.0
WFR		1-4	134.1	EBL		3-1	136.6

TABLE 3 CONT'D

Densities and the Passage of Time (Continued)

Lane	Sta	Date	Density (In pounds per cubic foot)	Lane	Sta	Date	Density (In pounds per cubic foot)
WFR		1-12	135.2	EBL	262	2-26	132.5
WFR	310	1-12	133.6	EBL		2-28	132.7
WFR		1-23	139.1	EBL	272	2-27	129.0
EFR	308	1-24	134.5	EBL		2-28	133.9
EFR		1-25	134.2	EBL	285	2-27	133.4
EFR		1-26	134.3	EBL		2-28	136.0
EFR		2-2	137.2	EBL	302	2-28	135.7
WBL	300	1-30	137.4	EBL		3-6	135.8
WBL		1-31	138.5	EBL	306	2-29	135.9
WBL	307	1-25	136.6	EBL		3-4	136.2
WBL		1-26	137.3	EBL	320	3-1	136.9
WBL	305	1-30	137.4	EBL		3-4	137.8
WBL		1-31	138.5	EBL		3-6	140.8
WBL	292	1-30	136.2	EBL		3-7	141.4
WBL		1-31	138.1	EBL	430	3-15	131.8
WBL	280	1-31	137.5	EBL		3-18	135.5
WBL		2-1	135.7			3-20	135.9
WBL	270	1-31	134.1			3-21	135.6
WBL		2-1	134.5			3-22	138.2
WBL	258	2-1	133.8	EBL	445	3-18	140.3
WBL		2-6	134.0			3-20	135.4
WBL	258	2-7	136.0			3-21	136.6
WBL	249	2-6	131.5			3-22	137.2
WBL		2-7	130.8	WBL	366	3-20	135.5

TABLE 3 CONT'D

Densities and the Passage of Time (Continued)

Lane	Sta	Date	Density (In pounds per cubic foot)	Lane	Sta	Date	Density (In pounds per cubic foot)
WBL		2-12	135.6	WBL		3-21	135.8
WBL	235	2-6	134.7	WBL	377	3-20	136.9
WBL		2-7	133.4	WBL		3-21	135.6
WBL *		2-8	131.8	WBL	389	3-21	132.7
WBL	225	2-6	135.5	WBL		3-22	133.3
WBL *		2-7	134.1	WBL		3-25	135.6
WBL		2-8	132.9	WBL		3-26	138.1
EBL	330	3-4	134.9	WBL	400	3-22	134.0
EBL		3-6	134.9	WBL		3-25	138.4
EBL		3-7	136.5	WBL	410	3-25	139.3
EBL		3-8	138.9	WBL		3-26	138.5
WBL	321	3-4	134.7	WBL	421	3-25	134.0
WBL		3-6	136.5	WBL		3-26	134.1
WBL		3-7	138.4	WBL	431	3-26	138.1
WBL	329	3-6	138.7	WBL	444	3-28	136.2
WBL		3-7	139.2	WBL		4-2	133.5
WBL	342	3-6	140.6	WBL		4-3	134.7
WBL		3-7	139.6	WBL		4-4	134.8
WBL	355	3-6	137.5	WBL		4-5	133.3
WBL		3-7	138.7	WBL	457	3-28	137.6
EBL	341	3-6	138.8	WBL	493	4-2	134.2
EBL		3-7	139.2	WBL		4-3	138.6
EBL	351	3-8	135.3	WBL	504	4-2	131.5
EBFR	313	3-8	138.9	WBL		4-3	132.4
EBL	365	3-8	134.6	WBL		4-4	133.8

TABLE 3 CONT'D

Densities and the Passage of Time (Continued)

