Lime-Stabilized Test Sections on Route 51, Perry County, Missouri

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Test sections to study the performance of lime-stabilized bases were constructed by the Missouri State Highway Department maintenance forces on Route 51, Perry County in the late summer of 1952. The existing roadway materials, consisting of about 2 in. of gravel base, 0.5 in. of bituminous surface, and soil subgrade of clays, silty clays, and silty clay loams were mixed with various types of lime additives for a depth of 6 in. This base was surfaced with a 0.5-in. bituminous seal. Lime additives included (a) hydrated lime, (b) quicklime, (c) a combination of hydrated and quicklime, and (d) a waste product of lime manufacture that was composed of approximately 50 percent lime hydrate, 40 percent calcium carbonate, and 10 percent flyash.

On the basis of preliminary laboratory tests the lime spread was determined to be 4.5 percent where hydrated lime was used, 3.4 percent where quicklime was used, 2.25 percent hydrated lime and 1.7 percent quicklime where the combination was used, and 9.0 percent where the waste lime was applied. Tests made immediately after mixing indicated a satisfactory and sometimes startling reduction in plasticity index with all type additives. It was noted, however, that the hydrated lime, whether in combination with quicklime or not, was consistently more effective in improving the roadway materials.

It appears that either hydrated or quicklime, or a combination of the two, will give adequate results when used as a base stabilizing agent under soil and traffic conditions (77 commercial vehicles per day) as found on this route. By the same measurements the results obtained with waste lime are less satisfactory and its use should probably be limited to base stabilization on very lightly traveled roads or to subbase stabilization on the heavier traveled roads.

● TEST SECTIONS to study the performance of lime-stabilized bases were constructed by the Missouri State Highway Department maintenance forces on Route 51, Perry County, in the late summer of 1952. The construction was in two sections.

Section I starts at the junction of Route J, 9.3 miles south of Perryville, and extends north for 5,141 ft. It is comprised of waste lime treated roadway material in the first 2,600 ft and material treated with a combination of quick and hydrated lime in the remaining 2,541 ft.

Section II starts 2.93 miles north of the Route J junction and extends north for 5,280 ft. It consists of hydrated lime treatment in the first 1,300 ft, quicklime in the next 1,300 ft and waste lime in the remaining 2,680 ft.

The roadway materials that were treated with lime consisted of about 2 in. of gravel base, 0.5 in. of bituminous surface, and soil subgrade of clays, silty clays, and silty clay loams. The waste lime used in the treatment was composed of approximately 50 percent lime hydrate, 40 percent calcium carbonate, and 10 percent flyash.

Preliminary laboratory tests established the optimum lime hydrate content for the roadway materials to be 4.5 percent by weight. On this basis the lime spread was determined to be: (a) 4.5 percent where hydrated lime was used, (b) 3.4 percent where quicklime was used, (c) 2.25 percent hydrated lime and 1.7 percent quicklime where the combination was used, and (d) 9.0 percent where the waste lime was applied.

Tests made soon after mixing indicated a very satisfactory and sometimes startling reduction in plasticity index with all type additives. It was noted, however, that the hydrated lime, whether or not in combination with quicklime, was consistently more

