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LOUISIANA SLABJACKING STUDY

by

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SYNOPSIS

This study was primarily oriented toward slabjacking procedures for raising slabs and filling voids on roadways and at bridge approaches, with special emphasis on Louisiana materials and equipment. The project was implemented through literature survey, field observation of existing materials and procedures, labotatory testing of materials used under existing procedures, and of new materials for possible use in the field, field trials of various materials for slabjacking slurry, slabjacking on test sections to investigate the effects of variation in hole spacing, material consistency, and pumping characteristics, and laboratory tests of field materials used on the test sections.

The following conclusions and recommendations resulted from this study:

Conclusions

1. Hole spacing is still a matter of judgement and no definite conclusions can be drawn. However, the following general guidelines may be acceptable:

    a. Do not place holes closer than 18 inches to edges or joints when jacking to lift slabs. If jacking to fill cavities, however, holes must be placed where cavities occur even if at a joint.

    b. Holes should probably not be spaced closer together than six feet due to the danger of slab weakening.

    Using these general guidelines the judgement of an experienced slabjacking foreman is probably the best guide to hole placement.

2. Holes $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter are probably best for jacking since no lifting superiority seems attributable to larger holes and less breaking of slab bottoms is likely to occur.

3. During this study it appeared that starting jacking at the area of least lift and proceeding to and through the area of greatest lift caused less cracking of the slabs than did jacking from the low point to the high point. Greater amounts of jacking must, of course, be done at low points once lifting of the slabs is started. If the low point occurs totally within a particular slab, initial jacking should probably begin at the low point to avoid overstressing and cracking the slab.

4. Jacking should be completed on parallel slabs in adjacent lanes as close to the same time as practicable. Filling of all voids in the jacked slabs and in

adjacent slabs is highly important in preventing slab deterioration when subjected to traffic.

5. Soils within the A-4 classification, relatively organic free, and devoid of clay lumps or other aggregations are satisfactory for use in slabjacking. The sandier soils within this classification will yield the highest strengths.

6. The addition of a wetting agent to the water used in slurry mixing appears to aid travel of the slurry while causing no loss of strength when compared to slurries mixed with water only.

7. The addition of emulsified asphalt in quantities up to 15 percent of the mixing water does not greatly increase the flow of the slurry. Some loss of strength is apparent for water-asphalt slurries when compared with those mixed with water only at the same relative viscosity and cement content.

8. A Portland cement content of four bags per cubic yard of soil yields strengths generally in the lower range of those achieved in soil cement stabilization in Louisiana.

9. On the basis of compressive strength, the addition of hydrated lime to the slurry does not appear to be justifiable.

10. Laboratory strengths obtained with a well graded native sandy loam soil were greater than those obtained utilizing agricultural limestone with the gradation shown in this report.

11. For slab raising, observation indicates that starting with a thick slurry until slab lift begins, then thinning the slurry to prevent stooling and aid slurry travel, may be a desirable procedure. Careful control of the slurry is important. The slurry must have enough flowability to insure proper spread and to prevent stooling, but within these limits should be as viscous as practicable, in order to obtain the maximum possible strength.

12. Lifting of slabs should be done in small increments. Lifting not more than $\frac{1}{4}$ inch in any one place prior to changing locations is probably good practice.

Recommendations

1. Holes should be spaced no closer than six feet apart and no closer than 18 inches to the edges or joints of slabs when jacking to raise slabs. Otherwise, spacing should be based on the judgement of an experienced slabjacking supervisor.

2. Holes should be drilled with a diameter of $1\frac{1}{4}$ to $1\frac{1}{2}$ inches to avoid breaking the slab bottoms.

3. As a general rule, jacking should start near the high point of the area to be jacked and proceed to and through the low point on a rotating basis. When the low point occurs totally within on slab, jacking should begin at the low point.

4. Jacking should be completed on all slabs where voids created by jacking in adjacent slabs ~~has~~ occurred, as soon as is possible after the voids are created. This action will help to avoid cracking of the slabs under traffic.

5. Soils within the A-4 classification relatively free of organic materials, clay lumps, or aggregations of any kind, should be used. Preference should be given to the sandier soils within this classification when practicable.

6. The slurry should consist of soil meeting the above criteria, wetting agent (Alconox or equivalent), water, and four bags of Portland cement per cubic yard. No other additives should be used.

7. For slab lifting, jacking should be initiated using a fairly thick slurry. As soon as lifting begins, the slurry should be thinned until good hole to hole travel is obtained.

8. Jacking should not be continued for long periods of time in any one hole even if no lift is occurring. Excessive pumping in any one location tends to cause cracking of the pavement.

INTRODUCTION

The large expansion in road building in the last 10 to 15 years, created primarily by increased federal funding for both interstate and primary road systems, has greatly increased the mileage of Portland cement concrete roadways. Many of these roads have now been in service long enough to start exhibiting those maintenance problems characteristic of concrete pavement, such as joint spalling, differential settlement and settlement of approach slabs. The occurrence of these difficulties has led to increased maintenance on pavements of this type. Mudjacking, or slabjacking as it is becoming more commonly called, is one of the most used methods of correcting these difficiencies.

The process of slabjacking has been somewhat of an art with no ~~very~~ clearly established methods of material selection, hole spacing, or jacking procedure having been adopted. Several states and the Bureau of Public Roads have done some work in this field but as yet no universally accepted materials or procedures have evolved from these studies. In an effort to clarify some of these points and with a special view of applying them to Louisiana materials, this study of slabjacking was initiated by the Louisiana Department of Highways in cooperation with the Federal Highway Administration, Bureau of Public Roads.

SCOPE

This study was designed to include a limited investigation of materials and procedures for slabjacking. The study is primarily oriented toward procedures for correcting differential settlement at joints, at bridge ends and in a series of slabs, and for filling voids at bridge ends and under slabs.

~~METHODOLOG~~Y

The methods used during this study for the evaluation of ~~mudjacking~~ techniques were as follows:

1. Literature survey.
2. Field observation of existing materials and procedures.
3. Laboratory testing of materials used under existing procedures and of new materials for possible use in the field.
4. Field trials of various materials for slabjacking slurry.
5. Field jacking and checking of results of hole spacing, material consistency, and pumping characteristics.
6. Laboratory tests of field materials used on test sections.

Many of the results obtained in this study are subjective in nature and cannot be reduced to tables or formulae. However, where possible, laboratory tests and field measurements were utilized to substantiate observations made.

