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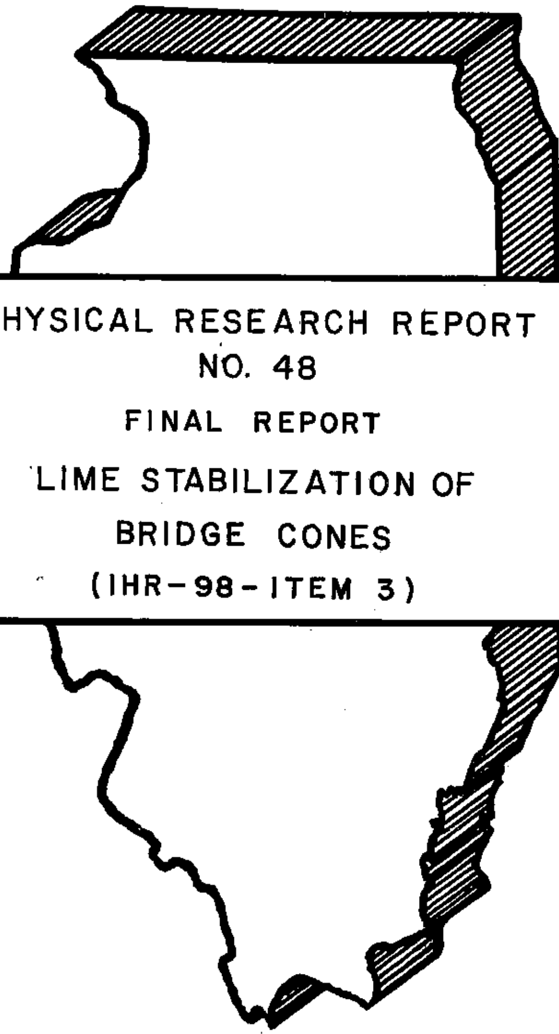

PHYSICAL RESEARCH REPORT NO. 48

FINAL REPORT

LIME STABILIZATION OF BRIDGE CONES

(IHR-98-ITEM 3)

SPRINGFIELD, ILLINOIS 62764

MAY 1973

State of Illinois
DEPARTMENT OF TRANSPORTATION
Bureau of Materials and Physical Research

FINAL REPORT ON LIME STABILIZATION OF BRIDGE CONES

IHR-98 - Item 3

By

R. K. Taylor

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16. Abstract

The addition of lime to the fill material used to construct bridge embankments was conceived as a possible solution to the problem of bridge approach settlements. The use of lime was proposed as a means of minimizing uneven settlement within the embankment and to more uniformly distribute the load to the underlying subsoil.

In addition to the lime stabilization of bridge cones, this study includes an investigation of the use of longer approach slabs to increase the settlement transitioning length and reduce the effect of the settlement on the riding quality of the approaches.

This report is a final report on the project and presents a summary of all data compiled during the study with emphasis on the data which were collected since publication of the second interim report.

The study has not provided conclusive evidence that the stabilization of bridge embankments with lime is an effective solution to the problem of approach slab settlement. The experience gained from the study, however, has indicated that the cost of constructing lime stabilized bridge cones is exceedingly high, and more economical solutions to the problem should be sought.

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Form DOT F 1700.7 (8-69)

TABLE OF CONTENTS

LIST OF FIGURES

LIME STABILIZATION OF BRIDGE CONES

INTRODUCTION

The settlement of bridge approach pavements has long been recognized as a problem of major importance by bridge design engineers. The bump resulting from this settlement often creates an unpleasant and sometimes unsafe driving condition which has drawn wide criticism from the traveling public. Many possible solutions to the problem have been proposed and tried but none have been entirely successful in correcting the situation.

Although the type of abutment and the methods and materials used to backfill behind the abutment may infrequently contribute to the settlement problem, in the majority of cases, the primary cause of the irregular bridge approach surface can be directly attributed to the settlement of the earth embankments immediately adjacent to the bridge. The degree of compaction and the type of fill material used to construct the embankment has an effect on the amount of settlement occurring within the embankment proper. Although some settlement may take place even within a properly compacted embankment constructed with suitable fill material, most of the settlement is believed to occur within the natural soils underlying the fill.

The use of lime treated fill material for constructing bridge embankments was considered as a possible solution to the problem of approach pavement settlement. Lime has frequently been added to roadway embankment material to increase the strength of the fill supporting the roadway. The addition of lime to bridge embankments to achieve a similar strength gain was proposed as a possible means of minimizing uneven settlements within the embankment and to more uniformly distribute the loads to the underlying subsoil.

In addition to the lime stabilization of bridge cones, this study includes an investigation of the use of longer approach slabs to increase the settlement transitioning length and reduce the effect of the settlement on the riding quality of the approaches.

Two bridge construction sections within the Chicago area were selected for incorporating the research features (Figure 1). The first trial installation was included in the construction of dual bridges carrying the northbound and southbound lanes of the First Avenue Expressway over 47th Street. The bridge site, identified as U-383(31), FA 133, Section 0102-683 HBK, Cook County, is referred to in this report as the First Avenue project.

The second experimental installation is located at the construction site of twin structures carrying Interstate 90 over Higgins Road. This site herein referred to as the Higgins Road project is identified as Project I-90-3(76)72, Interstate 90, Section 0404-31 HBK, Cook County. The location of both test sites is shown in Figure 1.

This report is the final report of the project. The first interim report (Illinois Research and Development Report 25, March 1970) described the details of construction of the First Avenue project and presented the preliminary settlement data obtained during the construction period. The second interim report (Illinois Research and Development Report 42, June 1972) presented additional settlement data compiled at the First Avenue site, described the construction and instrumentation of the Higgins Road project, and presented initial settlement measurements made during the construction of the Higgins Road project. This report presents a summary of all data compiled during the study with emphasis on the data which was collected since publication of the second interim report.

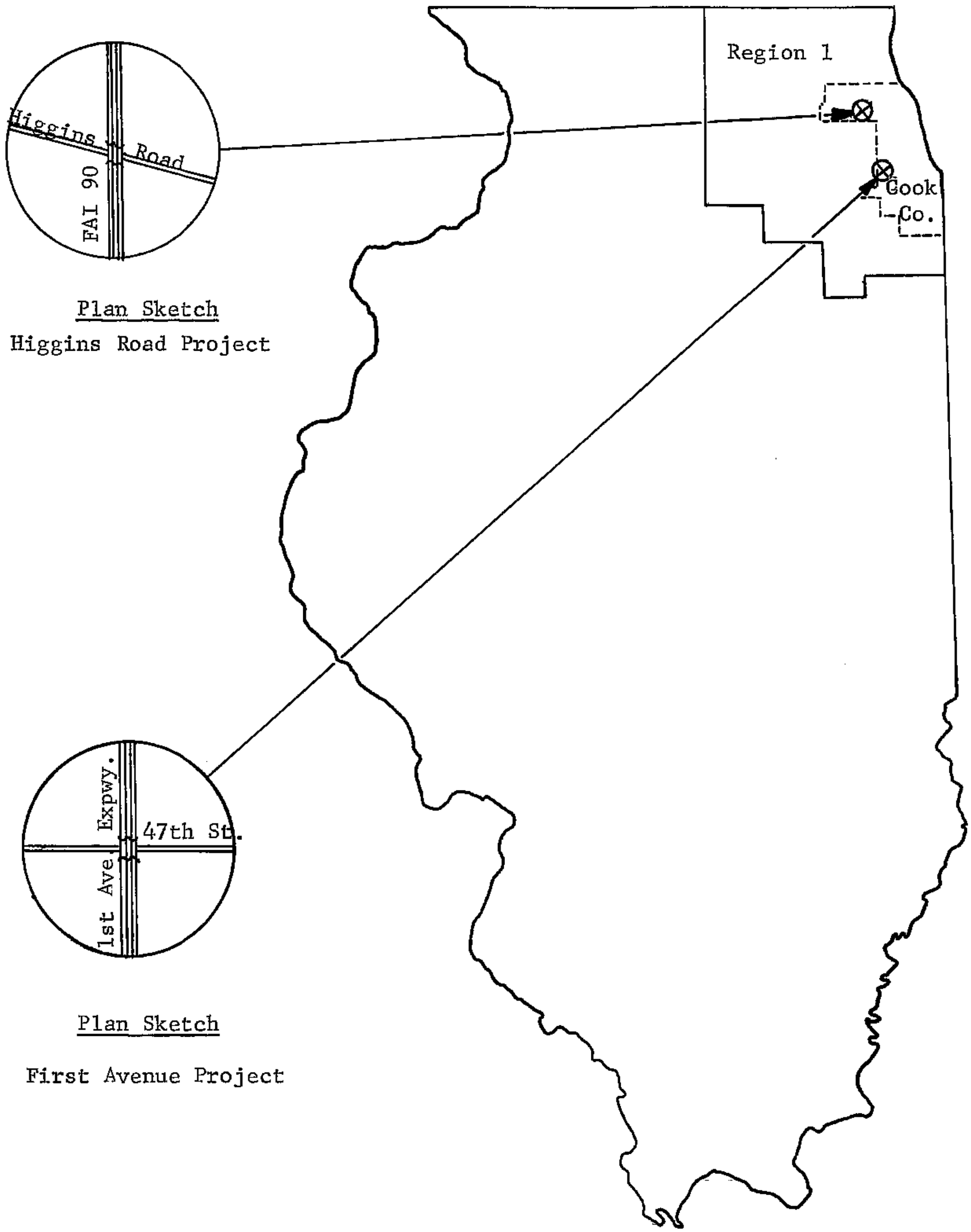


Figure 1. Location of experimental lime stabilized embankments.