TABLE 1

ROUTE 51, PERRY COUNTY, LIME STABILIZED SECTIONS

Location	Type of Lime	Date	Passing No. 4 %	Passing No. 200 %	Liquid Limit	Plastic Limit	Plastic Index	Group Classification	Group Index	Optimum Moisture %	Maximum Density lb	Moisture in Sample %	Density lb	% Compaction
Section I - Starts at Route J and Extends North for 5,141 ft														
Station	None	1952	81.8	50.8	37.5	16.0	21.5	A-6	7	11.1	119.5	-	-	-
1 + 00	Waste	1952	73.6	29 5	31.2	30 4	0.8	A-2-4	0	12.9	113.1	8.3	116.8	103.2
	Waste	1953	63.2	32 7	33.2	33.2	0.0	A-2-4	0	12 2	115 9	6 7	-	-
	Waste	1957	-	-	34.5	31.1	3.4	-	-	-	-	9.6	-	-
Station	None	1952	91.4	77 5	38.1	20.2	17.9	A-6	11	14.2	113.0	-	-	-
11 + 00	Waste	1952	86 0	50.6	31.5	26.8	4.7	A-4	3	14.9	110.3	6.9	110.5	100.2
	Waste	1953	88.9	69 6	31.4	21.8	9.6	A-4	7	14.6	112.6	8.2	113 0	100 4
	Waste	1957	-	-	33.5	23.9	9.6	-	-	-	-	12.5	-	-
Station	None	1952	70.7	25.7	24.9	16.9	8.0	A-2-4	0	7.2	129.7	-	-	-
24 + 00	Waste	1952	65.5	20.2	23.5	27.3	0.0	A-1-b	0	7 8	126.7	8.2	129.2	102.4
	Waste	1953	60.9	18.9	-	-	N. P.	A-1-b	0	10 1	119 8	4.1	-	-
	Waste	1957	-	-	27 7	27.0	0.7	-	-	-	-	8.6	-	-
Station	None	1952	76.6	49.7	38 2	16.2	22.0	A-6	7	12.1	118.8	-	-	-
33 + 00	Hyd Quick	1952	75.9	23.4	32.5	33.9	0.0	A-2-4	0	13.4	114.7	11.6	117.9	102.8
	Hyd Quick	1953	65.5	31.0	33.9	35.0	0.0	A-2-4	0	12 8	115 1	8.5	-	-
	Hyd. Quick	1957	-	-	-	-	N. P.	-	-	-	-	10.4	-	-
Station	None	1952	78.6	49.6	34 2	17.0	17.2	A-6	5	11.1	121 5	-	-	-
39 + 00	Hyd. Quick	1952	80.4	38.2	32.5	31.0	1 5	A-4	1	13.0	115.1	10.0	115.7	100.5
	Hyd Quick	1953	72.5	32.8	33 7	32.6	1.1	A-2-4	0	12 8	115.2	6.7	107.0	92.9
	Hyd. Quick	1957	-	-	34 8	30.8	4.0	-	-	-	-	13.1	-	-
Station	None	1952	68.1	25.3	25 9	18.4	7.5	A-2-4	0	7.5	128.4	-	-	-
42 + 00[a]	Hyd. Quick	1952	71.7	23 3	28.9	30.4	0 0	A-2-4	0	9 8	119.6	8.0	120.0	100.3
	Hyd. Quick	1953	66.7	22.4	30 4	29.6	0.8	A-2-4	0	10 9	118.8	5.4	-	-
Section II - Starts 2.93 Miles North of Route J and Extends North for 5,280 ft														
Station	None	1952	86.4	69.8	34.0	18.2	15.8	A-6	9	13.1	114.9	-	-	-
4 + 00	Hydrated	1952	85.7	39.7	32 3	33.0	0.0	A-4	1	16.3	107.4	13.9	108.8	101.3
	Hydrated	1953	82 9	50.0	37.5	33.8	3 7	A-4	3	16 8	107.3	13.5	107.5	100.2
	Hydrated	1957	-	-	38.2	30.8	7.4	-	-	-	-	14.1	-	-
Station	None	1952	85.0	70.6	34.1	18.2	15.9	A-6	9	11 9	117 2	-	-	-
22 + 00	Quick	1952	89.0	55 0	32.1	27.5	4 6	A-4	4	15.5	110.9	14.3	114.0	102.8
	Quick	1953	87.8	60 4	34 3	29.8	4.5	A-4	5	15.7	109 4	10 8	110.8	101.3
	Quick	1957	-	-	34.1	26.9	7.2	-	-	-	-	11.0	-	-
Station	None	1952	93.8	78.1	31 7	20.8	10 9	A-6	8	14.4	112.2	-	-	-
32 + 00	Waste	1952	87.1	59.5	33.5	28.1	5 4	A-4	5	15.1	110.9	16.2	107.2	96.7
	Waste	1953	81.0	58.3	33 5	26.9	6 6	A-4	5	13.3	112.6	9.5	109.6	97.3
	Waste	1957	-	-	34.0	24.2	9.8	-	-	-	-	11.8	-	-
Station	None	1952	-	-	-	-	-	-	-	-		Not Sampled		
40 + 00	Waste	1952	77.1	40.2	32.8	27.4	5.4	A-4	1	10.8	118.3	12.9	111.6	94.3
	Waste	1953	70.6	31.7	33 8	30.4	3 4	A-2-4	0	11.2	116.7	9.9	-	-
	Waste	1957	-	-	33.4	31.9	1.5	-	-	-	-	11.1	-	-