DISCUSSION OF RESULTS

Literature Survey

Conflicting guidelines found in available literature reveal that slabjacking has not yet been reduced to a science. Some sources recommend high asphalt contents and low cement contents(1), while other sources recommend high cement contents and no asphalt(2)(3). Some sources recommended $2\frac{1}{2}$ inch holes while others recommended $1\frac{1}{2}$ inch holes or smaller. There is fairly general agreement that the desirable hole spacing in a continuous area is about six feet, but little agreement as to spacing near edges and joints is evident. It is also generally agreed that pumping should be by small increments with no segment of the slab raised more than $\frac{1}{4}$ inch by any one pumping operation. There is, however, considerable disagreement as to the order of jacking, with some sources recommending working from the high point (area of least lift) to the low point and some recommending jacking first at the low point.

(1) Numbers in parenthesis refer to list of references.

Field Observations of Existing Materials and Procedures

Field observation of methods used for slabjacking within the Louisiana Department of Highways revealed no generally accepted materials or procedures were in use. Materials, mixing methods, hole size for pumping the slurry, hole patterns and order of pumping varied widely from district to district.

The Districts checked were all equipped with Koehring Model 50 slabjacking equipment. This unit is a self contained, trailer mounted device capable of mixing and pumping slurry at a maximum rate of 260 cubic feet per hour at a maximum pressure of 250 psi. A general view of the equipment used for jacking is shown in Figure 1.

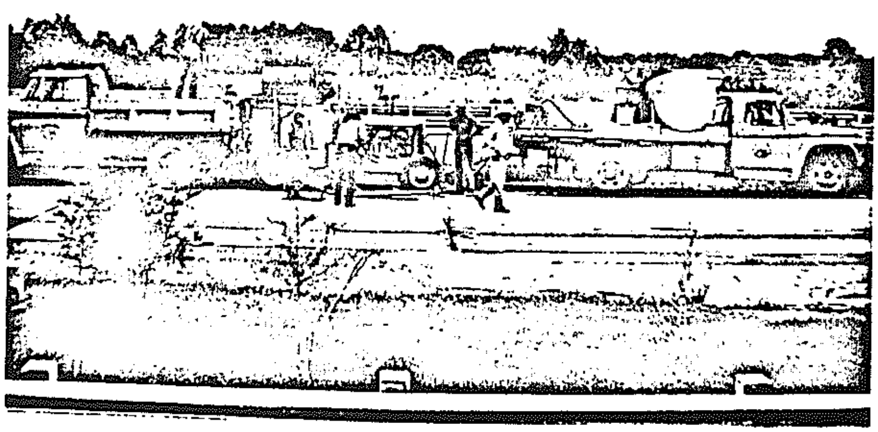

Figure 1 - Slabjacking Equipment

The materials used were generally a mixture of soil, cement, water and emulsified asphalt (MS-2) and were placed in the mixer as shown in Figure 2. The soils used were generally silty or sandy loams, some containing appreciable amounts of organic material (topsoil).

Figure 2 - Mixing Operation

The amount of cement used varied from less than 1 sack per cubic yard to 2 sacks per cubic yard. The percentage of asphaltic emulsion in the mixing water varied from 0 to approximately 15 percent.

The holes drilled for slurry placement varied from $1\frac{1}{4}$ inches in diameter to $2\frac{1}{2}$ inches in diameter and the spacing of the holes was a matter of judgement of the slabjacking foreman. The order of jacking, place of first jacking and the amount of jacking at each location varied greatly from district to district.

Laboratory Testing of Materials Used Under Existing Procedures and of New Materials for Possible Use in the Field

Samples of the soil material being used in 3 districts were obtained and gradations and classifications run. These tests revealed that in all three areas the materials were non-plastic silty or sandy loams, with two of the materials being topsoil containing a considerable amount of organic material. Since it was observed that materials in this general category (silty or sandy loams) apparently pumped well in the field, the one material not containing appreciable amounts of organic material and an additional sandy material were tested for compressive strength. The gradations and classifications of these materials are shown in Table 1.

TABLE 1

GRAIN SIZE ANALYSIS
OF SANDY AND SILTY SOIL SAMPLES

	SANDY SOIL	SILTY SOIL
% SAND	90	21
% SILT	4	63
% CLAY AND COLLOIDS	6	16
CLASSIFICATION	SAND	SILTY LOAM

The initial tests were made utilizing soil, hydrated lime and Type I Portland cement. The results of these tests are shown in Table 2.

TABLE 2

UNCONFINED COMPRESSIVE STRENGTHS
OF MIXTURES OF SOIL, CEMENT, HYDRATED LIME AND WATER

	SAND			SILTY LAOM	
	2 BAG*	4 BAG	5 BAG	2 BAG	4 BAG
TWENTY-FOUR (24) HOUR STRENGTHS,PSI	38	178	282	16	44
SEVEN (7) DAY STRENGTHS, PSI	102	401	710	42	185

*Mix design based on a batch of one (1) cubic yard volume. A bag refers to one (1) cubic foot consisting of a 70% Type I cement and 30% hydrated lime.

These results indicated that the sandy loam material achieved higher strengths with the same cement-lime content than did the silty loam material.

Further testing was then performed to determine whether the addition of lime to the mixture was beneficial. In order to test the samples under like conditions, a crude viscosity test was run on each material utilizing a large funnel held by a bracket and filled to a scribed line marking a volume of about 4 pints. The mixture was placed in the funnel to the scribed line and the time for complete flow from the funnel was measured in seconds and recorded as the viscosity. All tests shown in Table 3 below were on the sandy material at a viscosity of 15 seconds. Type III Portland cement was used for these tests.

TABLE 3

UNCONFINED COMPRESSIVE STRENGTHS OF
MIXTURES OF SOIL, CEMENT, HYDRATED LIME, AND WATER,
FIVE BAG MIX WITH VARYING CEMENT-LIME RATIOS

	100% TYPE III CEMENT	85% CEMENT-15% LIME	70% CEMENT-30% LIME
TWENTY-FOUR (24) HOUR STRENGTHS, PSI	305	169	103
SEVEN (7) DAY STRENGTHS, PSI	951	603	472

It may be noted that at 24 hours and at seven days those specimens in which only cement was used exhibited higher strengths. No further testing utilizing lime was ~~accomplished~~.

As mentioned previously, the initial testing with the lime-cement-soil mixture seemed to indicate higher strengths for the sandy materials. As a further check, compressive strength tests were run on several other materials utilizing 4 bags of Type III Portland cement and a constant viscosity. The percent passing the No. 200 sieve for these materials and the average seven (7) day compressive strengths of each are shown in Table 4.

TABLE 4

STRENGTH AND GRAIN SIZE CHARACTERISTICS
OF SOIL-CEMENT MIXTURES

	SANDY LOAM	SILTY LOAM	AGRICULTURAL LIMESTONE
PERCENT PASSING NO. 200 SIEVE	28	70	85
SEVEN (7) DAY COMPRESSIVE STRENGTH, PSI	318	115	260

These tests again indicate that native sandy materials do achieve substantially more strength in the mixtures than do finer soils. The sandy loam material also exhibited greater strength gain than did the agricultural limestone. The limestone did, however, show a larger strength gain than the silty material even though it's gradation was finer than that of the silty material.

