Technical Report Documentation Page

1. REPORT No.

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE

Construction of a Fill by a Mud Displacement Method

5. REPORT DATE

1962

6. PERFORMING ORGANIZATION

7. AUTHOR(S)

William G. Weber, Jr.

8. PERFORMING ORGANIZATION REPORT No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

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

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

13. TYPE OF REPORT & PERIOD COVERED

12. SPONSORING AGENCY NAME AND ADDRESS

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A highway fill was constructed across an open water cove on the west side of San Francisco Bay by displacing the underlying soft mud to depths of as much as 60 ft by the weight of the placed fill. Various construction methods were attempted and a method of obtaining reasonably uniform mud displacement developed. The fill failures were analyzed and the factors affecting these failures evaluated. The measured settlements and pore pressures are presented and evaluated. The performance of the highway after three years of use is given.

17. KEYWORDS

18. No. OF PAGES:

20

19. DRI WEBSITE LINK

http://www.dot.ca.gov/hq/research/researchreports/1961-1963/62-11.pdf

20. FILE NAME

62-11.pdf

Reprinted from HIGHWAY RESEARCH BOARD PROCEEDINGS
Vol. 41, 1962

Construction of a Fill by a Mud Displacement Method

WILLIAM G. WEBER, JR., *Associate Materials and Research Engineer, Materials and Research Department, California Division of Highways, Sacramento*

A highway fill was constructed across an open water cove on the west side of San Francisco Bay by displacing the underlying soft mud to depths of as much as 60 ft by the weight of the placed fill. Various construction methods were attempted and a method of obtaining reasonably uniform mud displacement developed. The fill failures were analyzed and the factors affecting these failures evaluated. The measured settlements and pore pressures are presented and evaluated. The performance of the highway after three years of use is given.

• A FILL was constructed across Candlestick Cove on the west side of San Francisco Bay, displacing up to 65 ft of soft mud. The first two contracts were constructed on an experimental basis to determine how to construct the fill, and the freeway completed under four more contracts.

The soil formation in the open water area of Candlestick Cove consisted of unconsolidated sediments of recent geological age, the upper layer of which was a very soft mud with its surface at about elevation —5. The bottom of the soft mud varied from elevation —40 to —80. This soft mud was underlain by a somewhat stiffer material consisting variously of clayey sand, sandy clay, or clay. Bedrock varied from elevation —110 to —220.

The freeway alignment was 11,600 ft across the open water section. Various alternates were considered during design (*i.e.*, bridge, mud stripping, and sand drains), all of which would have been expensive. The California Highway Commission authorized in 1952 the construction of an experimental fill southward from the north end of Candlestick Cove to determine the feasibility of constructing an open water fill by end dumping methods. This was successfully accomplished for the conditions at this location. In June 1953, a contract was let to construct an experimental fill where a greater thickness of soft mud existed to study construction techniques further. The remaining portion was then constructed under normal construction contracts. Figure 1 is a general view of the area.

PROPERTIES OF BAY MUDS

The moisture content of the soft bay mud varied from an average of 90 percent at elevation —5 to 60 percent at elevation —60. The individual moisture tests were scattered in a random manner over a range of 20 percent with the moisture tending to decrease with depth as the only evident trend.

62-11

Figure 1. General view of open water fill, final grading operations in progress.

The samples obtained before construction indicated that the shearing strength of the soft bay mud was near zero at elevation —5, and increased an average of 14 psf per ft of depth.

The consolidation tests indicated that the soft bay mud was fully consolidated under its loading prior to construction. A coefficient of consolidation of 3×10^{-3} sq ft per hr was obtained for conditions existing after completion of the working table.

The vertical permeability of the soft bay mud was 1.1×10^{-5} ft per hr and the horizontal permeability was 2.2×10^{-5} ft per hr, after construction of the working table.

The liquid limit of the soft bay mud varied from 50 to 60 and averaged approximately 55. The plastic index varied from 25 to 35 and averaged approximately 30.

The soft bay mud was underlain by a stiff mud layer with sand lenses or

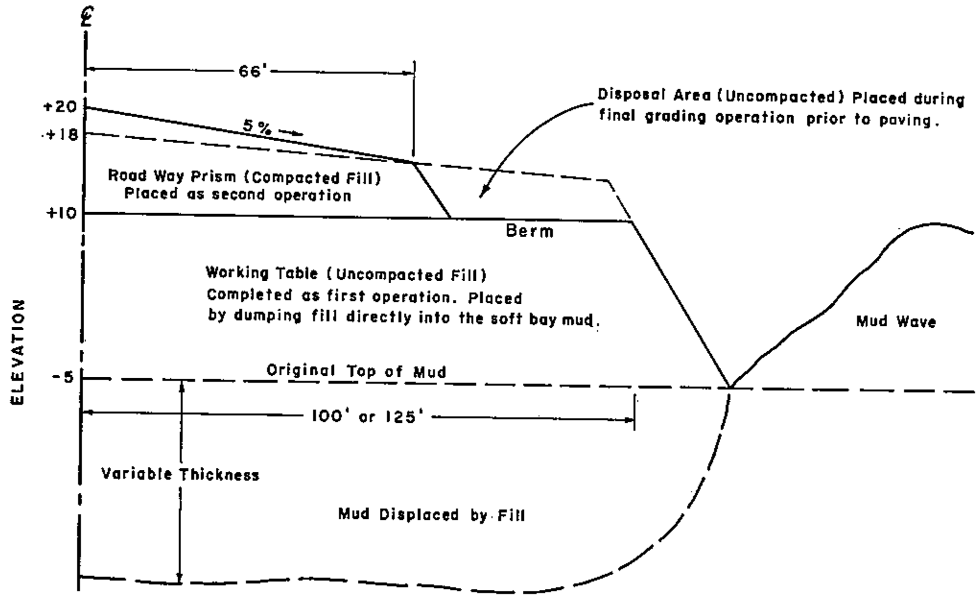

Figure 2. Typical cross-section of fill.

layers. The stiff mud layer had a shearing strength in excess of 1 ton per sq ft. Preconsolidation had occurred, perhaps due to desiccation, in recent geological times. The stiff mud layer had sufficient strength to support the fills; however, some settlement of the fill could be expected due to this layer.

CONSTRUCTION OF THE WORKING TABLE

The fill as constructed consisted of two parts, as shown in Figure 2. A working table was placed by end dumping methods and was in the uncompacted condition. A smaller compacted prism was placed on the working table and referred to as the roadway prism.

The requirement of the working table was to provide a stable platform on which to place the roadway prism. This could be accomplished by placing a wide working table, using the extra width as berms. During construction of the first unit, it was found that any height of working platform above the tide would result in large failures. It thus appeared that a stable platform could be built by using the weight of the fill to displace the soft bay mud. During construction of the first unit, mud displacement was attempted and found feasible with a reduction in the width of the working table from 400 to 250 ft. During the second unit, the construction methods were further studied and a method of operation developed where near total mud displacement was obtained.

The working table was constructed by end dumping methods, consisting of placing the fill material as close to the edge of the fill as practical and using a bulldozer to push the dirt over the side. Sections of the fill near the edge would then fail, then additional fill would be placed in the failed areas restoring them to the desired grade. The nose of the fill was maintained in a wedge shape by pushing the mud laterally. The displaced mud then formed large mud waves on each side of the fill.