[a] Not sampled in 1957 because material had changed from a modified soil, so to speak, to a structural material showing much hardness. The stabilized material from all locations has hardened (by 1957) to the extent that it will not completely break down when soaked in water. Because of this, it was thought that the mechanical analysis and compaction tests would be of no significance.

effective in improving the roadway materials.

The specified depth of treatment in all instances was 6 in. The thickness determinations made in the completed base at the center and 1 ft from edge at intervals of 300 to 400 ft showed Section I to average 6.2 in. and Section II, 5.9 in. In general, the determination made 1 ft from edge showed less than 6 in. and out of the 52 edge measurements in both sections, 21 measured 5.25 in. or less. In Section I the center averaged 7.2 in., the right edge 5.6 in., and the left edge 5.8 in. In Section II the center averaged 6.3 in., the right edge 5.6 in., and the left edge 5.7 in.

The above measurements indicate that depth of treatment was not too well controlled. These variations in depth can be attributed to the fact that equipment, such as flat bottomed plows, was not available for use in depth control. Motor graders were used for this control, as well as being used to do practically all of the mixing.

Water application was slow and inadequate, especially in Section I, due to a shortage of water distributors.

This was the construction personnel's first stabilization job and their inexperience was reflected in the quality of the work. As the job progressed, however, the quality improved.

All of these factors, which can probably be condensed into two general headings, (1) inexperience of construction personnel, and (2) shortage of equipment, have been reflected to a large extent in the performance of these stabilized sections.

This report describes the condition of the lime sections as they now exist and offers conclusions that have been reached after a 4½-year test period. Also included with

with the report is a table of test results of samples obtained from the stabilized base in 1952, 1953, and 1957. The only tests made on samples obtained the spring of 1957 were for plasticity and moisture. The stabilized material has hardened to the extent that it will not completely break down when soaked in water, so it was thought that mechanical analysis and compaction tests would not be of any significance.

ROAD CONDITION

Waste Lime—Station 0 to 26, Section I

The appearance of this portion is classed as "fair" to "poor." About 12 percent of the total area is showing distress in the form of alligator cracks. This includes about 3 or 4 percent of badly cracked area that is confined to the outer 1 to 2 ft for one-fourth of the length. A large part of this edge distress can probably be attributed to thin base. Approximately 600 sq ft (1. 2 percent) of complete failure has occurred. Maintenance has consisted of applying light seal in addition to the original seal and placing patches in the failed areas and several other small areas where surface blemish has occurred.

The base does not have much hardness (it could not be cored) but appears dry and flaky. The plastic index of the base shows an increase from 0. 8 to 3. 4 at one location since the fall of 1952 to the spring of 1957, an increase from non-plastic to 0. 7 at another location, and an increase from 4. 7 to 9. 6 at the third location. The moisture content of the base is higher than that found at any time before but is still 1. 5 to 2. 6 points below the optimum moisture as determined from samples obtained in 1953. This higher moisture was anticipated since this is the first time samples were taken in