RESEARCH OBJECTIVES

The primary objective of this investigation is to evaluate the effect of lime stabilizing bridge embankments for reducing the settlement of bridge approach pavements. Settlement occurring beneath and within the embankments during and after construction was measured and analyzed. Periodic measurements of the vertical movements of the approach slabs also were made to determine the total effect of the lime treatment for improving the riding quality of the approaches.

The secondary objective of the study is to investigate the feasibility of using longer approach slabs to reduce the effect of differential settlement by increasing the settlement transitioning length. At First Avenue, 40-ft approach slabs were constructed at the south embankments and compared with conventional 20-ft approach slabs at the north embankments.

EMBANKMENT CONSTRUCTION

The procedures used for the construction of the embankments at both the First Avenue and the Higgins Road projects are similar except for certain notable exceptions. A detailed description of the difference in procedures at the two sites was presented in the second interim report and is partially repeated herein as a matter of interest.

At both test sites it was originally planned to treat both of the south embankments of the dual structures with lime, and construct both of the north cones by conventional methods to serve as a control. The stabilized portion of each south embankment at both sites was to be bounded by a vertical line at the back of the abutment and by a 1:1 slope extending down from each shoulder line and a line 60 feet from and parallel to the back of the abutment.

This plan was altered at the First Avenue project because the original estimate of water for the lime stabilized embankment had been low and the unit bid price for water was unrealistically high. For this reason only the southeast cone was stabilized with lime.

On the Higgins Road project, both south cones were treated with lime; however, the original limits for the stabilized portion of the embankments were changed. Early in the project the contractor requested and received permission to extend the lime treatment to the entire embankment area between the roadway rather than stabilize each roadway embankment independently from each shoulder to natural ground at a 1:1 slope.

At the First Avenue project the embankments were constructed to their final elevation, and excavation of the completed cone was required before constructing the abutments. This procedure was not used at the Higgins Road project since the contractor elected to build the embankment up to the level of the bottom of the abutments, and then construct the abutments before completing the embankments. The lime stabilized soil was then pulverized and compacted by manual effort at the back of the abutment.

The stabilized embankments at the First Avenue site were constructed in lifts approximately six inches thick while at Higgins Road the thickness of each lift was about one foot. Phenolphthalein tests conducted in the field at Higgins Road indicated that good distribution of the lime was achieved in the one-foot lifts.

At the First Avenue project timber approach piles were used at both the stabilized and unstabilized embankments. The rate of pile precoring through the stabilized material was substantially slower than through the untreated embankment. At the Higgins Road site approach piles were used at the untreated embankment but not at the stabilized embankment since the fill height and the subsoil properties indicated that no approach pile cap was necessary.

APPROACH SLAB CONSTRUCTION

The First Avenue installation included an evaluation of 40-ft long approach slabs in comparison with the conventional 20-ft approach slabs (Figure 2). The use of the longer approach slabs was based on the premise that the additional length would provide a longer settlement transition length, and reduce the effect of the settlement on the riding quality of the bridge approach.

At both south embankments, including the stabilized southeast cone, a 40-ft transition slab was constructed between the 20-ft approach slab and the pavement. At the north embankments a standard 20-ft transition slab was used between the 20-ft approach slab and the pavement. At both the north and south locations, the adjoining ends of the approach and transition slabs were supported by a pile cap located 20-ft from the back of the abutment.

The approach slabs on the south stabilized embankments at Higgins Road were constructed as conventional 20-ft slabs between the bridges and the pavements (Figure 3). No pile caps were used to support the adjoining ends of the approach slabs and pavements. The slabs were constructed on a 16° skew at the back of the abutments and at right angles to the centerline of the roadway at the end of the slab adjoining the pavement. Therefore, the length of the short side of the slabs is 20 ft, and the length of the long side is about 30 ft. The roadways at this location consist of three 12-ft lanes for a total roadway width of 36 ft.

The approach slabs on the north unstabilized embankments consist of a conventional 20-ft slab adjacent to the bridge and a 20-ft transition slab between the approach slab and the pavement (Figure 3). The adjoining ends of the approach slabs and the transition slabs are supported by pile caps. The transition slabs were constructed on a 16° skew at the pile caps and at right angles to the centerline of the pavements at the ends adjoining the pavements.

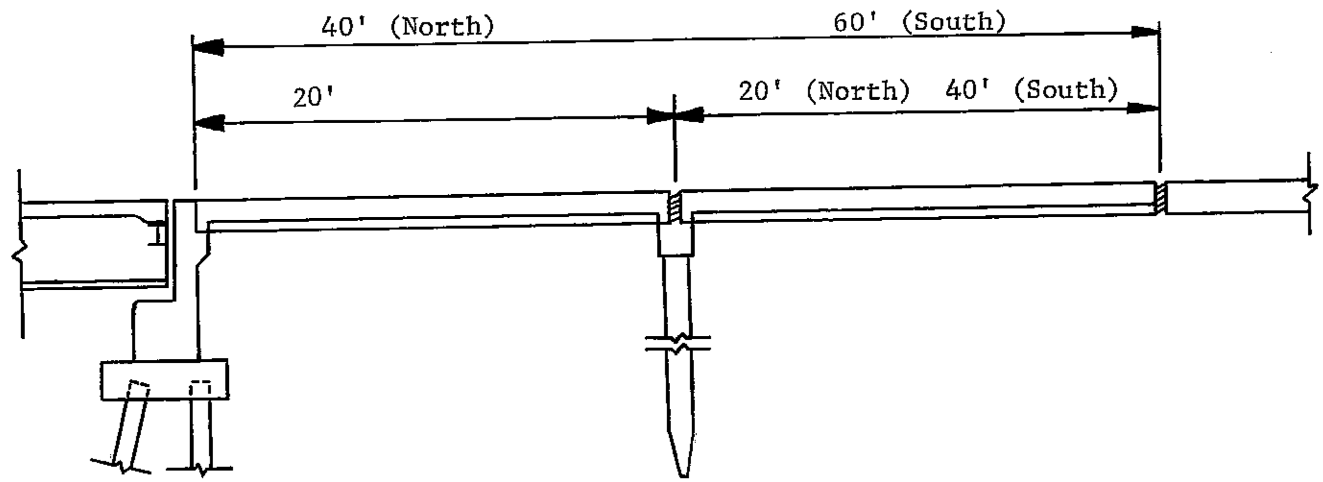


Figure 2. Section through approach slabs at First Avenue.