The studies from the first and second units indicated several items that affect the displacement of the soft mud by the fill. The various items affecting the displacement of the soft mud were the shape of the nose, rate of placing fill, type of fill material, elevation to which the working table was carried, effect of the tide, and extent of the mud wave.

The use of a wedge-shaped nose, with the sides of the wedge at about 30 to 45 deg to centerline, effectively moved the soft mud laterally producing a reasonably uniform mud displacement up to about 100 ft from centerline. A long, slender extension of the nose along centerline resulted in large mud displacement on centerline and small mud displacement at the sides. A blunt nose resulted in a vertical sawtooth type of displacement. The shape of the nose tended to control the evenness of the mud wave built up around the nose and controlled the shape of the cross-section of the bottom of the fill as later determined by borings.

The desirable rate of placing fill was one that would maintain the top of the working table at the desired elevation and still slowly advance the fill. The 12,000 cu yd per day average used was sufficient for this purpose.

The type of fill material used had an apparent effect on the starting of failures. Rocky fills did not fail as readily as fine-grain fills. Once a failure had started, the type of fill did not appear to have any effect on the rate at which failure occurred.

The elevation of the top of the working table was related to the driving force available for displacing the soft bay mud. It was found that to keep the mud wave moving, the top of the working table had to be 3 to 5 ft above the crest of the mud wave. The planned elevation of the top of the working table, elevation +10, was increased to as high as elevation +18 to displace the mud where high mud waves occurred.

The strength of the soft bay mud was reasonably uniform in the area of the open water fill and exerted a constant effect on the fill failures.

The tide varied at Candlestick Cove, from a maximum of elevation +8 to a minimum of −2. The weight of the water at high tide acted to resist failure of the fill by supporting the mud wave. As the tide stage dropped, the mud wave would fail flowing away from the fill generally causing the edges of the fill to drop. The tide drop that resulted in fill movement was about 3 to 5 ft.

The mud wave was formed as the fill displaced the soft mud. The mud waves that were formed extended 500 to 700 ft from centerline, depending on the amount of soft mud displaced. These mud waves had a crest 20 to 40 ft from the top edge of the fill. The mud wave crest varied from elevation +5 to +16. The back of the mud wave sloped on about a 5 percent grade to elevation +2 and then extended out at about a 2 percent grade.

The mud wave acted as a berm or support for the fill, greatly increasing the stability of the fill. In the completed fill section, with the roadway prism in place, stability analysis indicated that the mud wave contributed about 30 percent of the resisting force.

The tide had considerable effect on the height of the crest of the mud wave. As the tide stage rose, the crest of the mud wave would build up if failure of the fill occurred. As the tide stage decreased, the mud would start failing within itself and gradually tend to flow away from the fill.

The strength of the mud wave was determined after the fill failures. The shearing strength of the soft mud in the crest of the mud wave was found to vary from 0.05 to 0.30 ton per sq ft depending on the type of failure

Figure 3. Nose of fill dropped about 7 ft (see Fig. 4).

that had produced the mud wave. This strength was approximately uniform to a depth of about elevation —20 and then the strength increased as before construction.

As the work progressed, construction procedures were varied to obtain maximum mud displacement. This was done by varying the factors affecting the mud displacement. A record of the amount of fill yardage placed at each station was kept so that it would be possible to estimate the amount of mud displaced. The major factor affecting the failures, and as a result affecting the mud displacement, was the height of the crest of the mud wave. The strength of the mud in the mud wave was reduced by mud blasting so that the mud wave would tend to flow away from the fill. During periods of high tide and/or high crests of the mud wave, the elevation of the top of the working table was raised in the unstable area. The rate of advance of the nose of the fill was maintained between 10 and 30 ft per day to keep the mud moving uniformly. This method of controlling the mud displacement was successful in obtaining 80 percent or greater mud displacement under the roadway prism.

FAILURES DURING CONSTRUCTION OF THE WORKING TABLE

As the nose of the fill was advanced from the stable portion of the working table, a crack would develop near the stable portion as shown in Figure 3. Regardless of how far the fill was advanced past this crack, movement would continue to occur at this location until the nose had become stable. Then the cracking would

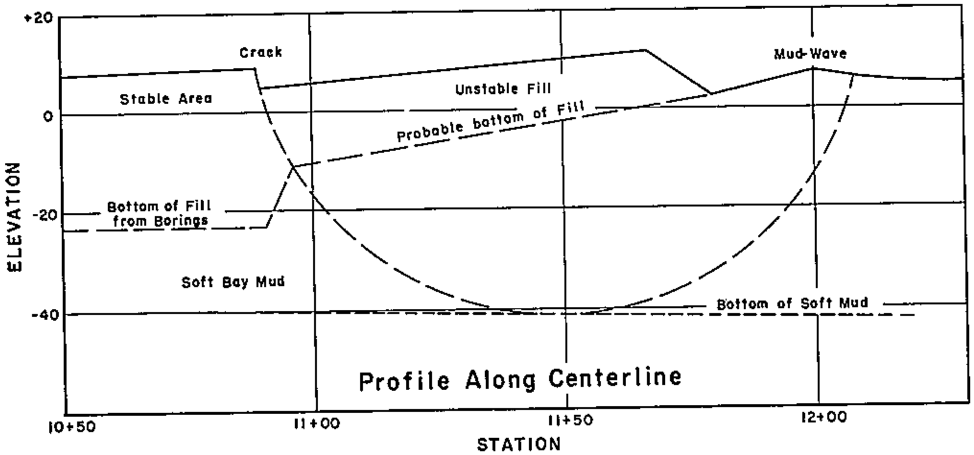

Figure 4. Typical shear-type failure.

advance to the point where the fill was again unstable. Studies were made on the failures by measuring the surface movements and running shear circles. From these measurements two primary types of movement were found to occur: (a) shear type—a rotary movement where the fill would have a large drop at the crack and little or no movement at the edge of the fill, as shown in Figures 4 and 5a; (b) squeeze type—a movement where the drop would be uniform over the failed area with a small horizontal movement occurring, as shown in Figures 5b and 6. The normal type of failure was the shear type. The mud was forced up about 20 to 40 ft from the fill and appeared to move in a vertical direction. The surface of the crest of the mud wave had a rough appearance. Occasionally a vertical face appeared on the side of the mud wave away from the fill. These shear failures appeared to follow a rotational movement.

On the few occasions that the fill was rapidly advanced, with small mud displacement, an unusual type of failure occurred that has been referred to as a squeeze-type failure. Generally, some factor (such as an extremely large build-up of the mud wave, a period of high tides, or an extended period where the nose of the fill was not advanced and then rapidly advanced) caused this condition to occur. The failed portion of the fill would crack in all directions and the settlement would occur rather uniformly. The failed area tended to settle at a slow, steady rate. The mud was pushed out from under the fill at an angle with a smooth appearance, and a high mud wave was not built up with this type of failure. When the soft mud was displaced to elevation —20 to —30, the movement would cease with the fill becoming stable. In analyzing this type of failure it was assumed that a sliding action occurred in the soft mud.