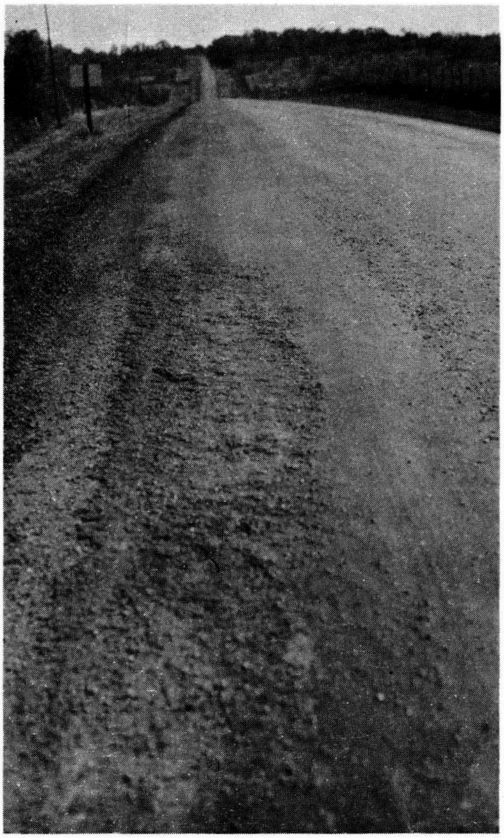

Figure 1. Waste lime, Section I, general view.

Figure 2. Waste lime, Section I, distortion in outer wheel track.

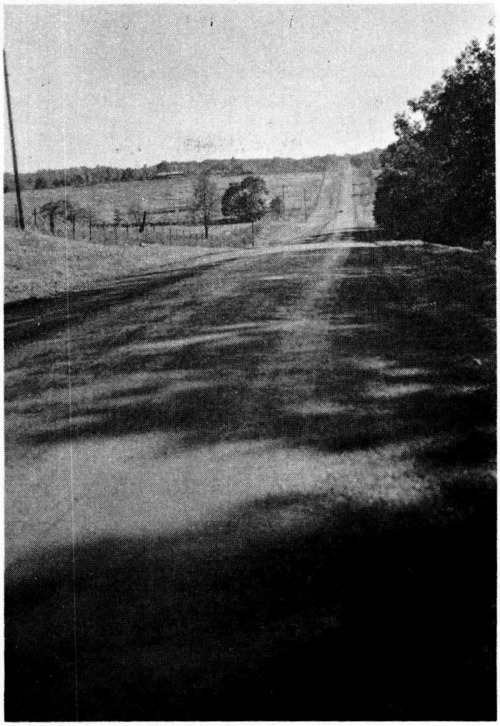

Figure 3. Hydrated-quicklime, Section I, general view.

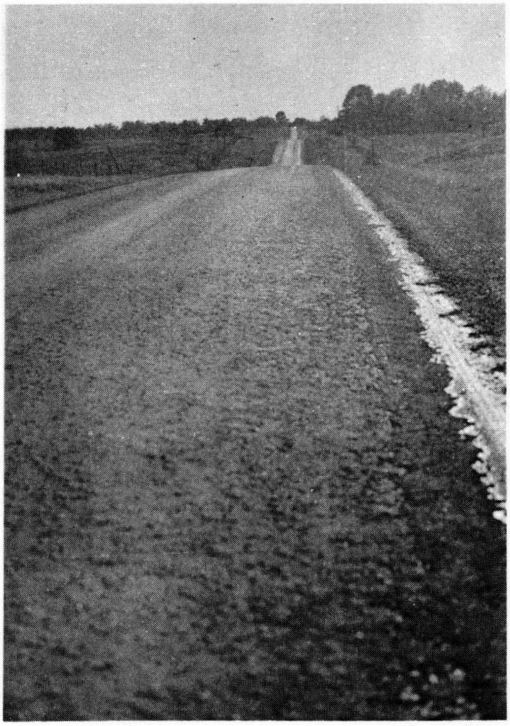

Figure 4. Hydrated lime, Section II, general view.

the spring instead of late summer or fall when the other sampling was done.

This section of waste lime is fairly smooth and is still giving good service, however, it is classed as the poorest of all the stabilized sections. One reason for this is that it was the first built and many construction inadequacies, such as poor edge and depth control, insufficient water in mix, existed because of inexperience of the personnel and shortage of water distributors and mixing equipment.