Laboratory tests were run utilizing a wetting agent (trade name Alconox) to determine the proportion required in the water to obtain a surface tension of approximately 30 dynes per square centimeter as outlined in the New York Throughway Report (2). The proper mixture was found to be approximately 1 part of Alconox to one thousand parts of water.

A sample of soil (sandy loam with 35% passing the No. 200 sieve) was selected, and tests were run by the method previously described until proper proportions were established to obtain equal viscosities with mixes containing the same soil plus 4 bags of Type I Portland cement per cubic yard and liquid ingredients of water only, water plus varying percents of asphaltic emulsion, and water plus one part per thousand of wetting agent. Compressive strengths tests, soaked (4 hour immersion) and unsoaked, were run on the resulting specimens. Table 5 shows the results of these tests.

TABLE 5

UNCONFINED COMPRESSIVE STRENGTHS OF SLURRY USING VARIOUS MIXING LIQUIDS

MIXING LIQUID	WATER	WATER WITH 5% MS-2*	WATER WITH 10% MS-2	WATER WITH 15% MS-2	WATER WITH ALCONOX**
7-DAY STRENGTH AFTER 4-HOUR SOAK, PSI	494	470	490	429	693
7-DAY STRENGTH WITHOUT SOAK, PSI	612	532	505	450	691

* Emulsified asphalt based on percentage of water in the mixture.
** Alconox added on the basis of one part to one thousand parts of water by weight.

It may be noted that in both the soaked and unsoaked state the strengths of the plain water and water-alconox specimens were higher than those of the samples containing water and emulsified asphalt at all percentage levels.

Field Trials of Material for Slabjacking Slurry

A variety of sandy and silty soils ranging from a silty loam A-4 with 74% passing the No. 200 sieve to a sandy loam A-2-4 with 22% passing the No. 200 sieve were tested for pumping characteristics. Since laboratory tests had indicated that the sandy soils yielded higher strengths than the silty ones, primary emphasis was placed on the pumping of sandy soils. A cement content of 4 bags per cubic yard was selected for use in all field tests.

These tests revealed that, with the equipment used, satisfactory pumping could not be accomplished with soils having less than about 35% passing the No. 200 screen. Frequent cleaning out of equipment and hoses was required when coarser materials were pumped. All materials having more than 35% passing the No. 200 sieve pumped satisfactorily including the material with 74% passing the No. 200 sieve.

During the period of these field checks, tests were also run to determine the beneficial effects, if any, of adding emulsified asphalt (up to 15% of water) or wetting agent (1 part to 1000) to the water used for pumping. Observation revealed that the addition of emulsified asphalt might slightly increase the ease of pumping, but that the water-wetting agent mixture was definitely superior. Hole to Hole travel of the water-wetting agent mixture could be obtained with mixes appearing drier than either the plain water mixes or the water-asphaltic emulsion mixes.

Field Slabjacking

Based on the results of the previously mentioned laboratory tests and field observations a decision was made to use the following materials for the experimental slabjacking.

1. The soil must be relatively organic-free material, having more than 35% passing the No. 200 sieve. The material must be free of clay balls or aggregations of any kind.

2. Wetting agent and water (1 part alconox to 1000 parts water) would be used for the mixing liquid. The wetting agent was disolved in the water in the water tank.

3. Four bags of Portland cement (Type I) per cubic yard of soil would be used.

Utilizing the described ingredients, and with mixing and pumping being accomplished by use of a Koehring Model 50 slabjacking unit, a variety of field slabjacking was accomplished.

Jacking Bridge Approach Slabs - - Approach slabs on two bridges where fairly large depressions of the approach slabs and the adjacent road slabs had occurred on a section of interstate highway were jacked. No very large voids were evident under any of the slabs and primarily the jacking process consisted of raising the slabs from a fairly firm seat on the subgrade to the proper elevation.

One and one quarter inch diameter holes were drilled and a one inch jack nozzle was used for all jacking.

Typical hole patterns suggested by the slabjacking foreman were approximately as shown in Figure 3. These patterns, when utilizing the water-alconox-soil-cement mixture, were successful in lifting the slabs with no cracking of either the approach slabs or the adjacent road slabs. However, occasional moderate difficulty was experienced in breaking the slabs loose and initiating the lifting process.

In an attempt to alleviate this difficulty, hole patterns utilizing holes close to the joint as suggested in various published reports of mudjacking were tried. These patterns however were not as successful as the foreman's pattern, since the slurry tended to push the joint filler from the crack between the approach slab and the roadway slab and escape to the surface. Further experimentation led to the conclusion that for this type of jacking the holes should not be as close as 12 inches to the joint between the slabs and that a minimum distance of 18 to 24 inches seemed desirable.

Once the initial lift of the slab was made, good hole to hole travel of the slurry was noted, indicating that a fairly good distribution of the slurry was probably obtained.

A level and rod were utilized by research personnel to control the lifting process. In addition, the slabjacking foreman utilized a series of three equal height sighting stands to check the lift. Figure 4 shows both methods being utilized.

Scale 1" = 10.0'