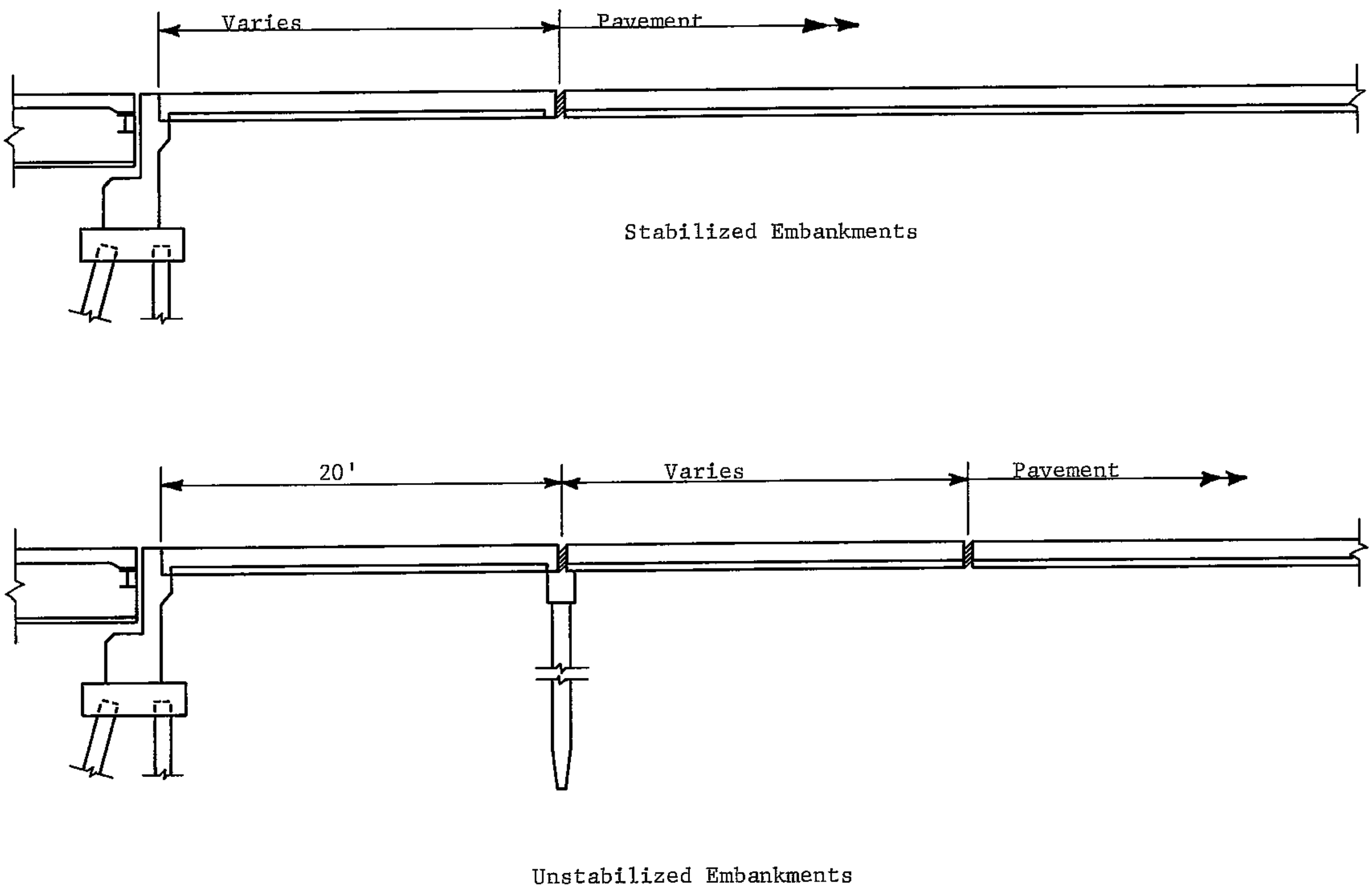


Figure 3. Section through approach slabs at Higgins Road.

LABORATORY ANALYSIS

As described in detail in the two interim reports, laboratory analysis of the subsoils underlying the embankments at both test sites indicate that the amount of settlement occurring beneath the bridge cones should theoretically be small. At the First Avenue site, most of the settlement was expected to occur within the upper 5-6 ft of clay. Beneath this level the soil consisted of a hard impervious clay which would settle little or none under the load of the embankment.

At the Higgins Road project consolidation tests conducted on samples of the subsoil underlying the embankments indicated that the soil consisted of clay which had been preloaded sometime in the past. The preloaded condition, which is thought to be due to desiccation of the clay layer, would result in small settlements of the subsoils under the load imposed by the earth embankments.

Because the settlements, which theoretically would occur beneath the embankments at both sites, are small, the effect of the lime stabilization on reducing the settlement of the subsoils cannot be accurately evaluated. However, an evaluation of the value of lime in reducing settlement within the embankment proper can still be accomplished.

INSTRUMENTATION

A detailed description of the instrumentation used to measure the embankment settlement was presented in the two interim reports; therefore, the instrumentation is described only briefly in this report.

At both test sites the bridge cones of the northbound lanes were instrumented with settlement platforms beneath the embankments and with smaller settlement plates on top of the embankments. The stabilized southeast cones were instrumented to determine the effect of the lime treatment in reducing embankment settlement.

The unstabilized northeast embankments were instrumented in a similar manner to serve as controls.

Prior to constructing the embankments at both sites, settlement platforms were seated on top of the natural ground at locations of 20, 40, and 60 ft from the back of the abutments. A fourth platform was seated in a pit dug to an elevation approximately 5 ft below natural ground. At the First Avenue site the fourth platform was located 30 ft from the back of the abutments while at Higgins Road the fourth platform was located 35 ft from the back of the abutments.

At First Avenue the four platforms were located beneath the east shoulder of the northbound lanes on a line parallel to and 3 ft from the edge of the pavement. The four platforms at Higgins Road were located beneath the west shoulder of the northbound lanes on a line parallel to and 3 ft from the edge of the pavement. At the Higgins Road site two additional platforms were installed on top of natural ground beneath the south stabilized embankments. One platform was installed below the east shoulder of the northbound lanes, and one platform was installed beneath the east shoulder of the southbound lanes. Both additional platforms were located approximately 20 ft from the back of the abutments and approximately 10 ft from the edge of the pavements.

The settlement platforms with settlement rods extending through the embankments are used to determine the settlement of the subsoils beneath the embankments. In order to determine the settlement within the embankments, smaller settlement plates were installed beneath the subbase of the shoulders within 3 ft of the rods extending upward through the embankments.

SETTLEMENT DATA AT FIRST AVENUE

The settlements of the subsoils at the First Avenue site, which were measured in the field, tend to verify the theoretical analysis which indicated that only small settlements would occur. Based on the Terzaghi theory of one dimensional consolidation, the total settlement of the 5-ft layer of clay directly beneath the embankments was predicted to be about 1 1/2 in. Time consolidation relationships between the laboratory sample and the field layer indicate that approximately 90 percent of the total consolidation of the field layer would occur in one year.

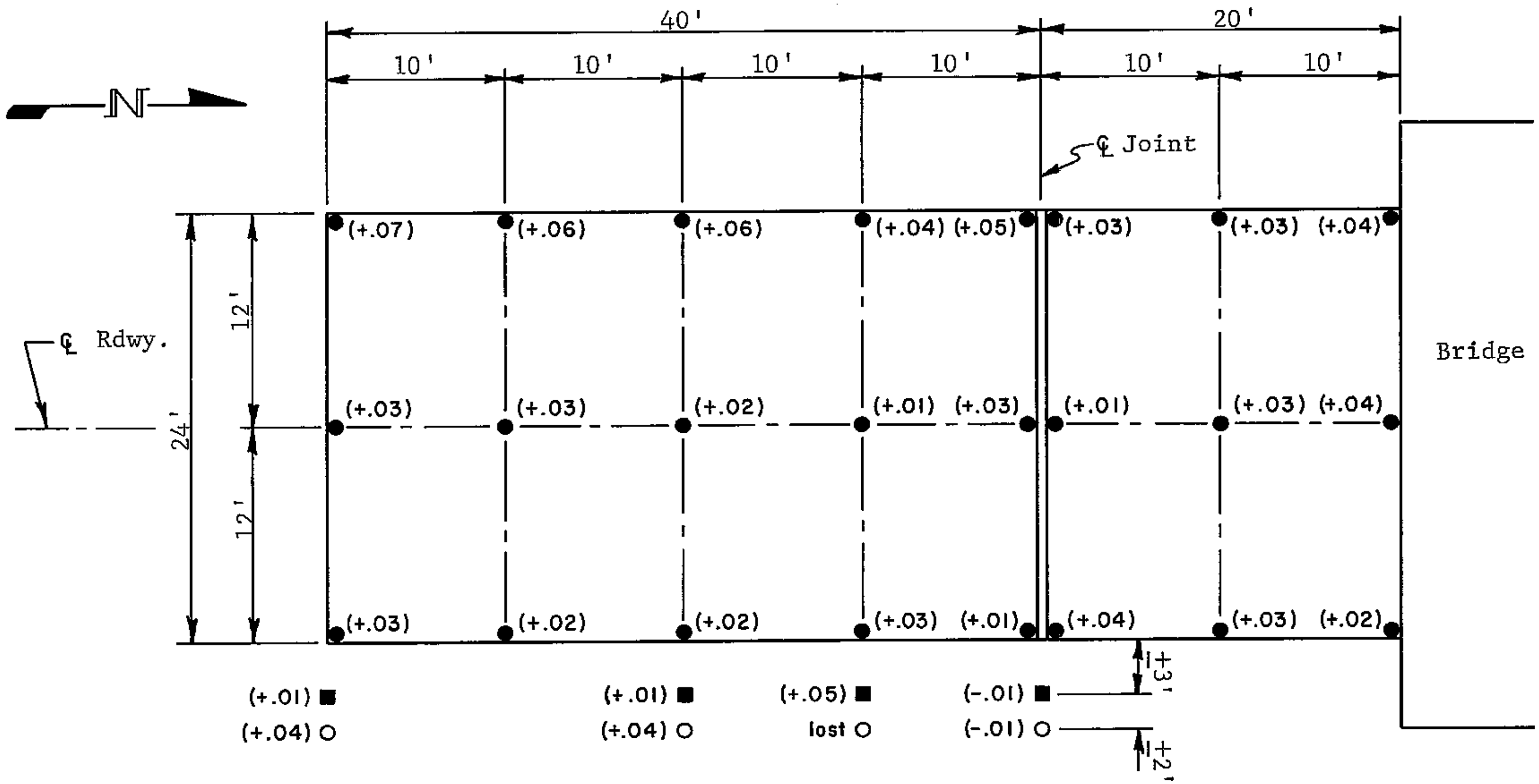
Field settlement measurements indicate that an average of approximately 1 3/4 in. of settlement occurred within the subsoils underlying both the stabilized and unstabilized embankments during the first year after the embankments were completed. An additional settlement of 1/8 in. was recorded during the following two years. Since the theoretical analysis is known to be only approximate, the difference between theoretical and measured settlements is believed to be within reasonable limits.

The primary purpose of this study is to evaluate the effect of the lime treatment in reducing the settlement of the approach slabs. At First Avenue nearly one year elapsed between completion of the embankments and the placement of the approach slabs which would explain why little settlement has been observed since the construction of the approach slabs.