Hydrated-Quicklime—Station 26 to 51 + 41, Section I

The appearance of this section is classed as "fair" to "good." About 450 sq ft (0.9 percent) of the area is showing distress in the outer 4 ft while another 5 percent of the surface area shows distress in the outer 1 to 2 ft (thin base at the edges is again probably the main factor). A regular shrinkage crack pattern (blocks of about 4 to 6 ft square) occurs throughout this section, the only section showing such pattern. Maintenance has consisted of resealing the section and patching some small areas to correct surface blemishes.

This base is definitely the hardest of all and shows much structural strength. Core drilling was attempted at four locations and cores were obtained at three. Because of the imperfection of the cores, no attempt was made to break them in compression, but after several weeks of soaking these cores remained virtually intact and apparently just as hard as before soaking. At one location the plasticity of the base remained the same, non-plastic, while at another location it increased from 1.5 to 4.0. Moisture in the base at one location was 2.4 points below optimum, at another it was 0.3 points above. (Part of the distress occurring in this section can also be attributed to construction inadequacies.)

Hydrated Lime—Station 0 to 13, Section II

This hydrated lime section is in excellent condition. There are a few minor blemishes in the seal coat. Two small areas of about 16 sq ft each have been patched and a 1- by 25-ft edge patch has been placed. Other maintenance has consisted of a light drag seal.

The base is fairly hard but two attempts at core drilling were unsuccessful. At the location sampled the moisture content was 2.7 points below optimum and the plastic index has increased from 0.0 to 7.4 in the period from 1952 to 1957.

This section has performed the best of all the lime stabilized sections.

Quicklime—Station 13 to 26, Section II

Appearance of this section is rated "good" to "excellent." One area covering 90 sq ft (0.4 percent of total area) has failed and has been patched. Approximately another 1 percent of the area is showing slight distress in the outer 4 ft. There is also a slight amount of edge ravelling and some minor surface blemishes. A light drag seal has been placed by maintenance.

The base is hard but not sufficiently so to permit obtaining a core. It is dry, being 4.7 points below optimum moisture content, and its plasticity index has increased from 4.6 to 7.2 during the 1952 to 1957 period.

Waste Lime—Station 26 to 52 + 80, Section II

The appearance is rated "good." About 600 sq ft (1.1 percent) is showing distress in outer 4 ft. About another 2 percent of the surface area is showing distress in the outer 1 ft along the edges. Much of this distress can be attributed to thin base at the edges. A light drag seal has been placed on the section since the original.

This base shows little hardness and could not be core drilled. At one location the moisture is 1.5 points below optimum while at another location it is practically at op-

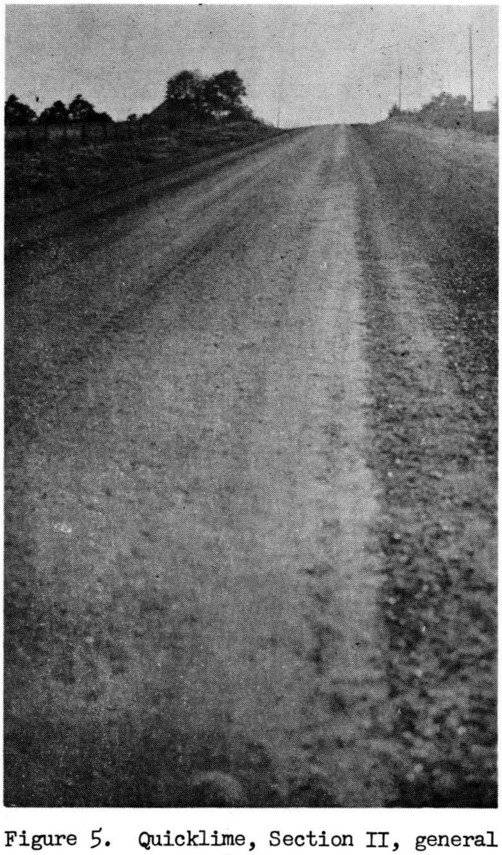

Figure 5. Quicklime, Section II, general view.

Figure 6. Quicklime, Section II, distortion in outer wheel track.