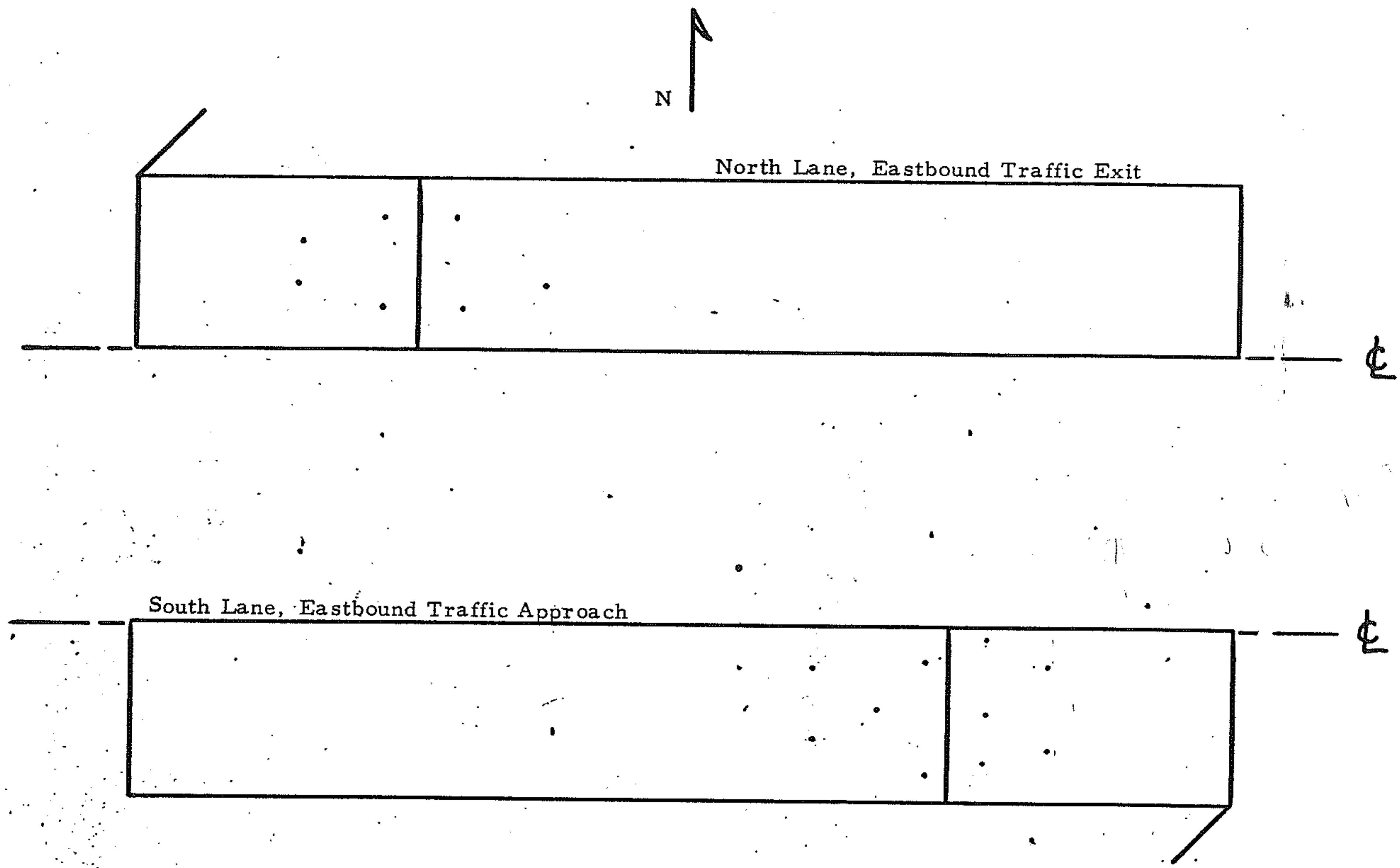

Figure 3 - Hole patterns established by Maintenance Supervisor to jack bridge approach slabs on Interstate 10.

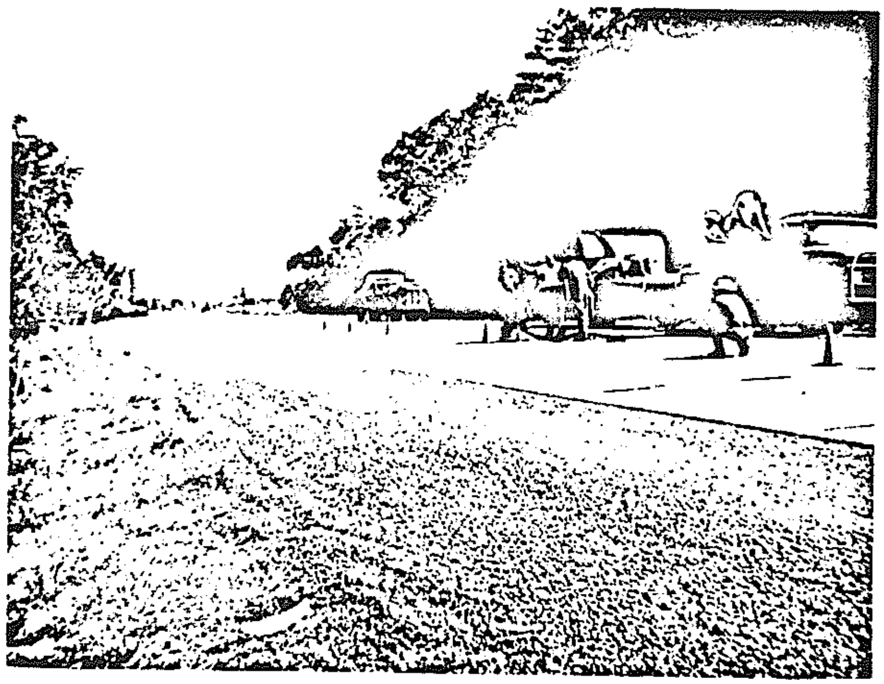

Figure 4 - Slabjacking Operation

Concrete cylinder molds were used to catch material from the pump nozzle for compressive strength testing. The material as pumped, when left in the field for 24 hours, moved into the laboratory humidity room for curing, and broken after seven days, yielded compressive strengths averaging 150 psi. The soil utilized for this jacking was a loam A-4 with 53 percent passing the No. 200 sieve.

After seven months of interstate traffic the slabs seem to be holding the elevations obtained during jacking quite well. No cracking of any of the jacked slabs has occurred.

Jacking Distorted Slabs - - During all slab jacking of roadway slabs 4 sacks of cement per cubic yard of soil were used, and an alconox-water solution (1 part to 1000) was used for the mixing liquid. The soils used were all A-4 sandy loams with from 36 to 48% passing the No. 200 sieve. Unless otherwise noted, the holes drilled for jacking were $1\frac{1}{4}$ inches in diameter. A level and rod were used for checking the amount of lift on all slabs. An effort was made to limit jacking to not more than two hundredths of a foot (about $\frac{1}{4}$ inch) during any one pumping. This procedure was generally successful. However, in some cases the initial lift of the slab occurred suddenly and was as much as $\frac{1}{2}$ inch.

Figure 5 shows a profile view of a section of roadway selected for slabjacking. This project is located in Calcasieu Parish near Lake Charles, Louisiana, and is adjacent to the Kayouchee Coulee Bridge on US 90 extension. The slab numbers shown in the figure represent the order of occurrence of the slabs west of the bridge.

It may be noted from the figure that a considerable amount of differential subsidence and displacement of the slabs had occurred. It is probable that most of the displacement of the slabs is due to poor subgrade conditions.

Jacking in this section was accomplished by selecting individual segments and pumping within these segments to achieve a smooth transition to succeeding areas. Figure 6 shows a plan and profile view of one of the selected segments. Pumping in this segment was initiated along the centerline on the south side of the road in slab No. 60. Hole spacing was approximately as shown. Material was pumped on a rotating basis along the centerline proceeding from slab 60 to slab 58 and back with no lift of the slabs occurring. About 2 cubic yards of material was pumped into these holes and the first movement occurred when a crack formed on the outside of the slab on the opposite side of the road. (See Figure 6) A crack was present in slabs 58 and 59 on the south side of the road prior to starting the jacking. The new crack did not start at that point, although it later extended into and across the slab being pumped (slab 59). No lift had been noted in the slab where cracking occurred prior to the appearance of the crack even though elevations were being checked on the slab. No leakage at joints or edges of the roadway was noted during pumping.