Observations made on the approach slabs located on the stabilized southeast embankment show that the slight vertical movements of the slabs were in the upward direction (Figure 4). Shortly after the approach slabs were placed, the adjacent shoulders heaved with respect to the approach slabs. The upward displacement of the approach slabs and shoulders is not believed to be a result of the lime treatment.

Slight upward movements of the approach slabs at some locations were also recorded at the northwest and southwest embankments which were not stabilized with lime. A limited amount of shoulder heave was also observed at the southwest embankment.

The upward displacements of the shoulders and approach slabs may have been caused by nonuniform thickness of the gravel subbase. At the time the small



PLAN

Legend

○ Settlement plates on top of embankment
■ Settlement platforms beneath embankment
● Elevation points on approach slabs
(±.XX) Difference in elevation in feet from October 1969 to August 1972

Figure 4. Plan of Southeast approach slab st First Avenue (stabilized embankment).

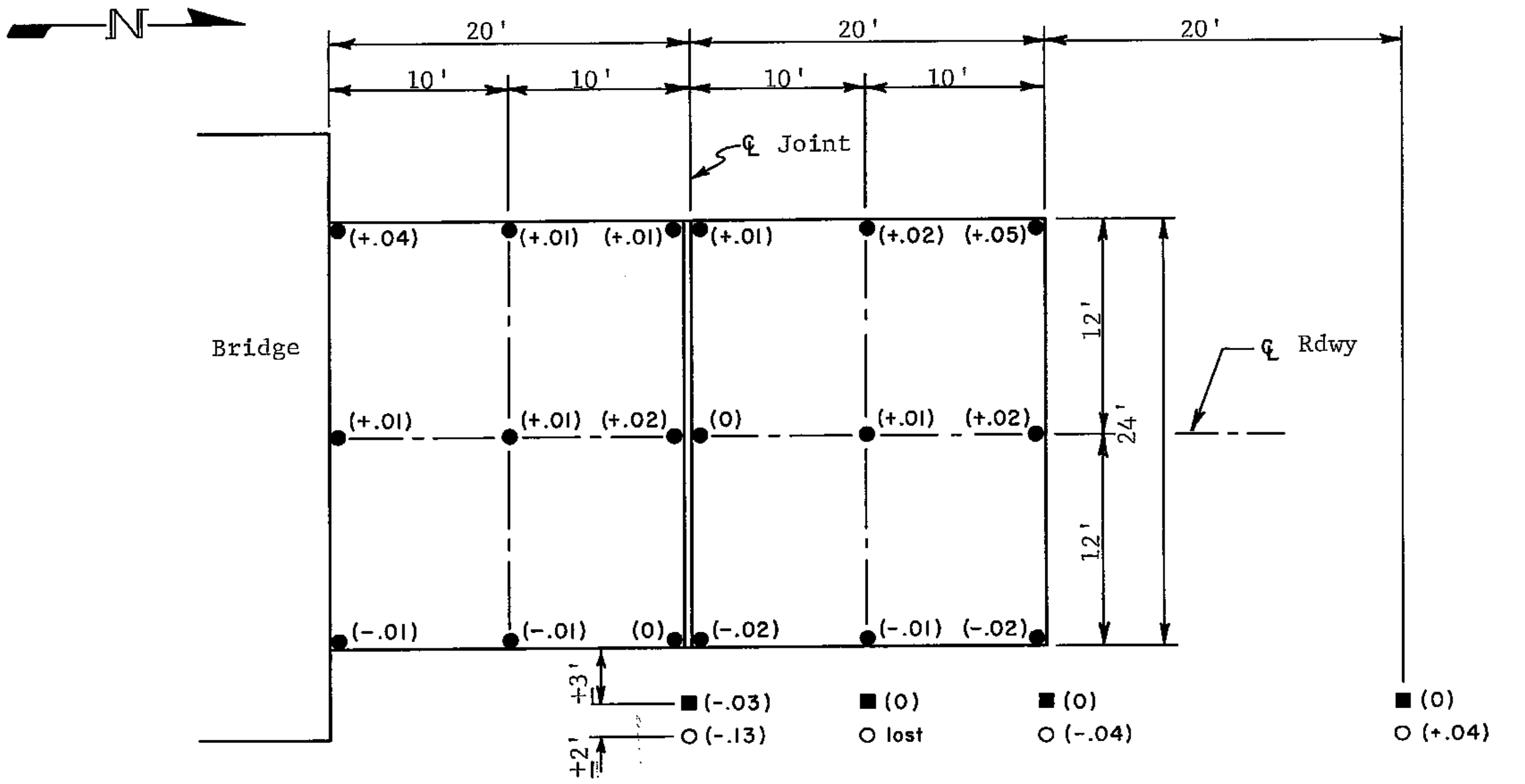
settlement plates were installed on top of the northbound embankments just beneath the subbase, the thickness of the subbase was observed to vary by as much as 10 in. The pockets formed in the uneven subbase may have prevented free drainage of water, and subsequent freezing of the trapped moisture may have caused the upward movements of the approach slabs and shoulders.

The small settlement plates located on top of the stabilized embankment indicate that, since the approach slabs were placed, the top of the embankment rose approximately 1/2 in. except at the plate located 20 ft from the back of the abutment where a settlement of 1/8 in. was recorded. The water which was trapped within the subbase may have flowed beneath the plates and, upon freezing, forced the plates upward at some locations.

At the stabilized embankment the three buried platforms located on top of natural ground beneath the embankments at distances of 20, 40, and 60 ft from the back of the abutment show that a negligible amount of vertical movement occurred in the subsoils. The platform located 5 ft below natural ground appears unreasonably to have moved upward about 5/8 in. An increase in elevation at this location is considered unlikely because of the physical nature of the subsoil underlying the platform; therefore, the recorded increase in elevation is attributed to an error in measured elevations.

At the north unstabilized embankment the changes in elevations on the approach slabs from October 1969 to August 1972 were moderate as shown in Figure 5. At most locations the measurements indicate a slight rise in elevation with the largest increase in elevation (5/8-in.) occurring at the northwest corner. Elevation changes of this magnitude are not sufficient to materially affect the riding quality of the approaches.

The settlement platforms beneath the northeast embankment indicate that no vertical movements took place in the subsoils beneath the embankment except at the



PLAN

Legend

○	Settlement plates on top of embankment
■	Settlement platforms beneath embankment
●	Elevation points on approach slabs
(±.XX)	Difference in elevation in feet from October 1969 to August 1972

Figure 5. Plan of Northeast approach slabs at First Avenue (unstabilized embankment).

platform located 20 ft from the back of the abutment where a settlement of about 3/8 in. was recorded.

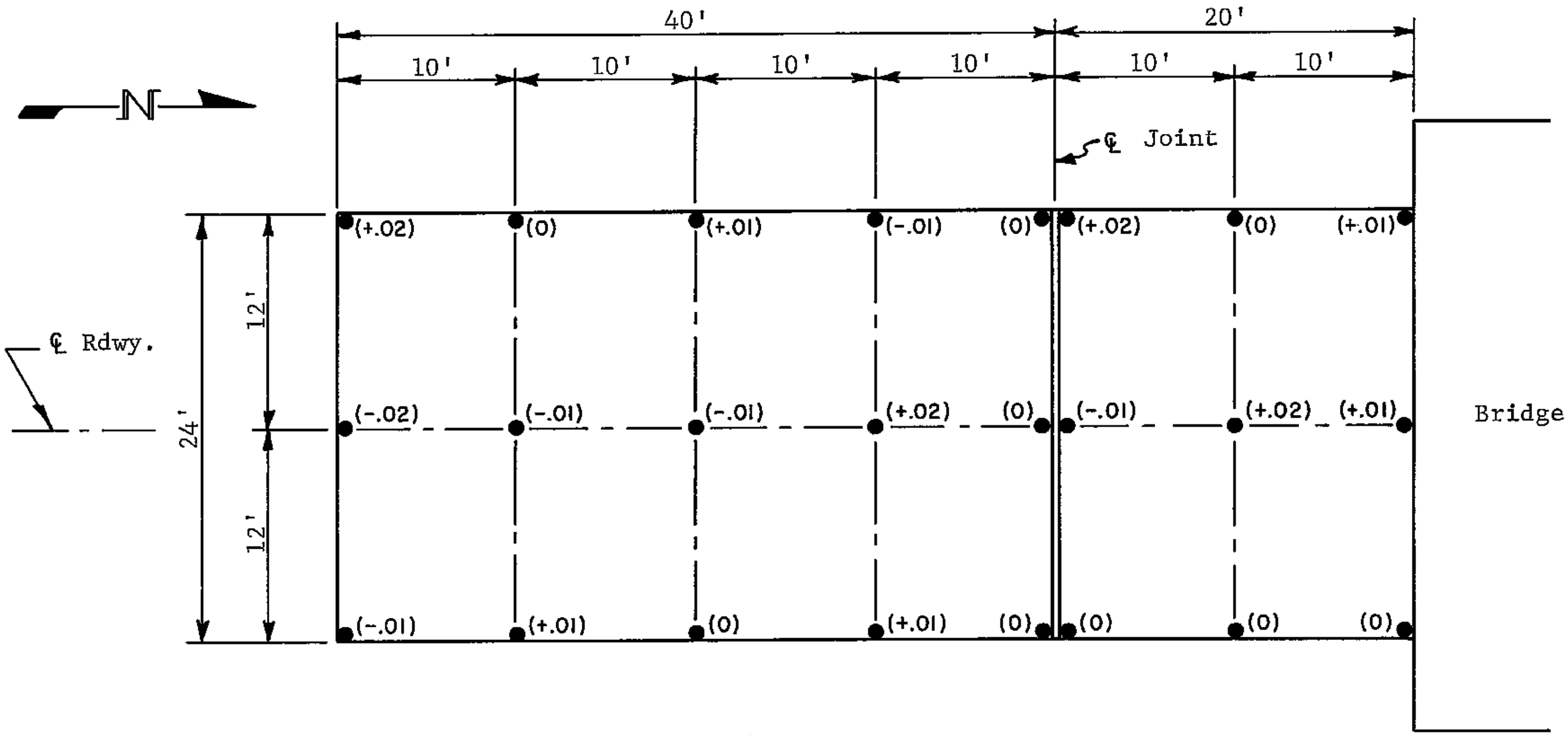
The vertical movements within the northeast embankment as indicated by the small settlement plates located beneath the subbase show that the movements ranged from 0 to $\pm$ 1/2 inch except at the plate located 20 ft from the back of the abutment. At this location a total settlement of about 1-5/8 in. was recorded. By deducting the settlement of 3/8 in. which occurred beneath the embankment at this location from the total settlement of the top of the embankment, a net settlement within the embankment of 1 1/4 in. is recorded. This settlement was not reflected in the movement of the approach slab at this location, possibly because the slab is supported by an approach pile cap which did not settle a corresponding amount. The variation in vertical movements within the embankments is evidence of localized settlements which can occur within an embankment constructed by standard methods.