Lane	Sta	Date	Density (In pounds per cubic foot)	Lane	Sta	Date	Density (In pounds per cubic foot)
EBL	376	3-13	133.0	WBL		4-5	135.8
EBL		3-14	135.7	WBL		4-8	135.3
EBL	388	3-13	136.5	WBL		4-9	135.3
EBL		3-14	137.7	WBL		4-10	137.5
EBL	399	3-14	137.9				
EBL		3-15	138.6				
EBL		3-18	137.1				
EBL	411	3-14	138.8				
EBL		3-15	135.3				
EBL		3-18	136.6				
EBL	420	3-15	135.1				
EBL		3-18	137.4				
EBL		3-20	134.7				
EBL		3-21	135.2				
EBL		3-22	136.2				
EBL		3-25	137.8				
EBL	494	4-3	133.2				
EBL	494	4-4	133.2				
EBL		4-5	134.6				
EBL	505	4-3	134.3				
EBL		4-4	135.8				
EBL		4-5	132.9				
EBL		4-8	136.3				
EBL		4-9	134.1				
EBL		4-10	134.7				
EBL		4-11	138.0				

EFFECT OF LABORATORY SIMULATION OF FIELD WORKING TIME

An earlier paper by J. L. Jester, Senior Resident Engineer, Texas Highway Department, (3), indicated that with cement stabilized bases laboratory density values decreased as time from mixing to molding increased. The study concentrated on a testing procedure that simulated a construction operation. With testing times ranging to two and a half hours densities uniformly decreased. The residency lab applied these delays over a four hour period. Dry densities decreased from 143.4 to 137.6 pounds over this period. This tendancy was taken into account in determining the field density requirement. Failure to do this would create a situation where field density would be geared to a totaly irrelevant goal. (Fig. 2)

DENSITIES ON THE FIRST AND SECOND DAYS AFTER MIXING

Field checks to see what happens in the early days of curing gives spotted results. An increase does seem to occur in density after the first day. In six tests where tests were taken on mixing day and the day following,four showed an increase and two a decline in density. Where densities were taken one day after mixing with a followup the next day, six were higher and five lower of eleven. Overall the pattern seems to lean, 10 of 17, higher. As the longer duration gives the high passing percentage the trend is up but apparently not clearly defined in the first or second day.(table 4).