The amount of material pumped into the slab segment with no leakage occurring indicates either a fairly large cavity under the slabs or a very soft and yielding subgrade. The presence of a cavity seems most logical since a cavity extending under the slab on the other side of the road could cause the travel of the slurry across the road and cause the cracking to occur. Jacking was proceeding at or very near the lowest point of the segment when the cracking occurred and no detectable rise of any of the slabs had occurred prior to the cracking. After the cracking occurred considerable additional pumping was required before the slabs started to move and were brought to the elevations shown.

In later segments jacking was tried beginning at the low point and beginning at the high point. In those areas where initial loosening of the slab segments began in the slab nearest the high point less cracking occurred than when the initial loosening was at the low point. It should be pointed out, however, that should the low point occur entirely within one slab instead of at the juncture of two slabs it would seem logical that initial jacking should commence at the low point. This situation was

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Vertical Scale: 1" = 0.5'

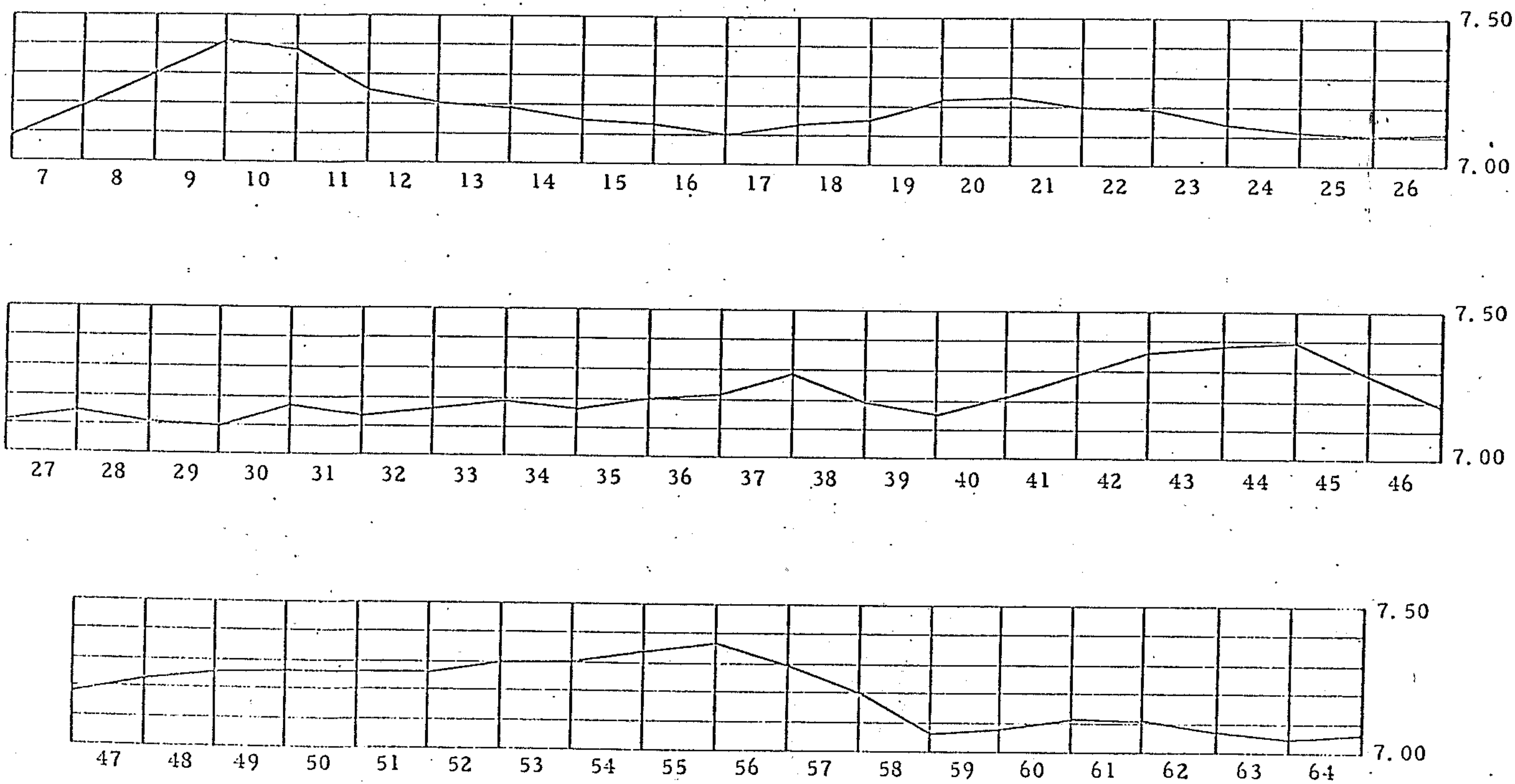

Figure 5. Initial profile of slabjacking test section on U. S. 90 extension at Lake Charles.