The settlements of the approach slabs at the northwest and southwest embankments, which were both constructed by standard procedures, were slight as indicated in Figures 6 and 7. These small settlements would have little effect on the riding quality of the approach slabs and for all practical purposes can be considered negligible.

The small vertical movements of the approach slabs, which occurred at all four locations, were not of sufficient magnitude to permit an effective evaluation of the use of the longer transition slabs for reducing the effect of bridge approach settlements.

SETTLEMENT DATA AT HIGGINS ROAD

A comparison of the total settlement which has occurred in the subsoils beneath the stabilized and unstabilized embankments as plotted in Figures 8 and 9 show that

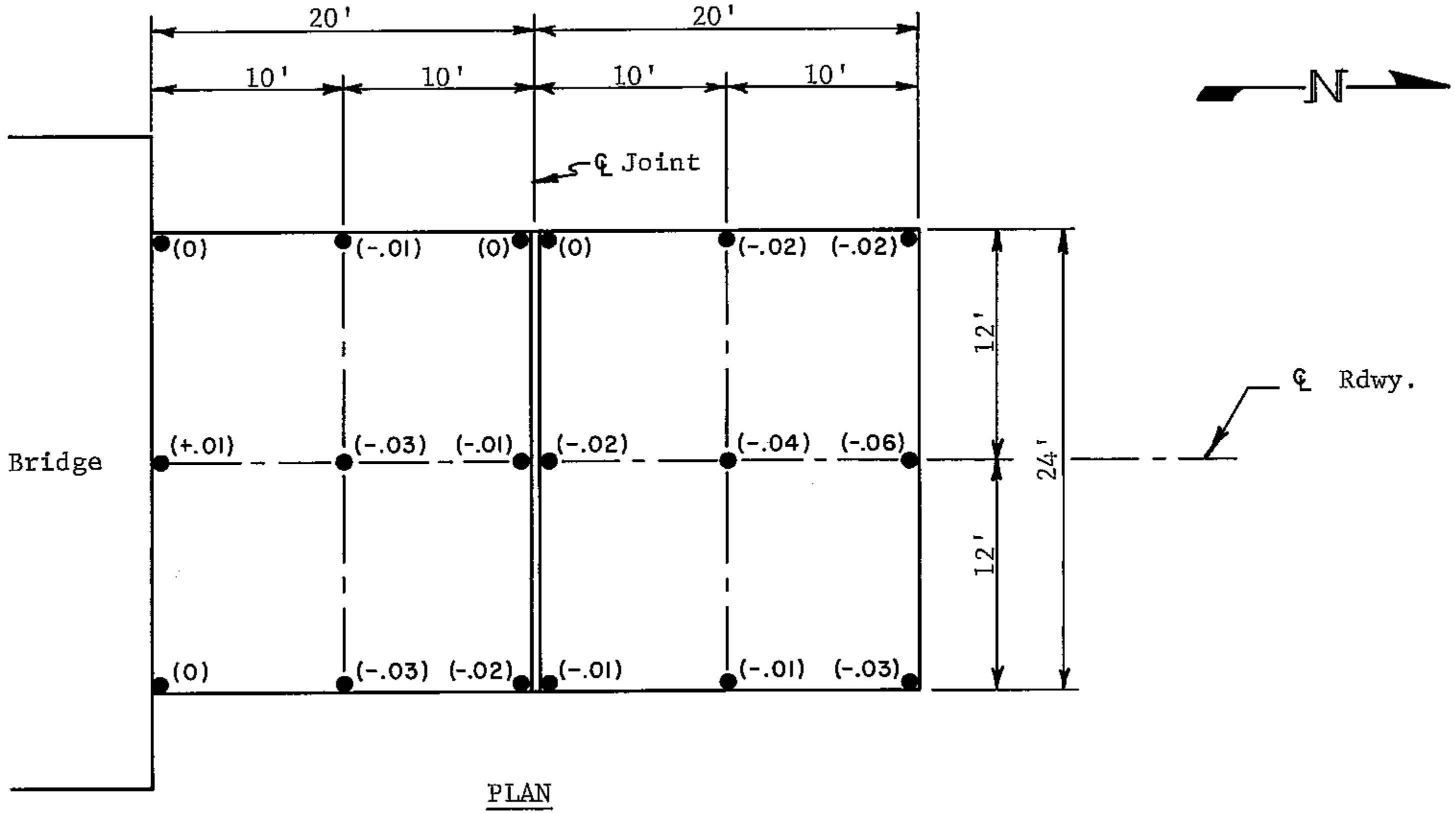


PLAN

Legend

● Elevation points on approach slabs
(±.XX) Difference in elevation from October 1969 to August 1972

Figure 7. Plan of Southwest approach slabs at First Avenue (unstabilized embankment).



Legend
● Elevation points on approach slabs
(±.XX) Difference in elevation from October 1969 to August 1972

Figure 6. Plan of Northwest approach slabs at First Avenue (unstabilized embankment).