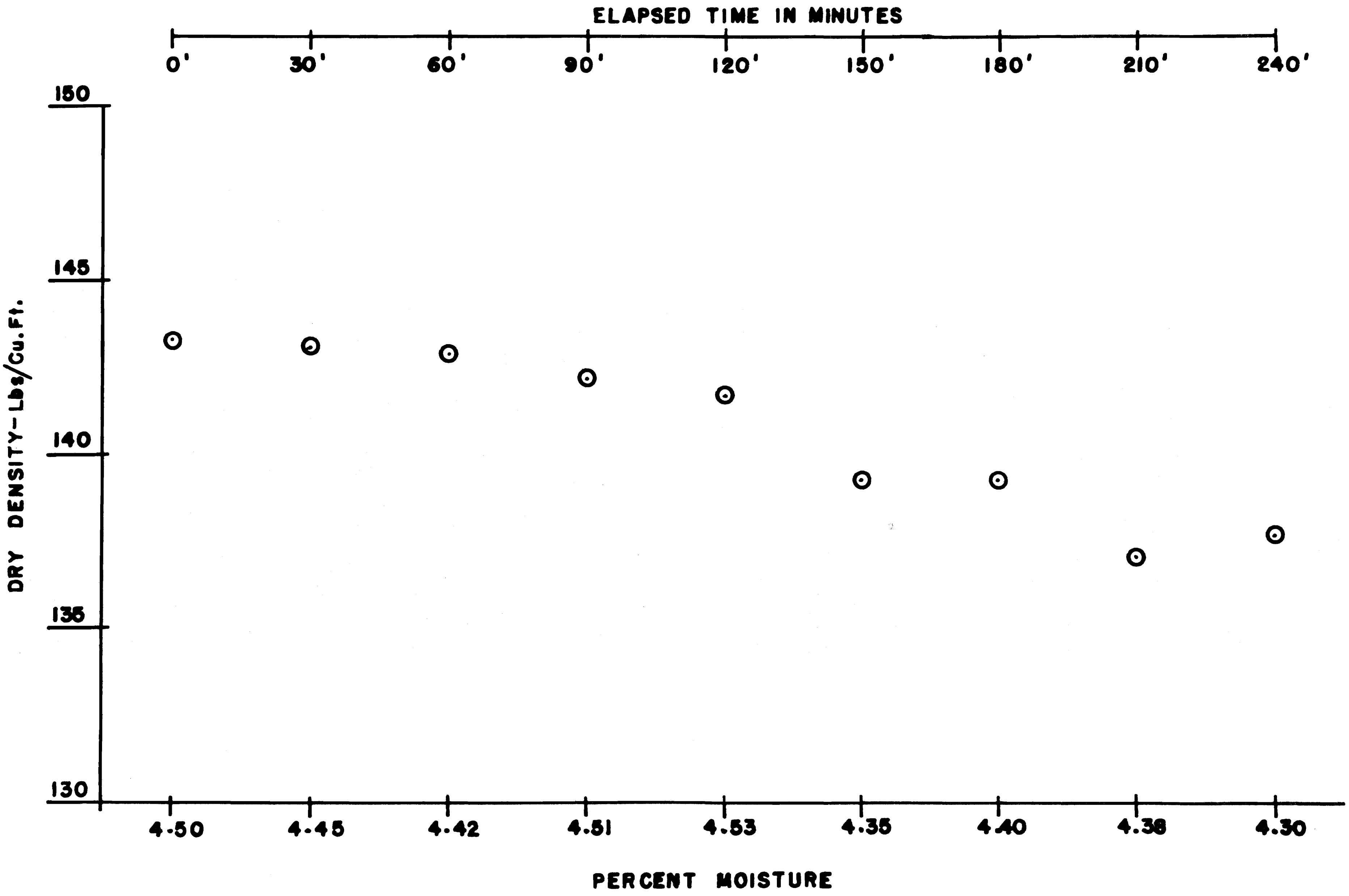

ELAPSED TIME IN MINUTES
0'
30'
60'
90'
120'
150'
180'
210'
240'
150
145
140
135
130
DRY DENSITY-Lbs/Cu.Ft.
4.50
4.45
4.42
4.51
4.53
4.35
4.40
4.38
4.30
PERCENT MOISTURE

FIG. 2

TABLE 4

DENSITIES ON FIRST OR SECOND DAY AFTER MIXING

(in pounds per cubic foot)

LANE	STATION	DATE OF MIXING	REQUIRED DENSITY	FIELD DENSITIES MIX DAY	M+1	M+2
Westbound Main Lane	192	2-8-68	130.8	134.7	135.0	
	202	2-7-68	133.0	135.5	136.1	
	212	2-6-68	131.6		136.2	134.3
	224	2-5-68	130.4		135.5	134.1
	235	2-5-68	130.7		134.7	133.5
	*269	1-31-68	134.8	134.1	134.5	
	280	1-30-68	133.2		137.5	135.7
	342	3-5-68	135.8		140.6	139.6
	355	3-5-68	133.4		137.5	138.7
	377	3-19-68	135.3		136.9	135.6
	*389	3-20-68	136.7		132.7	133.3
Eastbound Main Lane	262	2-26-68	132.2	132.5	131.0	
	273	2-26-68	130.4		129.0	133.9
	285	2-27-68	130.7	133.4	136.0	
	341	3-5-68	137.2		138.8	139.2
	399	3-13-68	134.5		137.9	138.6
	411	3-14-68	135.7	138.8	135.3	

WHY ARE THE RESULTS NOT MORE CONSISTANT?