There were many factors affecting the fill failures, as previously discussed. These factors were varied to obtain maximum mud displacement. The failure resulting was of a modified shear type. In this type of failure, the fill would crack in all directions with a large drop at the edge of the fill and a small drop near the stable portion of the fill. The stable portion of the fill advanced at about the same rate as the nose of

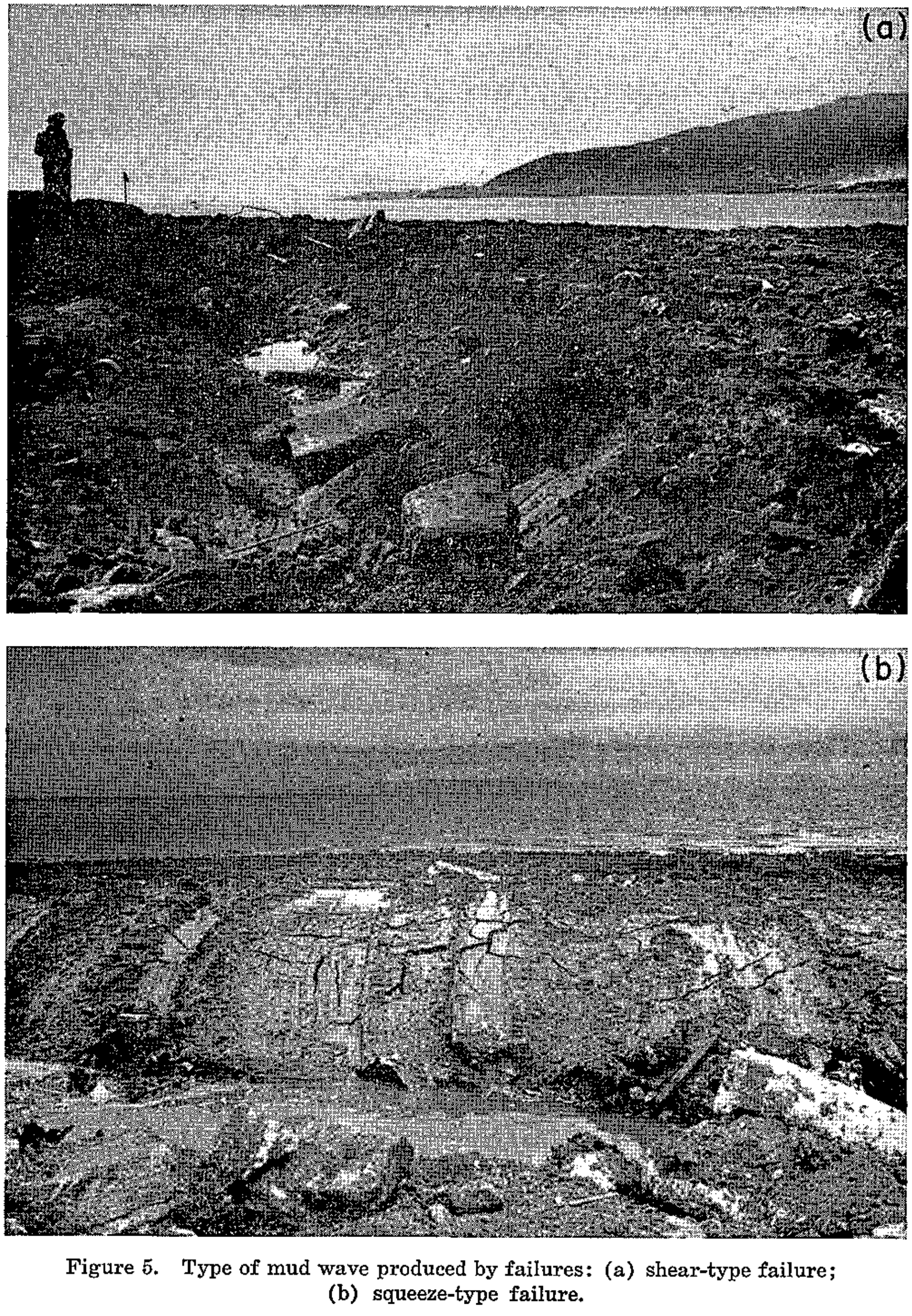

Figure 5. Type of mud wave produced by failures: (a) shear-type failure; (b) squeeze-type failure.

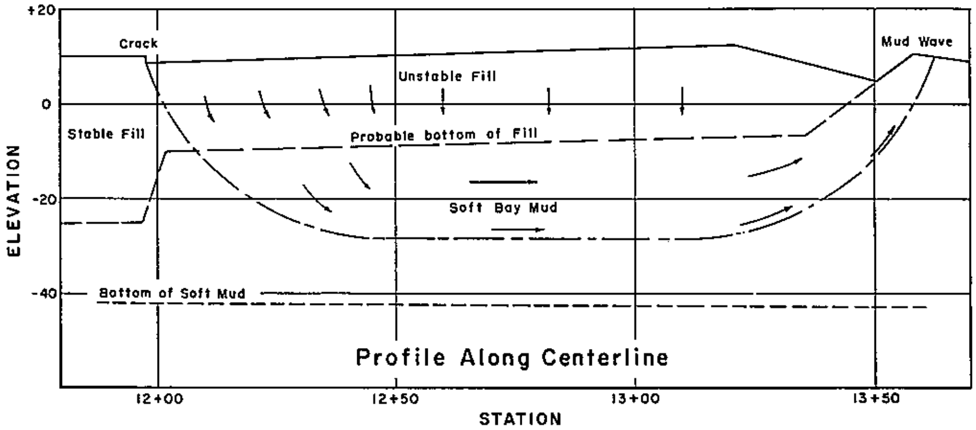

Figure 6. Typical squeeze-type failure.

the fill. This type of failure appeared to be a series of shear circle movements.

Stability analysis of the shear-type failures indicated a shearing strength of the soft bay mud of 70 to 210 psf or an average of 155 psf. The stability analysis of the squeeze-type failures indicated a shearing strength of the soft bay mud of 25 to 75 psf when the sliding surface was assumed just below the bottom of the fill. A shearing strength of 200 to 300 psf was indicated when the sliding surface was assumed just above the stiff bay mud. The sliding surface was probably 5 to 10 ft below the bottom of the fill.

Samples of the soft bay mud obtained from the mud waves soon after the fill became stable, indicated shearing strengths ranging from 50 to 200 psf. The higher strengths were obtained where shear failures had occurred and the lower strengths where squeeze failures had occurred.

Borings through the working table, made immediately after its completion, indicated shearing strengths from 150 to 250 psf immediately below the fill with the strength increasing with depth. There was an appreciable reduction in shearing strength due to the remolding of the soft bay mud by the fill failures. The shearing strength of the laboratory remolded samples of the soft bay mud varied from 50 to 100 psf.

The borings made at various times after completion of the fill indicated the shearing strength of the soft bay mud gradually increased with time, as shown in Figure 7. The time required for the soft bay mud to regain its original strength depended on the degree of remolding that occurred in the soft bay mud, and varied from one to two years. As further consolidation has occurred, the shearing strength of the soft mud increased and now exceeds its original strength. This increase in the strength of the soft bay mud has improved the stability of the main fill.