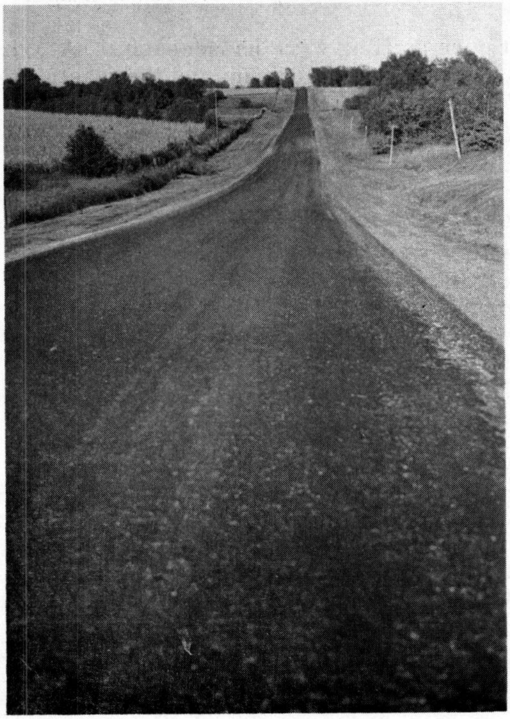

Figure 7. Waste lime, Section II, general view.

Figure 8. Waste lime, Section II, edge distress.

timum. At one location the PI of the base has increased from 5.4 to 9.8 since 1952, while at the other location a decrease from 5.4 to 1.5 was noted.

Blank Section

The 1.95 mile gap between the lime stabilization sections of Route 51 is similar to the lime sections in topographic, drainage, soil, and traffic conditions. In November of 1952 this section was in good to excellent condition because of recent conditioning by the maintenance division. At that time the pavement consisted of an average thickness of 2.13 in. of gravel base topped with an average thickness of 0.95 in. of bituminous surface. This section has required much maintenance since 1952. There have been several resealings and numerous small patches. The surface in April 1957 was very rough and showed much distress in the form of cracked and distorted areas.

SUMMARY AND CONCLUSIONS

Based on appearances, the sections are rated in order as to the service given during this 4½-year test period.

1. Hydrated lime—Station 0 to 13, Section II.
2. Quicklime—Station 13 to 26, Section II.
3. Waste lime—Station 26 to 52 + 80, Section II.
4. Hydrated-quicklime—Station 26 to 51 + 41, Section I.
5. Waste lime—Station 0 to 26, Section I.

It will be noted that Section II, as a whole, has performed the most satisfactorily. Factors that could enter into this performance, other than the type of lime used, are (1) drainage, (2) subgrade support, (3) the type of material processed, and (4) construction features.

As far as the first three factors are concerned they do not appear to have affected performance to any great extent. Drainage is perhaps slightly better in Section I; generally, subgrade support is better in Section II but there are some parts of Section I showing much distress that have similar subgrade; in general more clay is found in Section I and this type of material apparently reacts more favorably with lime.

The remaining factor, construction features, therefore, appears to be the most important. Section I was the first constructed and there were more construction inadequacies because of the inexperience of all personnel involved and a shortage of equipment. In this section mixing was not as thorough, the edges were not as well defined, the depth of processing was more variable, and less moisture was introduced into the mix. It is believed that Section II is better than Section I, as a whole, mainly because of better construction procedure.

The hardness of the base is rated in the following order: (1) hydrated lime-quicklime—Station 26 to 51 + 41, Section I; (2) quicklime—Station 13 to 26, Section II; (3) hydrated lime—Station 0 to 13, Section II; (4) waste lime—Station 26 to 52 + 80, Section II; and (5) waste lime—Station 0 to 26, Section I.

Actually the base in the hydrated lime-quicklime section is the only portion that shows hardness as expected. The waste product has definitely shown the least hardness while the quicklime appears to show slightly more hardness when used alone than does the hydrated lime.