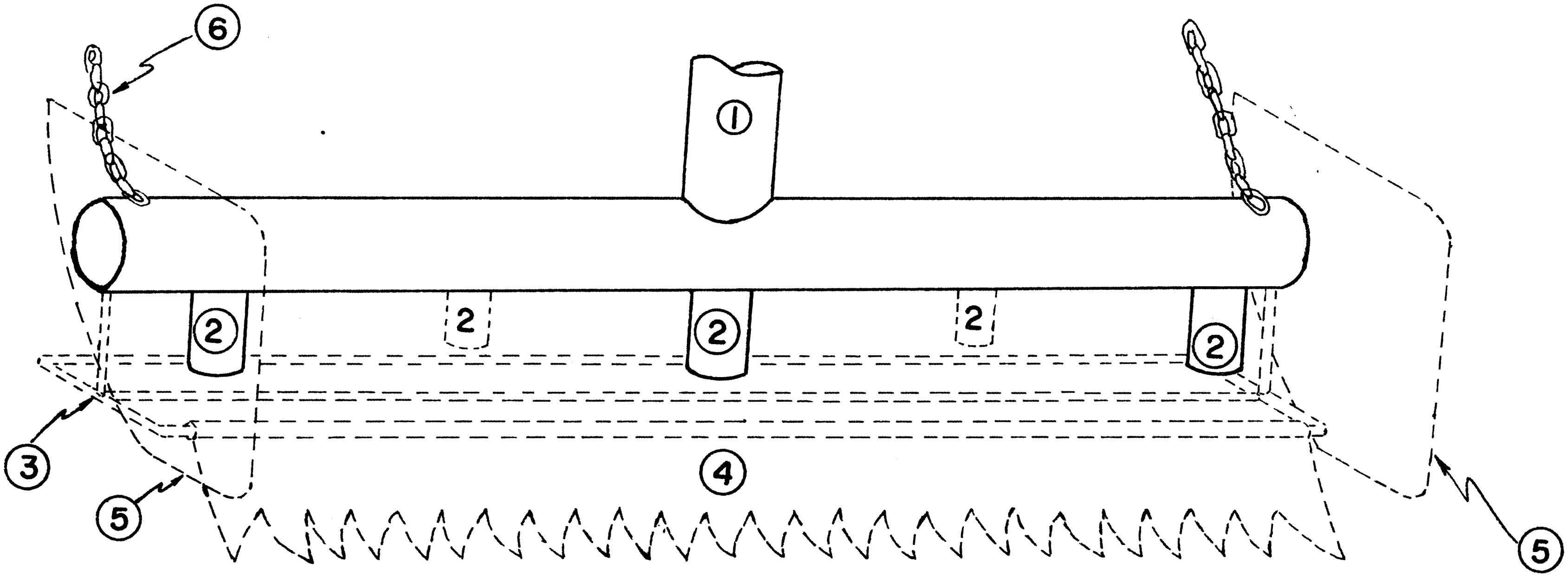
The degree of inconsistancy seems disturbing. After studying our operational patterns with the trade association engineer, and securing considerable revision of construction techniques, the plaguing nonuniformity did not leave use entirely. Visually we observed different shadings of the base, indicating possible variations in the rate of application and mixing of the cement. A simple collection device was developed. Canvas, a yard square, held rigid on the side with poles, collected the cement discharged. Initial testing revealed spreading rates from 11 to 19 pounds per square yard. The second day the range was from 7 to 27. Though the mixer passed over these areas, it seems unlikely that these wide variations could be corrected. Modifications were then made to the spreader bar device that diffused the cement being vacuum pumped from the transport. Initially, the three hole bar increased to five. A deflection bar and side frames were added during the ensuing weeks. (Fig. 3) Variations were minimized by the end of the month (Table 5). Advice and observation at the time seemed to be that an auger spreader would not be effective with the vacuum pump system required by these new type cement transports. How necessary is the uniform admix? According to P. T. Sherwood, the cement must be uniformly distributed to achieve its maximum effect(7). Further discussion and research indicates that keeping a minimum amount of fines is needed to 'float' larger aggregates in a mortar matrix to secure higher strength and durability.(6) (4).