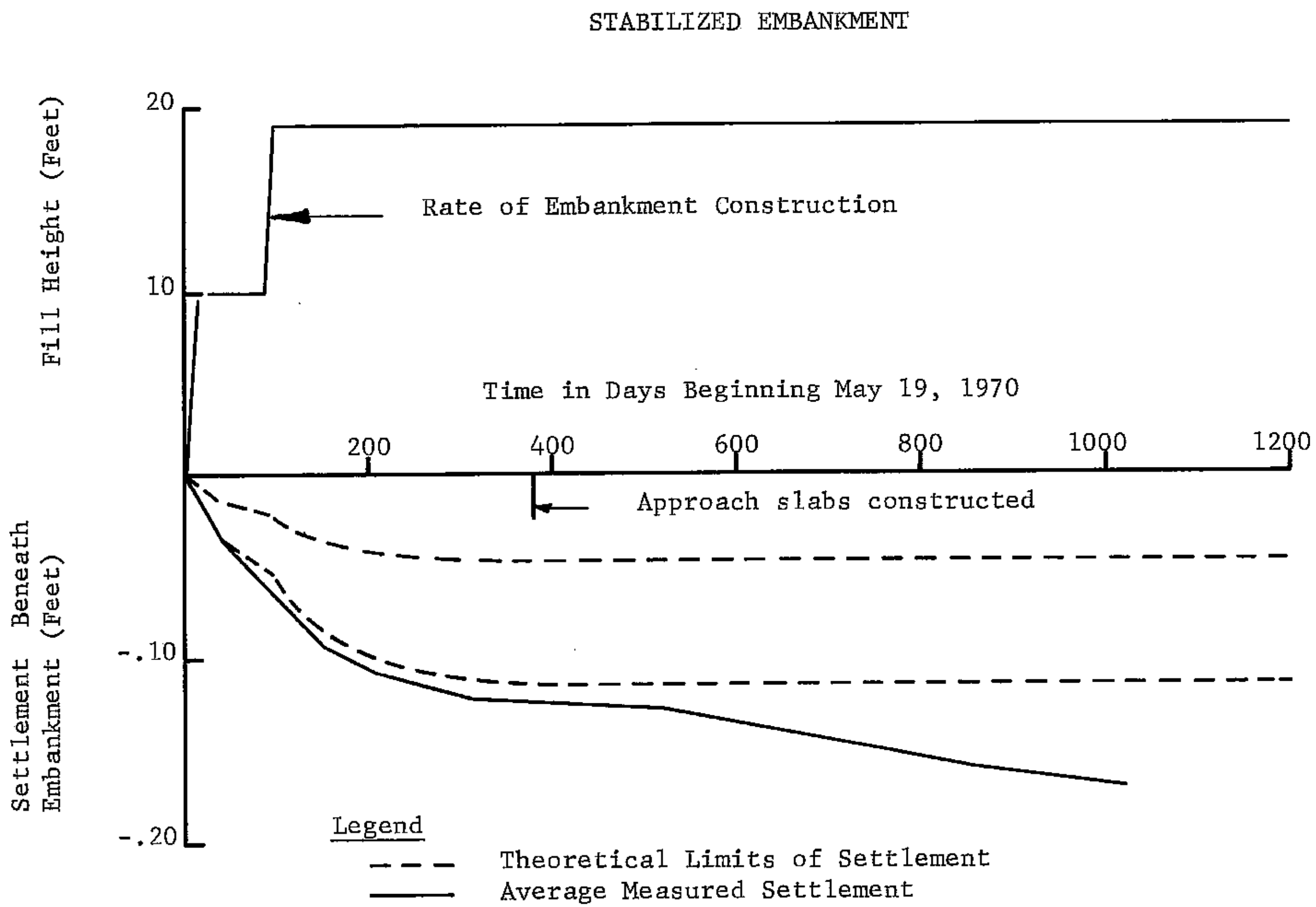


Figure 8. Theorectical and measured settlement of stabilized embankment correlated to rate of embankment construction (Higgins Road Project).

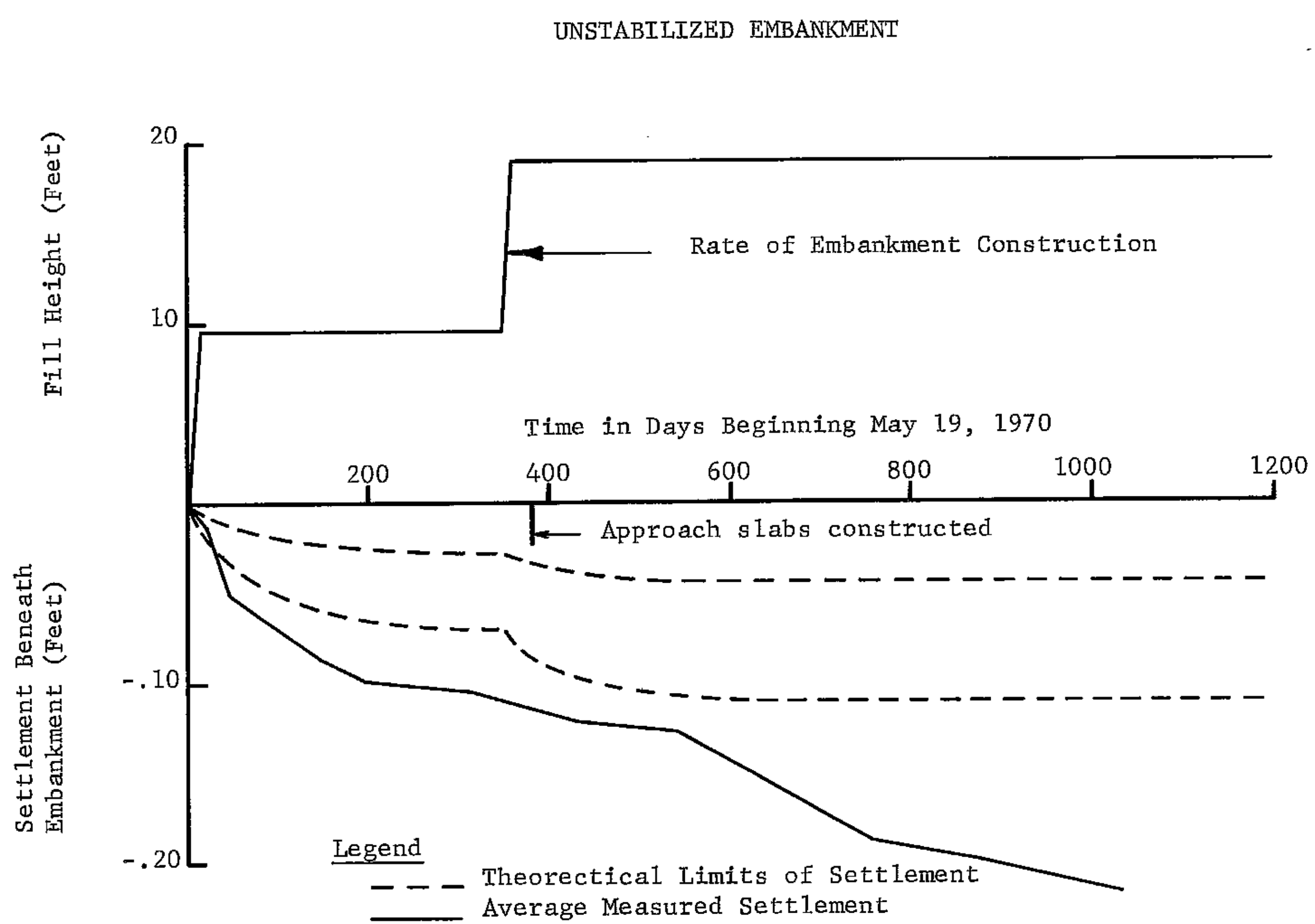


Figure 9. Theoretical and measured settlement of unstabilized embankment correlated to rate of embankment construction (Higgins Road Project).

more settlement has occurred beneath the north unstabilized embankment than has occurred beneath the south stabilized embankment. Since the stabilized embankment was completed about 200 days before the unstabilized embankment, more settlement theoretically should have occurred beneath the stabilized embankment during this time period than below the unstabilized embankment assuming all other factors to be equal.

The lime treatment may have contributed to a reduction in the magnitude of settlement at the stabilized embankment. The pressure transmitted to the subsoils from an embankment constructed by standard procedures varies parabolically with the maximum pressure occurring beneath the center of the embankment and the minimum pressure occurring at the edges of the embankment. The increase in strength and rigidity gained by stabilizing the embankment with lime may have resulted in a more uniform distribution of the overburden load to the underlying subsoils and, consequently, a more uniform settlement of the subsoils. If this is the case, the maximum pressure near the center of the embankment would be reduced which would result in a corresponding decrease in settlement beneath the central portion of the embankment.

Field measurements indicate that settlement is still occurring beneath both embankments; however, the rate of settlement is slower at the stabilized embankment than at the unstabilized embankment. The lime treatment may have influenced the slow rate of settlement at the south embankment. The rate at which the subsoil settles is dependent on the rate at which moisture is free to drain from the clay layer beneath the embankment. The cementing action resulting from the pozzolanic reaction that occurs when clay soils are treated with lime generally reduces the permeability of the soils. Therefore, the relatively impervious nature of the lime treated embankment may have retarded the free drainage of moisture from the upper surface of the subsoil. Although the rate of settlement is slower at the stabilized embankment than at the unstabilized embankment, the magnitude of the settlements may eventually become approximately equal.

Another factor which could have influenced the difference in the amount and the rate of settlement at the two embankments is the preloaded condition of the clay underlying the embankments. Consolidation tests conducted on Shelby tube samples taken from the subsoils indicate that the soil had been preloaded in the past by an equivalent load equal to or greater than the embankment overburden. The exact nature of the preloading condition is unknown, however, desiccation of the clay layer is suspected to be the primary cause. Terzaghi (4) states that, in the Chicago area, a thick layer of soft normally loaded clay is covered by a layer of stiff clay which has been precompressed by desiccation. The consolidation tests indicate that the degree of preloading may have been greater beneath the stabilized embankment than below the unstabilized embankment which could account for at least part of the difference in subsoil settlement.

An accurate prediction of ultimate settlement of a preloaded clay is difficult to attain. According to Terzaghi, if the settlement of a preloaded clay is estimated with the assumption that no preloading has taken place, the estimated settlements should be in the order of 4 to 10 times greater than the actual settlements. In Figures 8 and 9, the upper dashed lines represent 1/10 and the lower dashed lines represent 1/4 of the settlement which would theoretically have occurred if the subsoils had not been preloaded.

At both embankments the amount of measured settlement which has occurred exceeds the theoretical limits for predicted settlement. The difference between measured and theoretical settlement is not regarded as significant since the dashed lines represent only a general approximation of the subsoil settlements.

The primary purpose of this study is to evaluate the effect of the lime stabilization on reducing the approach slab settlement. Since the approach slabs were completed at the Higgins Road Project, more settlement has occurred within the subsoils beneath the northeast unstabilized embankment than has occurred at the southeast stabilized cone. A plot of the average settlement occurring beneath the stabilized embankment in Figure 10 shows that about 5/8 in. of settlement has occurred since the approach slabs were constructed. A similar plot of the settlement occurring beneath the unstabilized embankment in Figure 10 indicates that an average of about 1-1/4 in. of settlement has occurred since the approach slabs were placed.