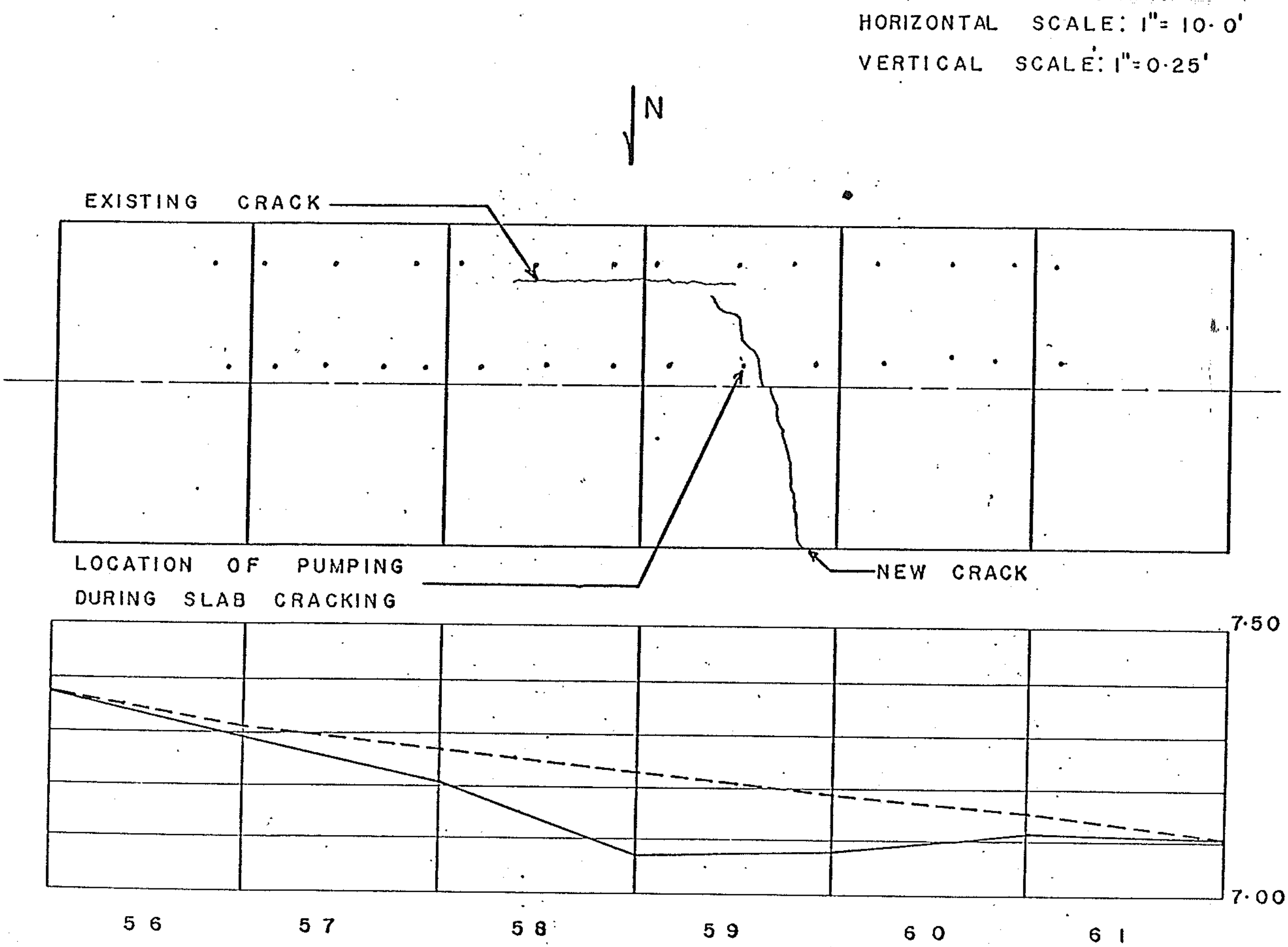

Figure 6. Plan and Final profile of a segment of the slabjacking test section on U. S. 90 extension at Lake Charles.

not encountered in this study.

Hole spacing was also studied in these segments. No definite determination of a desirable hole spacing could be made. However, observations did indicate the following:

1. Holes placed closer than 18 inches to a joint or edge tended to cause leakage prior to lifting.
2. The slurry will travel at least 6 feet, though the exact distribution is not known.
3. Holes spaced too closely tend to weaken the slab and increase the danger of cracking. Figure 7 shows a segment with cracking which might be attributable to close hole spacing.

The consistency of the mix was varied to try to determine a desirable flow for lifting slabs. Again, no definite determination could be made. However, experience indicated that starting with a fairly thick slurry until lift began, then thinning the slurry for the remaining pumping was feasible and seemed to work well. Unfortunately none of the slabs pumped could be removed to determine the effect of this method. The elevations are remaining fairly stable two months after the completion of the jacking.

Cracking of one slab in the lane opposite the one where the jacking had been accomplished occurred during one night. It seems probable that this cracking was caused by traffic over the slab which had been raised somewhat during jacking in the other lane. An unfilled cavity caused by the adjacent lane jacking probably existed under the slab. (See Figure 8) Failures of this type indicate the desirability of jacking the entire roadway cross-section at the same time. This procedure is of course highly impractical due to traffic problems associated with blocking the entire roadway. However, jacking of parallel slabs in adjacent lanes probably should be accomplished as nearly at the same time as is practical, preferably during the same day.

Roadway jacking was accomplished at a location near Monroe, Louisiana in which $2\frac{1}{2}$ inch diameter holes were utilized. These holes did not seem to appreciably increase the ease with which slabs could be lifted. It is probably better to use smaller holes such as the $1\frac{1}{4}$ inch holes used near Lake Charles since less breaking of the slab bottom is likely to occur.

Cavity Filling - - A section of interstate roadway near Lake Charles was selected for experimentation with void filling under this study. This section of roadway crossed an area where incomplete removal of organic material had caused considerable subsidence of the embankment and sub-base. The subsidence was confined primarily to an old stream trace and the slabs were still bridging the

Horizontal Scale: 1" = 10.0'
Vertical Scale: 1" = 0.25'