DISPLACED MUD

Borings were made, as the working table was constructed, to determine the depth to which the mud was being displaced. The borings were made at each station on centerline and about 75 ft right and left of centerline. Based on these boring data, profile and cross-sections of the bottom of the fill were determined and typical

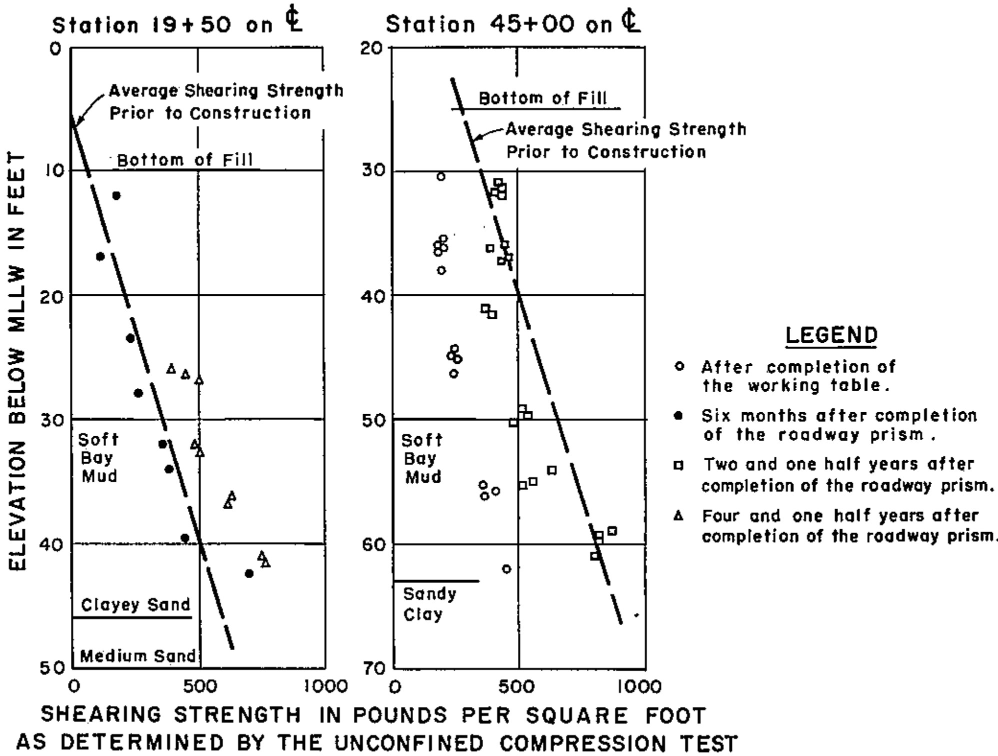

Figure 7. Shearing strength of soft bay mud at various times during and after construction of open water fill.

examples are shown in Figures 8 to 14.

Stations 6+00 to 60+00 had a great variation in the amount of displaced mud. There were several locations where the amount of soft mud remaining below the fill varied from 0 to 40 ft in a distance of 100 ft. These variations occurred in both the profile and cross-sections. The two experimental units are in this section of the roadway and account to a great extent for the variable amount of soft bay mud remaining below the working table.

The section of roadway from Stations 60+00 to 120+00 was the area where controlled mud displacement was used. Essentially total mud displacement was obtained in this area. There are fewer than 5 ft of soft mud remaining below the working table in about 50 percent of the locations where borings were made. Only one location indicated over 20 ft of soft mud remaining below the working table.

CONSTRUCTION OF THE ROADWAY PRISM

As the working table was completed, the roadway prism was placed on it. The roadway prism consisted of a 10-ft high fill placed in 8-in. compacted lifts, 130 ft wide on the top with 2:1 side slopes. Profile grade of the roadway prism was +20 as constructed. In the final grading operations, cuts and fills were made to

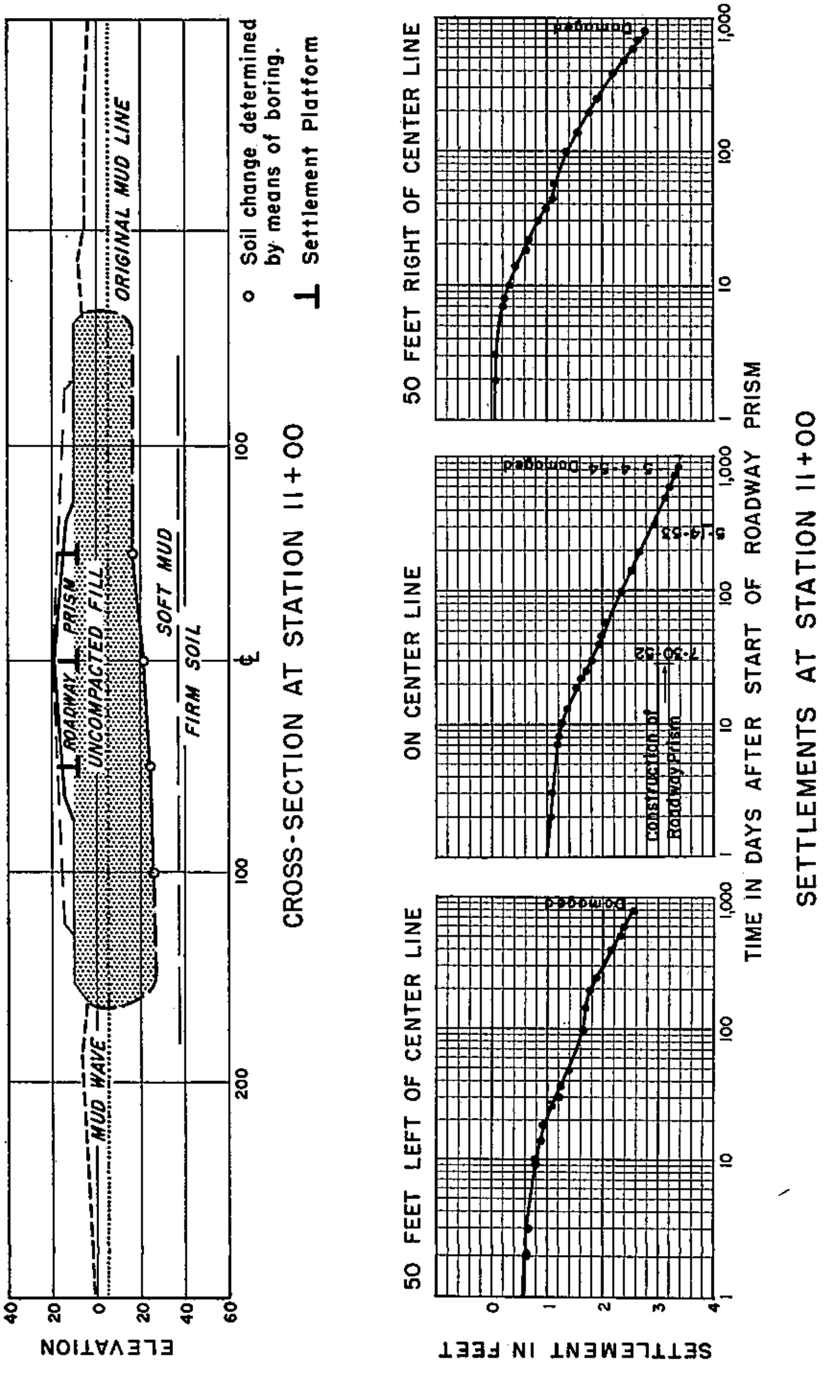

Figure 8. First unit, 300 ft wide.