WHY ARE THE RESULTS NOT MORE CONSISTANT?

(Continuation)

This raises a question as to whether 'lower' grade bases with more fines wouldn't be more economical for a cement treated project. This query isn't to be solved here but certainly the case for uniform mixing through a pug mill mixing specification does seem appropriate.

SPREADER BAR
With Improvements



1 Entry Port
2 Exit Port
3 Deflector Bars
4 Spreader Mat (Rubber)
5 End Plates
6 Chain

Key
—— Initial Installation
- - - - Job Modifications

Table 5

CEMENT SPREAD PER SQUARE YARD

DATE	TEST NO.	CEMENT SPREAD IN POUNDS PER SQUARE YARD
3-6	1	17.83
	2	19.19
	3	11.58
3-7	1	18.01
	2	7.63
	3	27.88
	4	18.51
3-7	1	17.62
	2	25.38
3-8	1	21.47
	2	48.45
	3	28.13
3-8	1	22.27
	2	25.25
3-13	1	27.27
	2	19.65
	3	48.65
3-14	1	26.13
	2	31.53
3-14	1	23.30
	2	20.15
	3	28.39

Table 5 cont'd

CEMENT SPREAD PER SQUARE YARD

DATE	TEST NO.	CEMENT SPREAD IN POUNDS PER SQUARE YARD
3-15	1	29.04
	2	21.85
3-15	1	25.10
	2	31.83
	3	23.81
3-18	1	13.25
	2	25.33
	3	13.83
	4	23.83
	5	35.52
3-19	1	24.73
	2	20.87
	3	28.37
	4	23.27
3-20	1	20.84
	2	21.92
	3	24.67
3-21	1	30.47
	2	21.33
	3	26.33
	4	20.35
3-21	1	25.69
	2	21.50
	3	21.22

EXPECTING UNIFORMITY IN NON UNIFORM MATERIALS

A look at the various laboratory determinations of material densities indicates one of the limitations facing this work. For untreated base the densities ranged from 133.3 to 140.5 pounds per cubic foot. Although the material came from two different sources, they were all crushed limestone, meeting similar gradation, binder, wear and binder constant requirements. Both sources are here in Bexar County within three miles of each other, and each actually has remarkable variations from the same source. (Table 6) From the Ackerman pit, material densities ranged from 133.4 to 138.4; from the Olmos pit, 133.3 to 140.5.

With the addition of cement, the variations remain with us, ranging from 133.1 to 141.5. Interesting too, when the cement is added 12 of 19 tests revealed a density decrease.

TABLE 6

RAW MATERIAL

					Density	
Lane	Sta	Sta	Source	Type Base	Untreated	Cement Treated
					(In pounds per cubic foot)	
WBL	250	269	068	A1	133.3	138.75
WBL	229	241	070	A1	140.5	133.4
WFR	307	317	070	A1	140.5	139.5
WBL	297	309	070	A1	140.5	141.4
WBL	286	297	070	A1	140.5	139.7
WBL	274	286	069	A1	136.9	135.9
WBL	262	274	069	A1	136.9	137.5
WBL	250	262	069	A1	136.9	134.8
WBL	243	250	069	A1	136.9	138.7
WBL	218	229	A163	A2	138.4	133.1
WBL	206	218	A163	A2	138.4	134.3
WBL	198	206	A163	A2	138.4	135.7
WBL	186	198	A163	A2	133.4	133.5
EBL	186	198	A163	A2	138.4	138.6
EBL	198	210	A163	A2	138.4	136.0
EBL	210	222	A163	A2	138.4	136.0
Leon Creek U/C	93	101	060	A4	138.9	140.3
WFR	307	317	060	A4	138.9	138.3
EFR	307	317	060	A4	138.9	138.3

NOTE	NUMBER
0 = OLMOS	Refers to Stockpile
A = ACKERMAN	

A LOOK AT THE EFFECT OF TIME REQUIRED TO COMPLETE THE INITIAL WORK AND THE RESULTING DENSITIES.