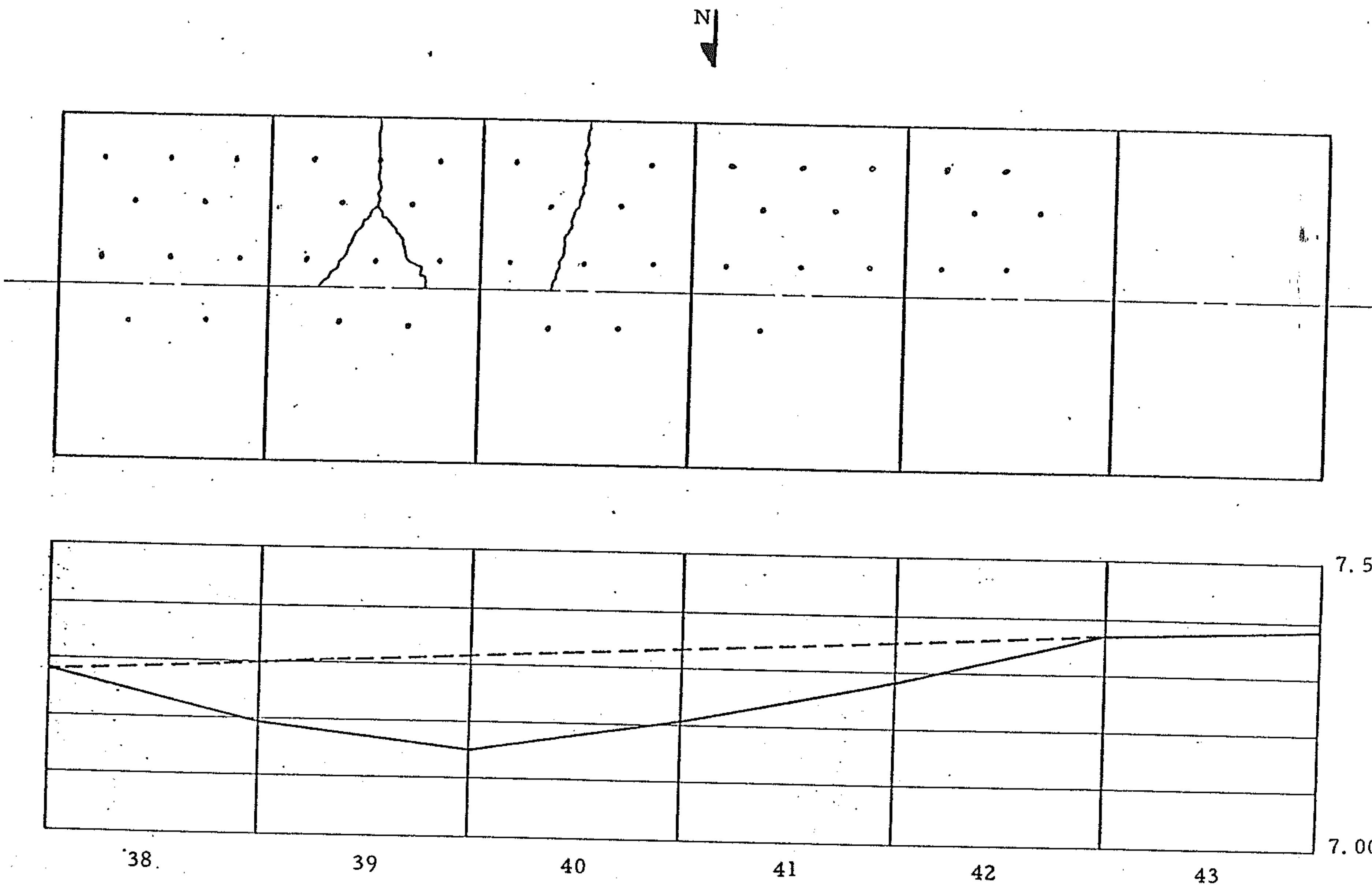

Figure 7. Plan and final profile of a segment of the slabjacking test section on U. S. 90 extension at Lake Charles.

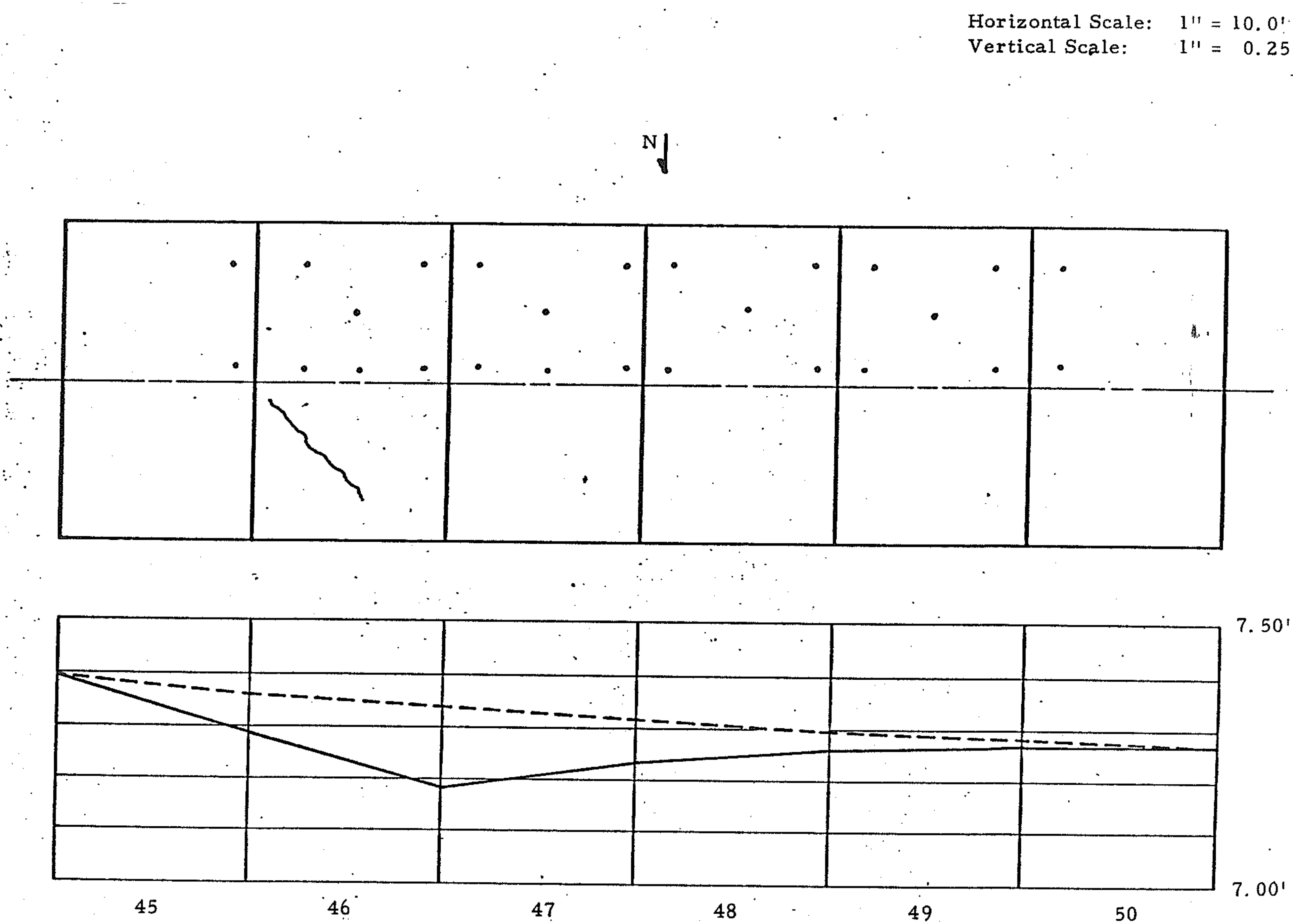

Figure 8. Plan and final profile of a segment of the slabjacking test section on U. S. 90 extension at Lake Charles.

cavity which was as deep as three inches at some locations.

Holes were made at six feet intervals into the slabs to try to determine the extent of the voids and to check the flow of the slurry. Pumping was continued until flow between all holes known to be within the cavity was evidenced by flow of slurry from the holes when adjacent holes were jacked. Utilizing the wetting agent - water slurry, filling of the voids was accomplished with slurry almost as viscous as that used in slab raising after lift has started. The same materials and equipment used for slab raising performed satisfactorily.

Filling of cavities at bridge ends where erosion had caused cavities near abutments was also observed for this study.

The slurry used must be thinner than that used in the other types of jacking cited since little if any pressure can be exerted on the slurry and most of the flow must be gravity flow. The filling of the voids did appear quite successful utilizing the same materials and equipment used for roadway jacking.