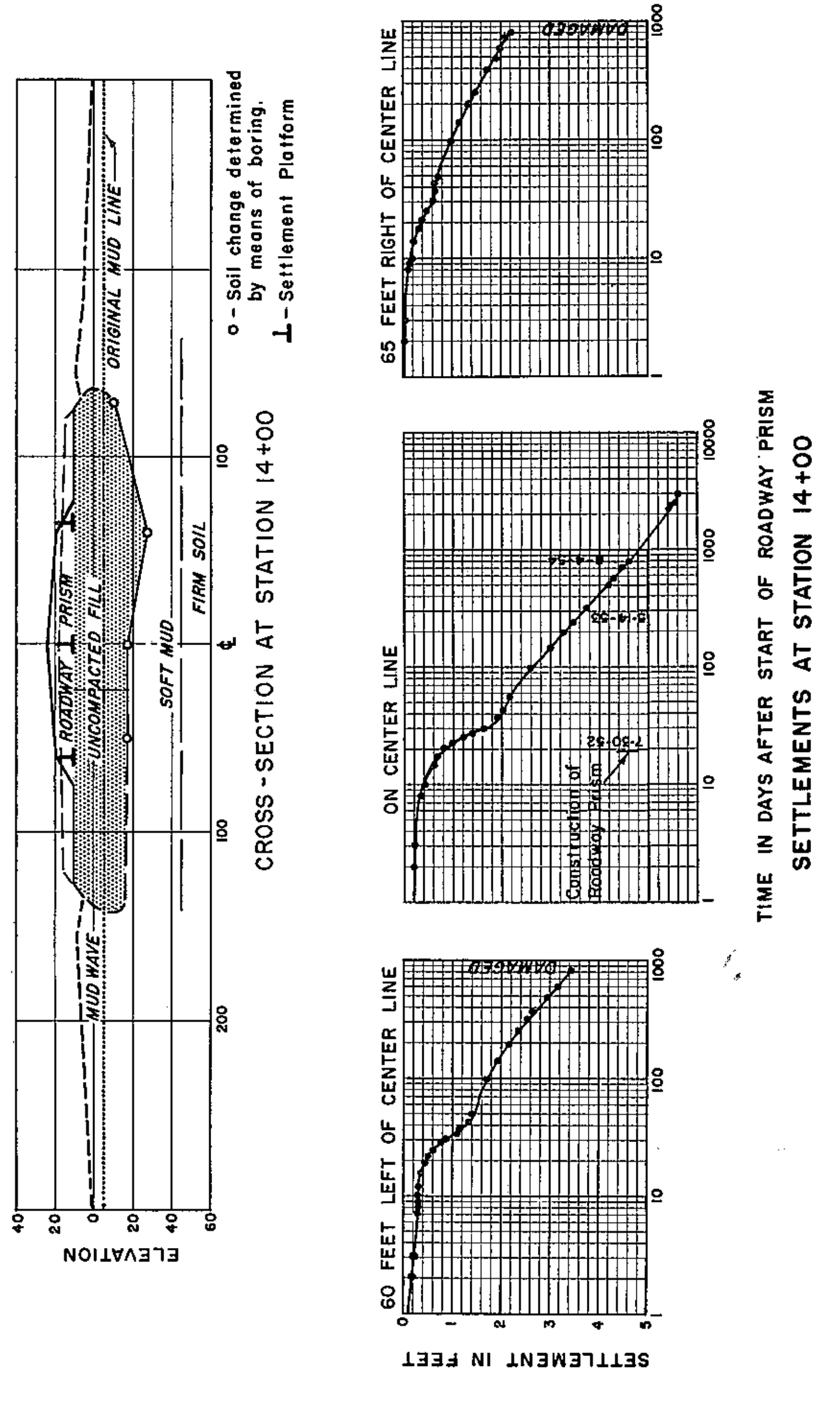

Figure 9. First unit, 250 ft wide.

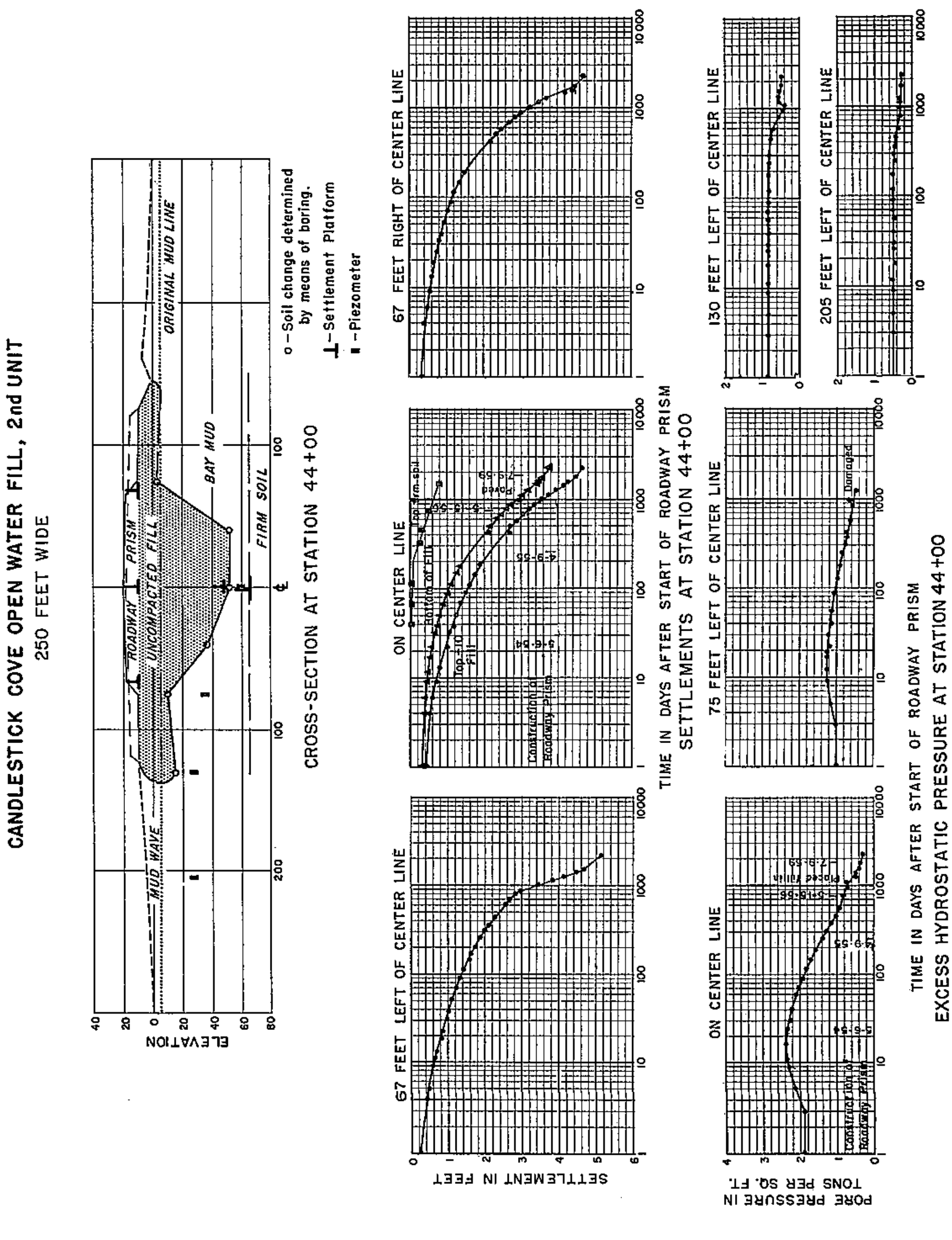

Figure 10. Second unit, 250 ft wide.