Why so much more hardness in the section where a combination of quick and hydrated lime was used? This section contains more clay as a whole and it appears that clay reacts more completely and satisfactorily with lime. However, there are some areas within this section that are no more clayey than the material processed in Section II but they still show much hardness. For instance at Station 42, Section I the raw soil sample before lime was added had a PI of 7. 5. This base is hard enough to make a pick ring now and the core obtained at this location remained hard and intact after several weeks of soaking.

Apparently the combination of hydrated and quicklime causes some reaction that produces greater hardness than do the other types of limes used on this project. The next hardest is the quicklime section. Since quicklime is involved in both instances, there is the possibility that the heat generated by the quicklime hastens and carries to further completion the reaction of the lime with the silica in the soil to form insoluble calcium silicate.

The tests of samples show the moisture content of the base to be higher than it was four years ago. This increase is greater in Section I which might account to some extent for the poorer performance of this section. However, in all instances except one, the moisture content of the base is below the optimum moisture as determined on samples obtained in 1953. In this one instance the moisture content is only 0. 3 points above the optimum. In Section I, the moisture content of the base averages 1. 7 points below optimum while in Section II it averages 2. 3 points below. It is believed though that much significance should not be placed on these observations since the slight differences could well be attributed to variations in the material.

In general, the plastic index of the base has increased since construction in 1952.

Station 1 + 00, Section I—PI reduced from 21. 5 to 0. 8 in 1952 which is 3. 7 percent of original PI of soil. At present the PI is 3. 4 or 15. 8 percent of that of the original soil.

Station 11 + 00, Section I—PI reduced to 26. 2 percent of original in 1952, now is 53. 7 percent of original PI.

Station 24 + 00, Section I—Reduced to 0 percent of original in 1952, now is 8. 8 percent of original.

Station 33 + 00, Section I—No change.

Station 39 + 00, Section I—8. 7 percent of original in 1952, at present it is 23. 3 percent.

Station 4 + 00, Section II—Was 0 percent in 1952, at present it is 46. 8 percent.

Station 22 + 00, Section II—Has increased from 28. 9 percent in 1952 to 45. 3 percent in 1957.

Station 32 + 00, Section II—PI showed 49. 6 percent of original in 1952, now shows 90 percent.

Station 40 + 00, Section II—No sample obtained before processing with lime. However, the lime base at this location is the only one showing a decrease in PI. It has decreased from 5.4 to 1.5 during the 4½-year period.

The average daily traffic count on the lime sections as well as the intervening gap is 454 vehicles of which approximately 77 are trucks and busses. In these conditions the 6-in. lime stabilized base has given better service than the intervening gap that consists of 2.13 in. of gravel topped with 0.95 in. of bituminous surfacing. This comparison does not have much significance, however, since the lime sections are twice as thick as that in the intervening section.

A large part of the distress occurring in the lime sections is along the edges where thin base is found. This is especially true in the waste lime sections where a combination of thin base and inadequate hardness is found.

It is believed that it can be definitely concluded that either hydrated or quicklime or a combination of the two is superior to the waste lime product in the quantities used on this project. The quantity of waste lime used was approximately twice the amount of hydrated or quicklime.

It appears that either hydrated or quicklime or a combination of the two will give satisfactory results when used as a base stabilizing agent, in soil and traffic conditions as found on this section of Route 51. This is with the provision that the depth of treatment is adequately controlled and the soil and lime are properly mixed, moistened, and compacted. It is believed, however, that still more satisfactory results would be obtained if a minimum thickness of 2 in. of bituminous surface were used instead of a thin seal coat.

Soil modified by the waste lime should be excellent for use as a subbase and possibly as a base under a 2-in. bituminous surface on lightly (less than 50 commercial vehicles) traveled roads.

There are some rather definite indications that the amount of reduction in plasticity gained immediately after mixing is not permanent. Whether or not the material will regain all the plasticity it possessed before stabilizing remains to be seen. Therefore, it appears that more sampling and testing of the experimental sections is desirable. By further sampling and testing it may be found that the changes in plastic index can be ascribed to sampling since the roadway materials on this project vary to some extent transversely as well as longitudinally.