Laboratory Tests of Field Materials Used on Test Section

During the fairly extensive slab lifting operations on the section of U. S. 90 extension near Lake Charles, a large number of samples were molded for compressive strength testing. These materials were taken from the nozzle of the mudjack hose directly into concrete cylinder molds, kept for 24 hours in the field, then transported to the laboratory moist room and cured for an additional six days. Seven day compressive strengths for the specimens ranged from 50 psi to 350 psi, with the thicker slurries having the higher strengths. This variation illustrates the importance of good slurry control and of keeping the water content of the slurry as low as possible. The use of wetting agents or ~~perhaps~~ other additives to keep the water content low while obtaining sufficient flow definitely seems worthwhile.

General Discussion

The apparatus used for jacking on this project utilizes a combination mixing - pumping unit. In a continuous mixer of this kind variations in slurry viscosity and mixture proportions are difficult to control. A separate mixer of the batch type where materials could be more easily controlled would probably be a great aid to the jacking process. Better control of viscosity and strength of the slurry could probably be obtained utilizing such equipment.

Due to the short duration of this study very little was learned about the long term durability of the jacking accomplished during the study. The observations made during this study do, however, indicate good short term stability utilizing the described mixtures.

The breaking of the slab in a lane adjacent to the one being jacked when the voids caused by the jacking were not filled prior to traffic use, indicates the importance of filling all voids created by the jacking as soon as possible. Special care should be taken to see that all voids are filled at the ends of depressions or dips after the slabs have been raised to the desired elevation.

CONCLUSIONS

1. Hole spacing is still a matter of judgement and no definite conclusions can be drawn. However, the following general guidelines may be acceptable:

    a. Do not place holes closer than 18 inches to edges or joints when jacking to lift slabs. If jacking to fill cavities, however, holes must be placed where cavities occur even if at a joint.

    b. Holes should probably not be spaced closer together than six feet due to the danger of slab weakening.

    Using these general guidelines the judgment of an experienced slabjacking foreman is probably the best guide to hole placement.

2. Holes $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter are probably best for jacking since no lifting superiority seems attributable to larger holes and less breaking of slab bottoms is likely to occur.

3. During this study it appeared that starting jacking at the area of least lift and proceeding to and through the area of greatest lift caused less cracking of the slabs than did jacking from the low point to the high point. Greater amounts of jacking must, of course, be done at low points once lifting of the slabs is started. If the low point occurs totally within a particular slab, initial jacking should probably begin at the low point to avoid overstressing and cracking the slab.

4. Jacking should be completed on parallel slabs in adjacent lanes as close to the same time as practicable. Filling of all voids in the jacked slabs and in

adjacent slabs is highly important in preventing slab deterioration when subjected to traffic.

5. Soils within the A-4 classification, relatively organic free, and devoid of clay lumps or other aggregations are satisfactory for use in slabjacking. The sandier soils within this classification will yield the highest strengths.

6. The addition of a wetting agent to the water used in slurry mixing appears to aid travel of the slurry while causing no loss of strength when compared to slurries mixed with water only.

7. The addition of emulsified asphalt in quantities up to 15 percent of the mixing water does not greatly increase the flow of the slurry. Some loss of strength is apparent for water-asphalt slurries when compared with those mixed with water only at the same relative viscosity and cement content.

8. A Portland cement content of four bags per cubic yard of soil yields strengths generally in the lower range of those achieved in soil cement stabilization in Louisiana.

9. On the basis of compressive strength, the addition of hydrated lime to the slurry does not appear to be justifiable.

10. Laboratory strengths obtained with a well graded native sandy loam soil were greater than those obtained utilizing agricultural limestone with the gradation shown in this report.

11. For slab raising, observation indicates that starting with a thick slurry until slab lift begins, then thinning the slurry to prevent stooling and aid slurry travel, may be a desirable procedure. Careful control of the slurry is important. The slurry must have enough flowability to insure proper spread and to prevent stooling, but within these limits should be as viscous as practicable, in order to obtain the maximum possible strength.

12. Lifting of slabs should be done in small increments. Lifting not more than $\frac{1}{4}$ inch in any one place prior to changing locations is probably good practice.

IMPLEMENTATION RECOMMENDATIONS

Although long term effects of the procedures investigated in this study have not been evaluated due to the short period of time since most of the field work was performed, there seems to be ample justification for utilization of certain procedures, and materials at this time.

It is therefore suggested that the following recommendations be implemented immediately:

1. Holes should be spaced no closer than six feet apart and no closer than 18 inches to the edges or joints of slabs when jacking to raise slabs. Otherwise, spacing should be based on the judgment of an experienced slabjacking supervisor.

2. Holes should be drilled with a diameter of $1\frac{1}{4}$ to $1\frac{1}{2}$ inches to avoid breaking the slab bottoms.

3. As a general rule, jacking should start near the high point of the area to be jacked and proceed to and through the low point on a rotating basis. When the low point occurs totally within on slab, jacking should begin at the low point.

4. Jacking should be completed on all slabs where voids created by jacking in adjacent slabs has occurred, as soon as is possible after the voids are created. This action will help to avoid cracking of the slabs under traffic.

5. Soils within the A-4 classification relatively free of organic materials, clay lumps, or aggregations of any kind, should be used. Preference should be given to the sandier soils within this classification when practicable.

6. The slurry should consist of soil meeting the above criteria, wetting agent (Alconox or equivalent), water, and four bags of Portland cement per cubic yard. No other additives should be use.

7. For slab lifting, jacking should be initiated using a fairly thick slurry. As soon as lifting begins, the slurry should be thinned until good hole to hole travel is obtained.

8. Jacking should not be continued for long periods of time in any one hole even if no lift is occurring. Excessive pumping in any one location tends to cause cracking of the pavement.

9. A separate batch type mixer for the initial proportioning and mixing of the slurry seems desirable. Better control of slurry viscosity and strength can probably be obtained than with a continuous mixing-pumping operation.

10. Further observation of the long term stability of the areas jacked under this study should be accomplished.

If the listed procedures and materials are adhered to and close surveillance is maintained in order to employ the jacking process before extensive deterioration of the slabs has occurred, some savings in money and considerably increased safety may be realized.

Actual monetary savings to Louisiana at this time probably would not exceed fifty thousand dollars annually due to the relatively new conditions of most of the concrete roadways in the state. This savings could increase considerably with the age of the pavements over the next few years.

The increase in safety due to the use of the suggested slabjacking procedure is more difficult to evaluate but is certainly obvious. The use of patches, especially of a different material (such as asphalt), is disconcerting to the average driver who encounters them. This is especially true at bridge approaches where overlays of asphaltic material may create the illusion of a void.

Rough or deteriorated spots in the pavement also constitute a considerable traffic hazard which might be eliminated by timely use of the slabjacking procedure.

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