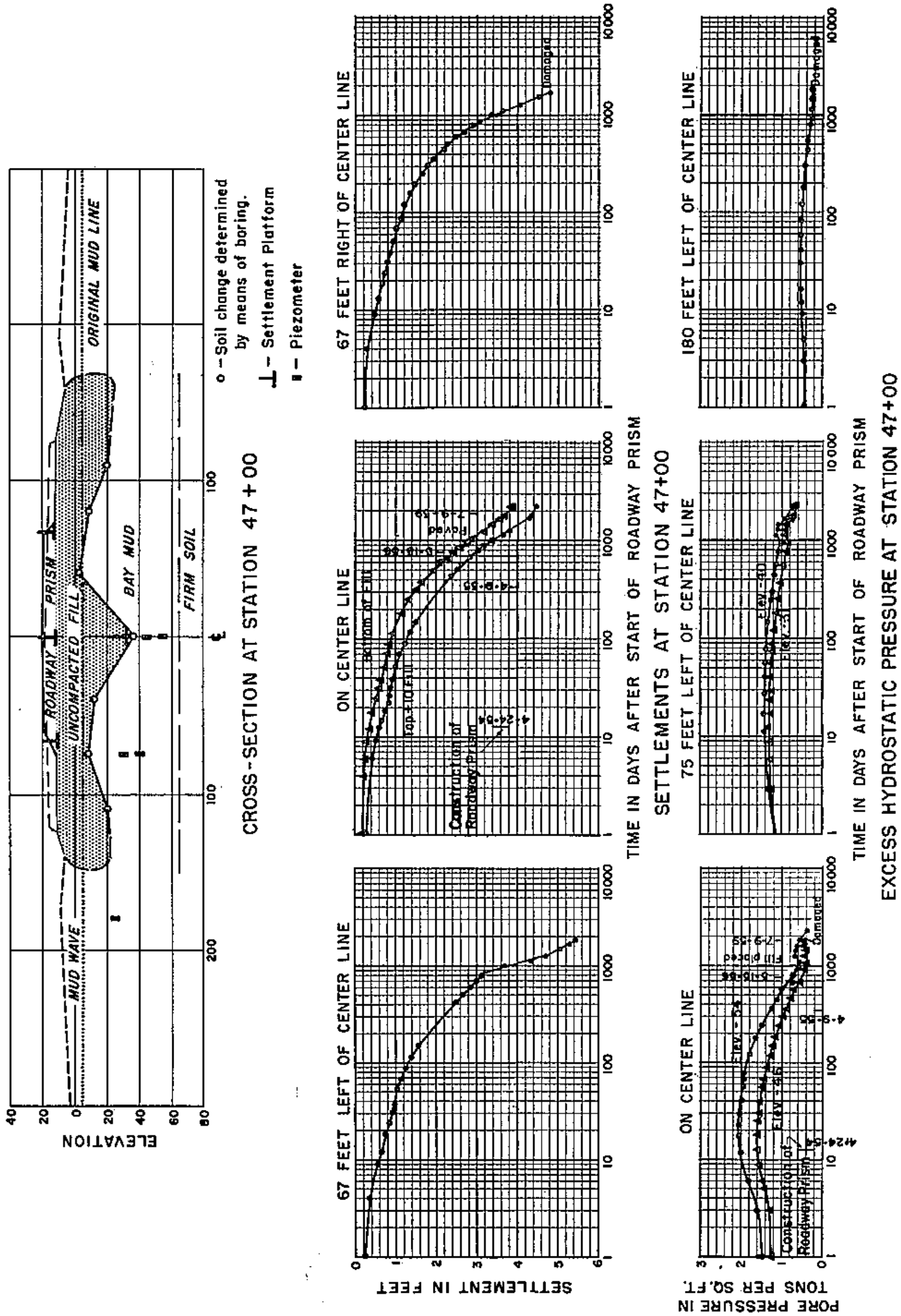

Figure 11. Second unit, 250 ft wide.

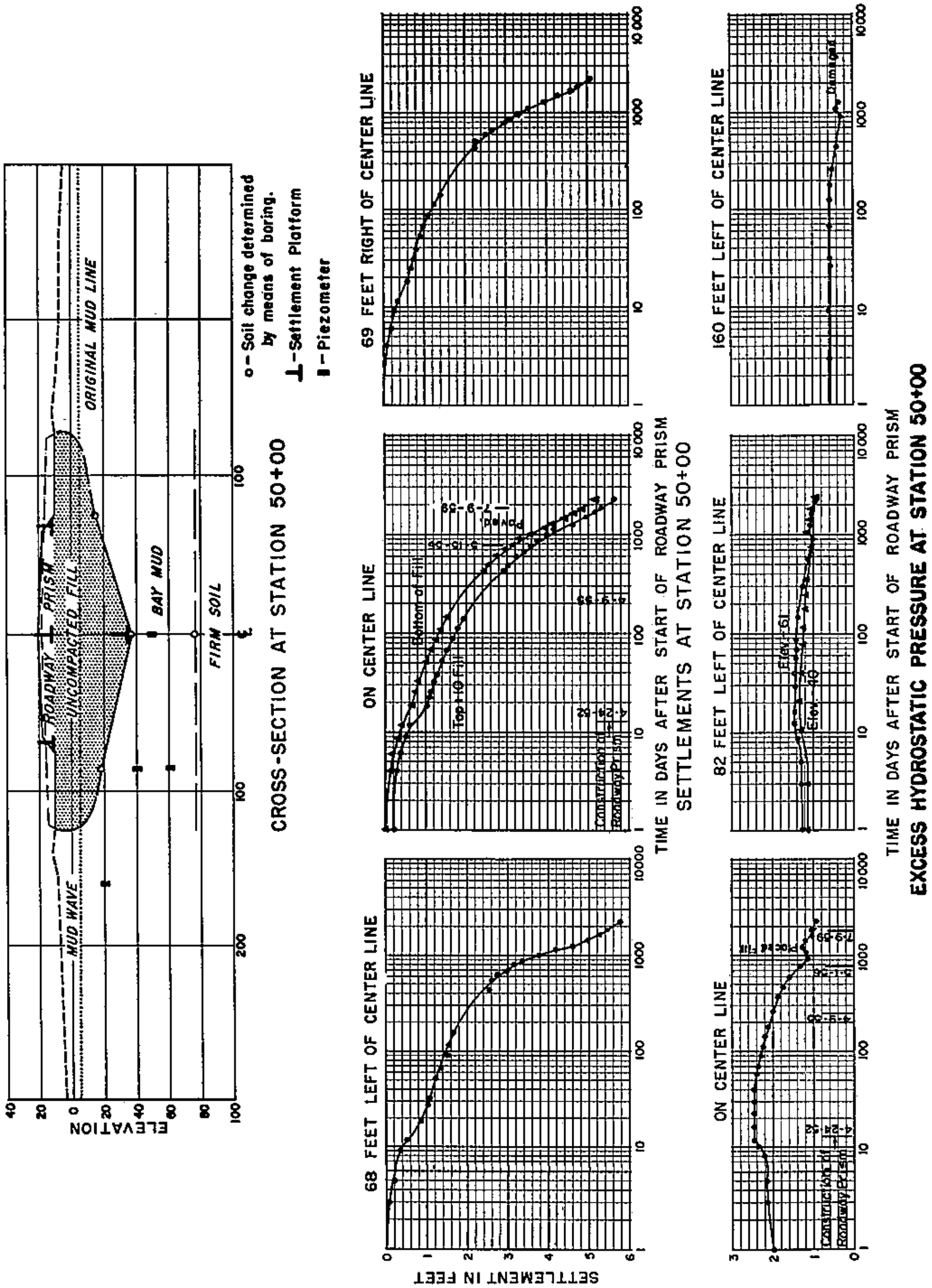

Figure 12. Second unit, 250 ft wide.