The time required to finish the mixing and laying operation of the cement and base was viewed in relation to the densities that resulted. Target time set by the specifications was six hours. All involved here were well aware of the need to complete operation with dispatch due to the cement and its hydration action. Unforseen circumstances will occur occasionally on construction work. Seven cases required more than the six hours, and to look at their bright side, they did permit an opportunity to see what might happen to the density. The sample is obviously small. In three cases the final density was less than the first test. Four of the five cases noted,where mixing was completed in less than six hours, showed an increase in density with the passage of time. In view of earlier noted results, the trend is with the passage of time. We may tentatively feel that the six hour limitation provides a desireable safety factor. (Table 7).

Table 7

TIME DENSITY RELATIONSHIP

Lane	Sta	to	Sta	Total Time (Hours)	Field Densities Initial	Field Densities Final
					(In pounds per cubic foot)	
WBL	243		250	5 1/3	133.0	135.1
WBL	250		262	5 7/8	133.8	136.0
WBL	262		274	6	134.1	134.5
WBL	218		229	6	135.5	132.9
WBL	250		269	6	133.8	136.0
WBL	206		218	6 1/2	136.2	134.3
WBL	297		309	6 7/8	137.4	138.5
WBL	286		297	8	136.2	138.1
EBL	198		210	8 1/6	132.9	134.3
EBL	210		222	8 1/2	132.3	
WBL	274		286	8 3/4	137.5	135.7
WBL	229		241	9	134.7	131.8

SUMMARY AND CONCLUSIONS

Primarily, the findings of this report are that a high density can be achieved with cement stabilized base. The higher 98% maximum density is possible and the 95% requirement is attainable with reasonable care on all but atypical sections. These field tests also substantiated prior tests that cement stabilized base will gain density with proper curing and the passage of time. Care needs to be taken in the uniform distribution of the cement with the base. It seems likely here that a premixing operation may be in order. Considerable variations occur in the base material both prior and subsequent to the mixing. Careful correlation between field and laboratory testing and standard setting is of considerable importance.

Secondarily, there does seem to be a need for further field study. Whether additional care in mixing and high density requirements are economically necessary seems worthy of further thought. The observation that more fines as are common in a lower grade base might make for an easier to finish, more durable, stronger base is also a valid consideration. Current studies on other admix materials could provide relevant guidelines with cement stabilization (5). Correlation of construction experience and data, with laboratory testing, and studies of maintenance cost records should lead to further improvement. Hopefully unnecessary requirements will then be removed and where required additional controls be instituted.

SUMMARY AND CONCLUSIONS

(Continuation)

For these developments to materialize,todays problems in communication must be solved. Engineers on construction with governmental agencies, with contractors laboratories, universities, and design operations, as well as with trade organizations must share their information intelligibly and work together. Hopefully increased knowledge and better communications should lead to true economies of construction a most worthy engineering goal.

APPENDIX I - REFERENCES

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APPENDIX II

GRADATION

Type	Grade	Percent Retained					Liquid Limits	Plasticity
		1 3/4	7/8	5/8	#4	#40		
A	1	0	10-35	35-55	45-70	70-85	35	10
A	2	0-10			45-75	60-85	40	12
A	4	0	0		40-75	60-85	45	15

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KEY WORDS

Highways, Admixtures, Cement, Construction, Base, Density Control, Nuclear Testing, Stabilization

TABLE OF ILLUSTRATIONS

SUMMARY

Recent Construction Experiences with Cement Stabilized Base, by Malcolm L. Steinberg, presents data taken on an expressway project in San Antonio, Texas. Results show how high densities are attainable, that the passage of time with proper curing results in higher densities, the importance of mixing time considerations and uniform distribution of the admix are noted. Assistance from trade association engineers was helpful.