The difference in the magnitude of the settlement occurring beneath the embankments since the approach slabs were constructed can be at least partially attributed to the difference in construction rate of the two embankments. The stabilized embankment was completed to the final fill height of about 19 ft within 90 days, and the approach slabs were not constructed until about 300 days later. The first 9-1/2 ft of the unstabilized northeast embankment was completed in 15 days; however, nearly a year elapsed before the fill was completed to a height of 19 ft. The approach slabs were constructed on the unstabilized cone within 40 days after the embankment was completed.

The small settlement plates located on top of the southeast stabilized embankment indicate that the top of the embankment has settled an average of about 1/2 in. since the approach slabs were placed (Figure 11). Since the average settlement of the subsoils beneath the southeast embankment was also about 1/2 in., very little settlement has occurred within the embankment proper. At the northeast unstabilized embankment the small settlement plates indicate that the top of the embankment settled almost linearly from 1-3/8 in. at a location 20 ft from the back of the abutment to 2-1/4 in. at a distance of 60 ft from the back of the abutments. By deducting the corresponding settlement beneath the embankment at the same locations, an average settlement within the embankment proper of 1/2 in. has occurred since the approach slabs were constructed.

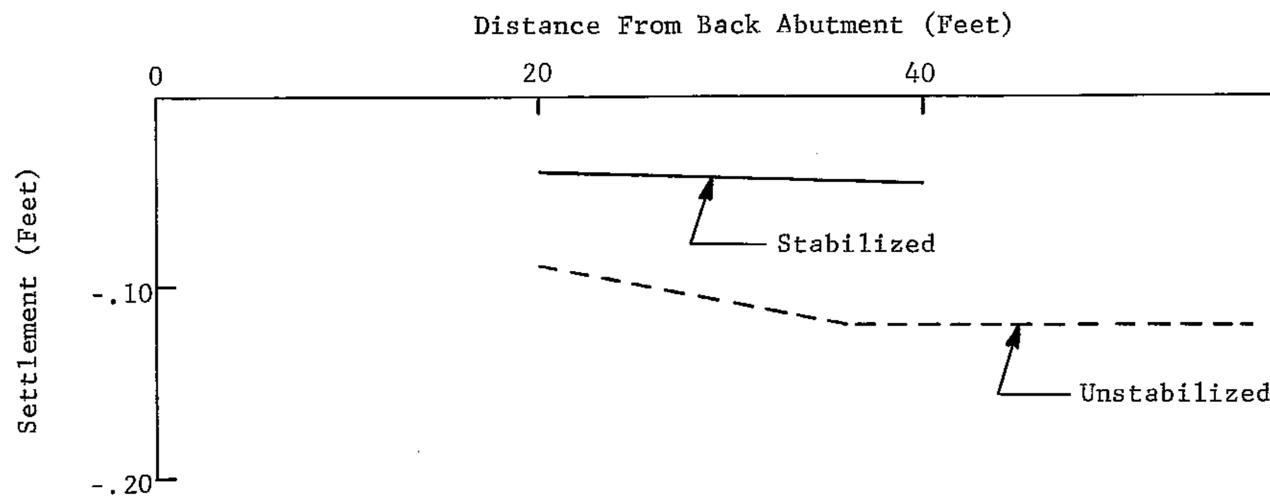


Figure 10. Settlement of subsoils beneath northbound embankments from July 1971 to March 1973.

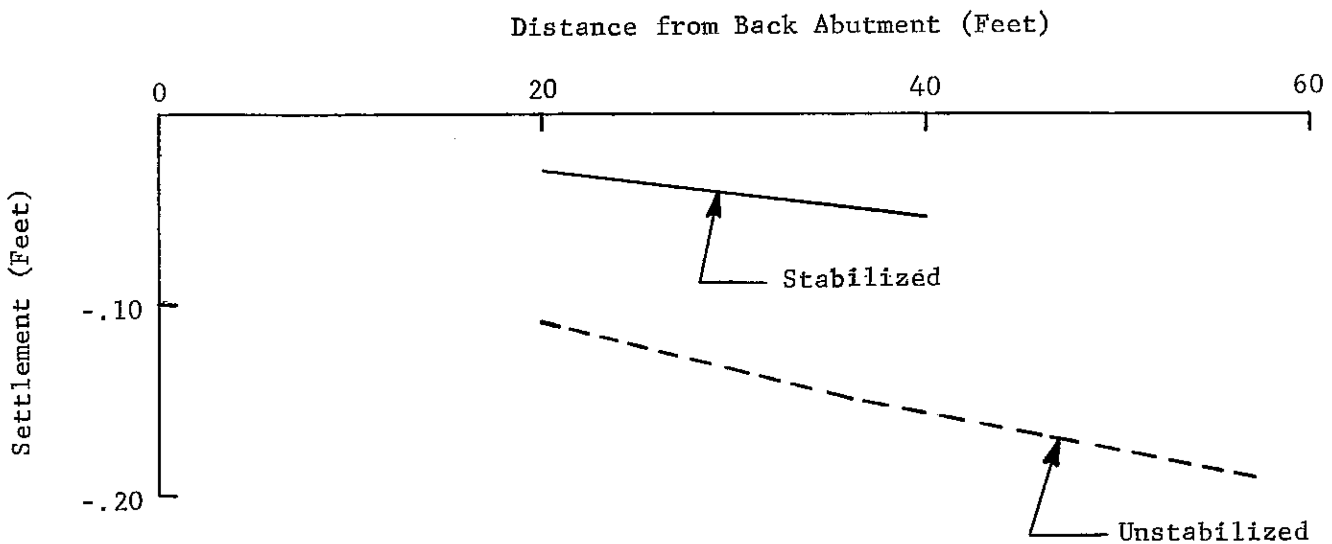


Figure 11. Settlement of top of northbound embankments from July 1971 to March 1973.

Although the lime treatment possibly reduced the settlement within the stabilized embankment, the variation in settlement within the embankments cannot be entirely attributed to the effect of the lime. The varying construction rate of the embankments would also have influenced the rate of settlement within the embankments.

The purpose of the approach slabs is to provide a transition pavement for the differential settlement occurring between the unyielding bridge abutment and the roadway pavement. As was expected, the settlement of the approach slabs at Higgins Road from July 1971 to March 1973 increased with the distance from the back of the abutments (Figures 12 and 13). Although the settlement of the approach slabs at the south stabilized embankments was slightly less than at the north unstabilized embankments, the difference in settlement can be only partially attributed to the use of the lime as a stabilizing agent.

The most probable reason for the difference in settlements is the variation in the rate of embankment construction as described previously. Other factors which may have contributed to the difference in settlements include the different types of approach slab construction at the north and south approaches. Two slabs with their adjoining ends resting on an approach pile cap were used at the north approaches, while a single slab with no pile cap was constructed at the south embankments. Because of the interrelated factors which may have influenced the settlements at this site, the contribution of the lime additive toward reducing the settlements cannot be directly ascertained.

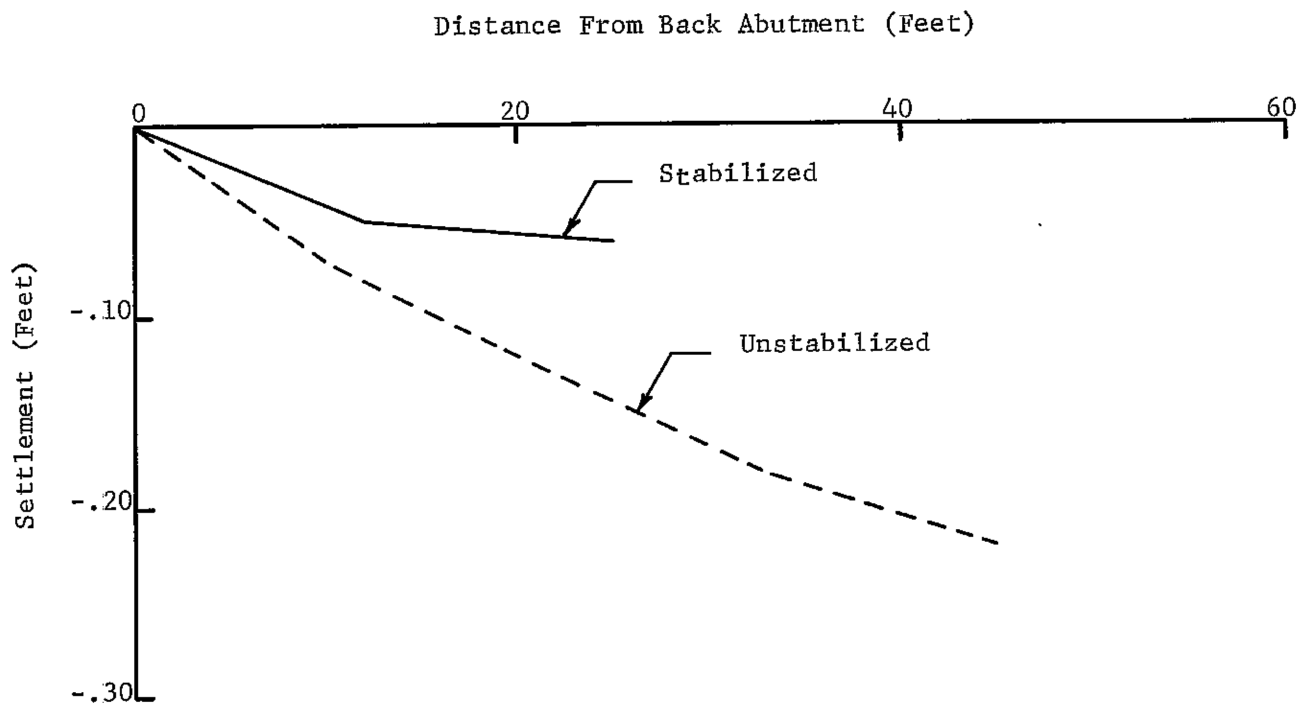


Figure 12. Settlement of northbound approach slabs from July, 1971 to March, 1973.