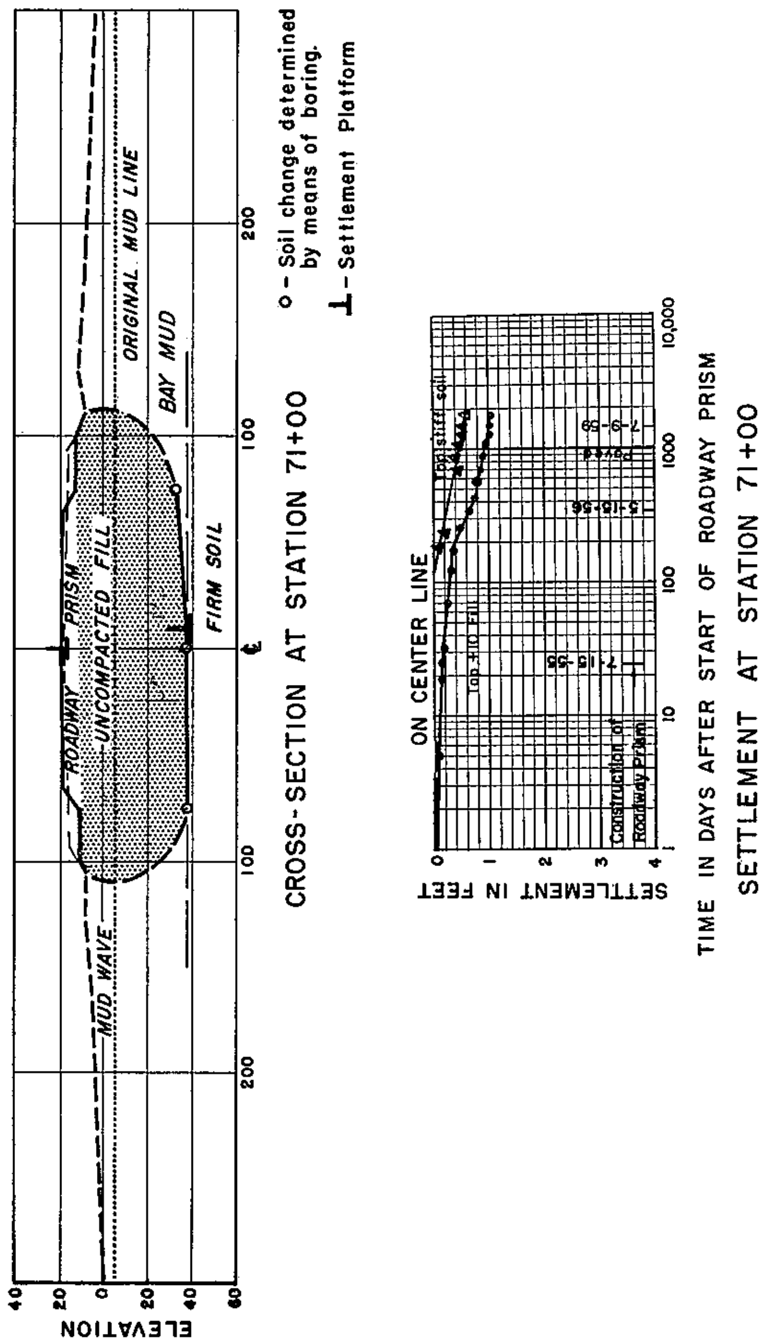

Figure 13. Third unit, 200 ft wide.

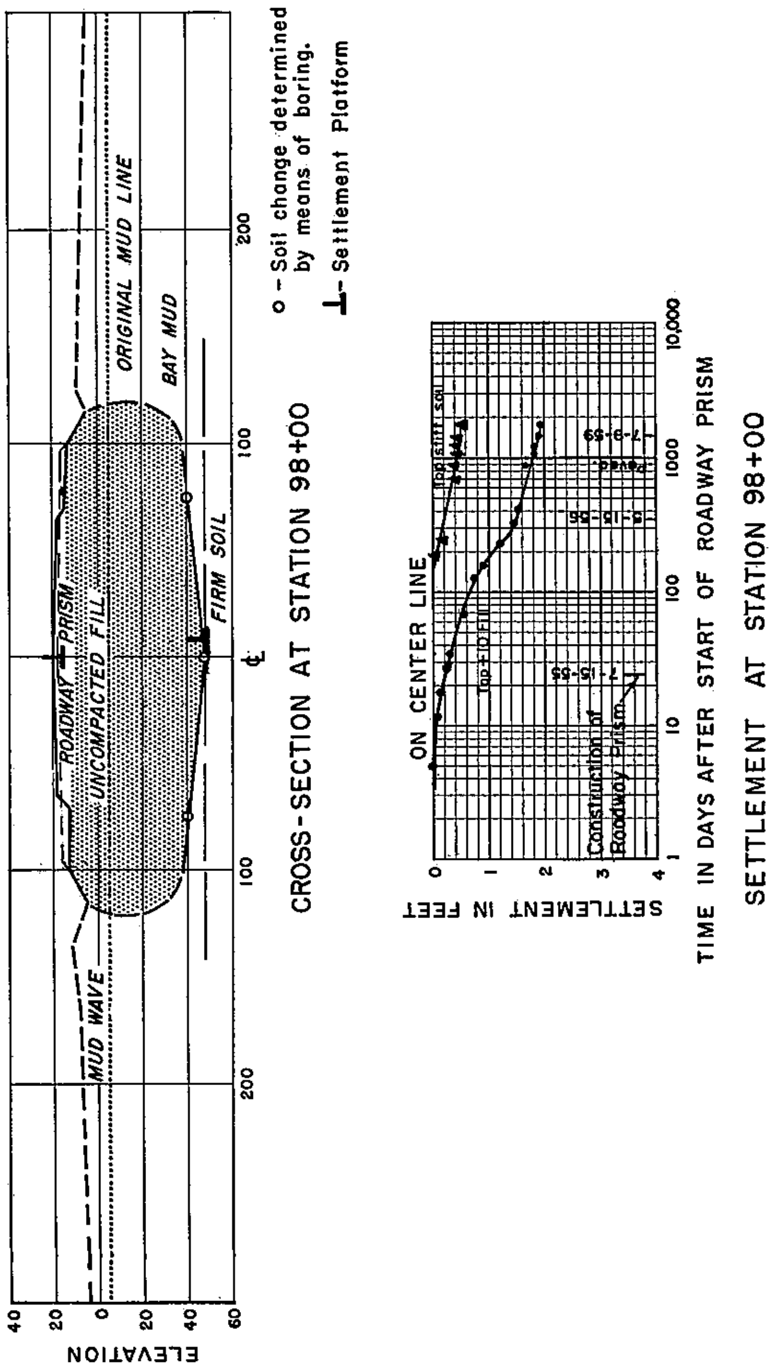

Figure 14. Third unit, 200 ft wide.

bring the profile grade to +18, with a 2-ft structural section specified.