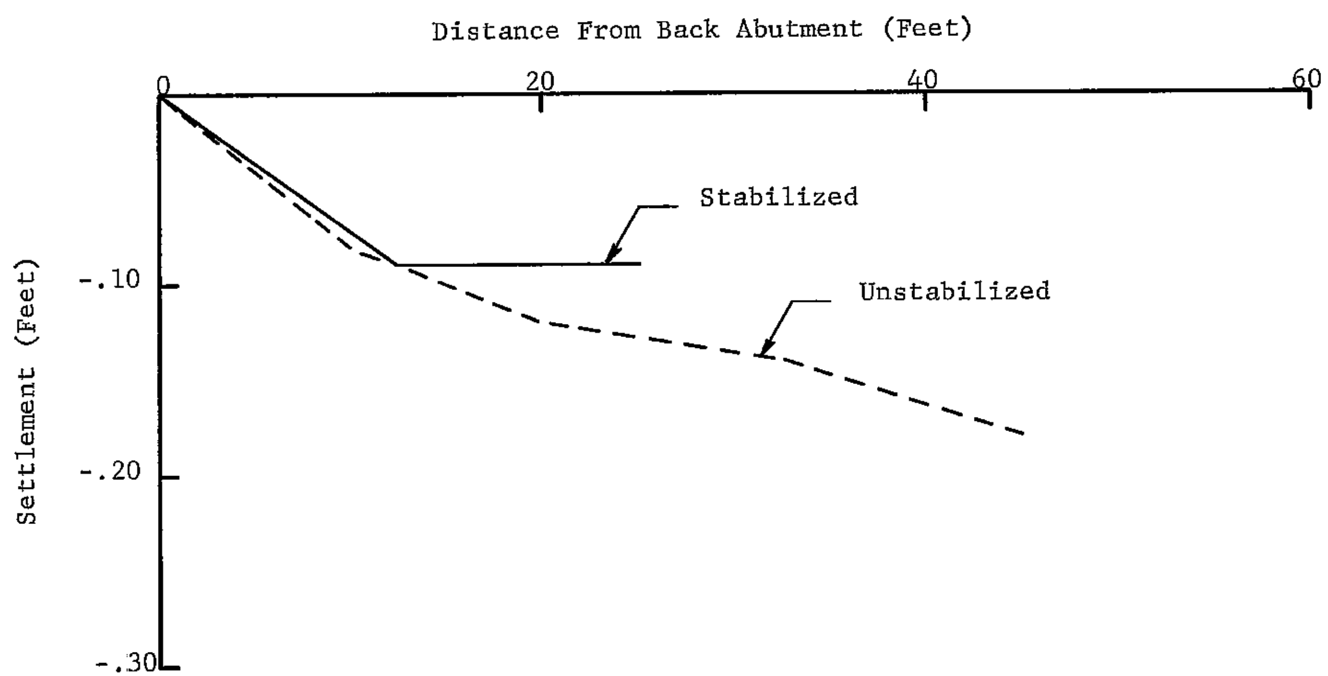


Figure 13. Settlement of southbound approach slabs from July, 1971 to March, 1973.

SUMMARY COMMENTS

A meaningful evaluation of the use of lime as a stabilizing agent for bridge cones is difficult to derive from the results of this research. Many interrelated factors are present which preclude the isolation of the effect of the lime treatment in reducing the approach slab settlements.

At both test sites, the magnitude of the subsoil settlement was too small for making an effective comparison of the lime stabilized cone and the control section. Borings indicate that the settlement of the subsoil at First Avenue would be limited to the upper 5-6 ft of clay. Beneath this level the soil consists of hard impervious clay in which little or no settlement was expected to occur. Consolidation tests conducted on soil samples extracted from the 5-ft layer of clay directly beneath the embankments indicated that the ultimate settlement of the layer would be about 1-1/2 in. Time-consolidation relationships established between the laboratory samples and the field layer indicated that at least 90 percent of the ultimate settlement would occur within one year after the embankments were constructed. Since nearly one year elapsed between the completion of the embankments and the construction of the approach slabs, little settlement was observed after the approach slabs were placed.

At the Higgins Road site, the borings indicated that the upper 10-12 ft of clay would settle beneath the load of the embankments. However, consolidation tests conducted on Shelby tube samples taken from the subsoil indicated that the soil had been preloaded sometime in the past.

Since the soil was preloaded by an equivalent load equal to or greater than the embankment overburden, the ultimate settlement resulting from the loads imposed by the embankments is greatly reduced. The ultimate settlement of the preloaded clay was predicted by approximate methods to be in the order of 1 3/8 in. Although the measured settlement of the subsoils beneath both embankments exceeds the predicted settlement, the magnitude of the subsidence is still considered small for evaluating the use of lime as a stabilizing agent.

At First Avenue most of the settlement within the embankments occurred before the approach slabs were placed. Settlement within both the stabilized and unstabilized embankment was very slight and can be considered negligible.

After the approach slabs were placed at Higgins Road, more settlement occurred within the unstabilized embankment than within the stabilized embankment. Although the lime treatment may be responsible for most of the difference in settlement, the reduction in settlement within the stabilized embankment cannot be entirely attributed to the effect of the lime treatment. Another factor which may have contributed to the difference in settlement is the difference in construction rates of the stabilized and unstabilized embankments. Since the south stabilized embankment was completed nearly 300 days before the approach slabs were placed, most of the settlement within the embankment should have occurred prior to the construction of the approach slabs. The north unstabilized embankment was not completed until about 40 days before the approach slabs were placed, which could result in more subsidence occurring within the embankment after the approach slabs were constructed.

The First Avenue installation also included an evaluation of using longer approach slabs to increase the settlement transitioning length. No noticeable difference in behavior between the 40-ft approach slabs constructed at the south embankments and the 20-ft approach slabs constructed at the north embankments was observed. The small vertical movements which have occurred on all the approach slabs at First Avenue are not large enough to materially affect the riding quality of the approaches.

At Higgins Road more settlement of the approach slabs occurred at the north unstabilized embankments than at the south stabilized embankments. The difference in settlement cannot be attributed solely to the stabilizing influence of the lime because of the difference in the construction rates of the embankments.

The cost of constructing the stabilized embankment for the First Avenue project was considerably higher than originally estimated. The unit bid prices for the project were (1) \$6.00 /cu yd for soil-lime stabilized embankment, (2) \$30 /ton for the lime, and (3) \$0.20 /gal for water. During the construction of the stabilized embankment, it became apparent that the amount of water needed to complete the project had been grossly underestimated. Nearly 3,500 gallons of water were used for stabilizing the first six-inch lift. It became obvious that at this rate the original estimate of 9,000 gallons would be greatly exceeded. Since the unit price of \$0.20 /gal was considered unrealistically high for the amount of water being used, a decision was made to discontinue the construction of the second experimental cone proposed for the project.

A total of 5,277 cu yd of soil-lime stabilized embankment were used in the First Avenue project for constructing one of the four bridge cones required for the dual structures. The total unit cost for the embankment in place inclusive of water and lime was about \$9.60 /cu yd. The total cost for the embankment based on the unit bid prices was \$50,712. With a unit cost of \$2.30 /cu yd established for the standard embankment, the difference in cost for stabilizing the one embankment with lime was \$38,575.

The cost of constructing the stabilized embankments for the Higgins Avenue project was much more reasonable. The unit cost for the lime-soil stabilized embankment was \$4.80 /cu yd which included the cost of the lime and the water. The total cost for stabilizing two of the four embankments required for the dual structures on the Higgins Avenue project which consisted of 7,040 cu yd of lime treated embankment-material was about \$33,800. At a unit cost of \$2.12 /cu yd established for the standard embankment, the cost differential for incorporating the lime treatment for the two embankments was \$18,900. On the basis of the more reasonable construction costs at the Higgins Avenue Project, the cost for stabilizing the bridge embankments with lime for one structure is estimated to be about \$18,000 to \$20,000.

This study has not provided conclusive evidence that the stabilization of bridge embankments with lime is an effective solution to the problem of approach slab settlement. The experience gained from the study, however, has indicated that even if the use of the lime were proven to be an effective method of reducing approach slab-settlements, the cost of constructing lime stabilized embankments is exceedingly high and more economical solutions should be sought.

IMPLEMENTATION

The information derived from this study indicates that the limited benefits derived from stabilizing bridge embankments with lime do not justify the high construction costs of the lime treatment. Therefore, no recommendation is made to implement the results of the study.