In the two experimental units, hubs were placed 100 and 125 ft from centerline at each station to observe any surface movement of the berm during placing of the roadway prism. The settlement of these hubs was not accelerated by the placing of the roadway prism. There was about 0.1 ft of horizontal movement of these hubs away from centerline. Cracking was noted about 85 ft from centerline in the berm area during the placing of the roadway prism. These cracks were tension cracks due to the consolidation of the uncompacted fill under the loading of the roadway prism. There were no indications that shear failures occurred anywhere during the placing of the roadway prism.

At a few locations, the crest of the mud wave increased slightly in elevation and abnormally large settlements occurred 75 ft from centerline as the roadway prism was placed. At all of these locations the borings 75 ft from centerline indicated that the soft mud had been displaced to elevation—10 to —20. There were no indications of movement of the mud at other locations with the same range of mud displacement 75 ft from centerline. It is felt that such factors as the size of the mud wave, strength of the soft mud, and strength of the uncompacted fill accounted for these variations. These observations indicate that some plastic flow of the soft mud may have occurred where the soft mud was displaced to elevation —20 or less.

During the final work on the open water fill in 1957, there was a surplus of dirt. This fill was placed on the berm so as to make the berm level with the completed roadway. The fill in this disposal area is in an uncompacted condition. No failures occurred during the placement of this fill.

THEORETICAL SETTLEMENTS

There were three soil layers with varying degrees of compressibility at Candlestick Cove underlying the roadway prism. The layers were the uncompacted fill, the soft bay mud remaining below the working table, and the stiff bay mud underlying the soft bay mud. The settlement of the roadway prism was dependent on the rates of settlements of all three layers.

It was not practical to obtain undisturbed samples of the uncompacted fill; therefore, no theoretical settlement calculations could be made.

Theoretical rates of settlement of the soft bay mud were calculated for numerous locations. The settlement was calculated using the consolidation tests from the samples obtained after completion of the working table, and assuming double drainage. The theoretical settlement calculations indicate that the rate of settlement will be approximately uniform for varying periods after construction regardless of the thickness of the soft mud remaining below the fill. Where only a few feet of soft mud remain below the fill the settlement would be completed soon after construction. Settlement would continue where greater thickness of soft mud remained below the fill until the settlement was completed for that thickness of soft mud. The settlement log-time curves thus formed a close group following the same rate of settlement until the settlement was completed for various thicknesses of soft mud remaining below the fill. The differential settlement would thus be small until the completion of the consolidation for the least thickness of soft bay mud and then the thicker mud locations would continue to settle resulting in differential settlement.

Theoretical settlements of the stiff bay mud were calculated assuming double drainage even though the stiff bay mud is underlain by the Franciscan formations. The reason for this is that extensive sand layers or pockets exist in this stiff mud layer, and they probably provide some drainage. The calculated ultimate settlements of this layer are from 2 to 4 ft. The estimated theoretical rate of settlement is very slow, with an estimated 100 to 200 years being required for its completion.

MEASURED SETTLEMENT

As placement of the working table progressed, settlement platforms were placed on centerline at each station on the surface of the working table. A limited number of settlement platforms were also placed 75 ft right and left of centerline. These settlement platforms would measure the total settlement of the roadway prism. At five locations, settlement platforms were placed at the bottom of the fill and would measure the settlement due to the soft bay mud and stiff bay mud. Four settlement platforms were installed at the top surface of the stiff mud layer to measure the settlement due to this layer. Typical settlement curves are shown in Figures 8 to 14.

The total settlement curves from Stations 6+00 to 60+00 are quite similar. The slope of the log-time settlement curves is about the same and indicates that only small differential settlement is occurring between any two adjacent stations. The total settlement to date in this area is between 3 and 6 ft. The settlement since paving has varied from 0.3 to 1.5 ft and has produced long, rolling waves in the pavement. It is expected that this differential settlement will continue to increase for many years.

The total settlement curves from Stations 60+00 to 120+00 indicate that little settlement occurred during the placing of the roadway prism. The slope of the log-time settlement curve was constant during construction of the roadway prism and for about six months after its construction. About six months after construction of the roadway prism, the slope of the logtime settlement curve sharply increases for about three months, generally resulting in about one-half foot of settlement. The slope of the log-time settlement curve then, about the time of paving, assumes either of two slopes—a flat slope indicating little or no settlement, or a slope indicating minor settlements. There is no relationship to the amount of soft mud underlying the fill. A large mud displacement was obtained throughout most of this area with small settlements occurring after construction. The settlement in this area after paving varied from 0.1 to 0.6 ft with minor waviness in the pavement surface. The settlement appears to be completed in few areas.

The settlement due to the uncompacted fill has varied widely. The consolidation of the uncompacted working table was generally small and appeared to be completed within a year after construction. The rock fill consolidated about 0.1 ft and the soil fill about 1 ft under the loading of the roadway prism.

Settlements of the surface of the stiff mud were measured at only four locations, and because of these limited data, only general trends can be noted. The slope of the log-time settlement curves was small after completion of the roadway prism and then gradually increased. At two locations, the present settlement of the surface of the stiff mud has exceeded the estimated settlement for 20 years. At one location the settlement followed the estimated rate of settlement, and at the other location the settlement now appears completed. This settlement which varies from ½ to 2 ft, was probably due to the heterogeneous nature of the stiff bay mud.

Comparing the settlement after construction from Stations 60+00 to 120+00 of the surface of the roadway prism with the surface of the stiff bay mud, it was found that where near total displacement occurred, the two surfaces were settling the same amount. The settlement of the roadway prism was therefore directly related to the consolidation occurring in the stiff mud layer. With little or no soft mud remaining below the fill and the consolidation of the working table complete, the settlement of the roadway prism should be essentially the same as the settlement of the surface of the stiff bay mud. Where there was not total mud displacement, the settlement of the surface of the working table exceeds the settlement of the surface of the stiff bay mud layer.

Subtracting the settlement due to the stiff mud layer and the uncompacted working table from the settlement of the surface of the working table, it was found that the resulting settlement due to the soft bay mud was erratic from Stations 6+00 to 60+00. The nature of the erratic settlement was that in some areas the settlement was occurring faster than estimated, slower than estimated, or close to the estimated rate. Examination of the settlements and amount of soft mud remaining below the fill showed that, where near total mud displacement was adjacent to a small mud displacement area, the settlement in the high mud displacement area occurred at a higher than estimated rate. Where small mud displacement was adjacent to high mud displacement area, the settlement in the small mud displacement area occurred at a slower than estimated rate. This effect may possibly be due to arching action of the fill and extends up to 200 ft from the changes in soft mud displacement. In areas outside this arching effect, the settlement due to the soft bay mud is closely following the theoretical rate of settlement.

EXCESS HYDROSTATIC PRESSURE READING

Piezometers were installed below the working table in the two experimental sections of the open water fill. The piezometers were similar to the nonmetallic type developed by Casagrande for use at Logan Airport.

The piezometers were placed so as to obtain a half cross-section of the excess hydrostatic pressure: one or more on centerline, one or more 75 to 80 ft left of centerline near toe of roadway prism, and one under the crest of the mud wave. Four piezometers were installed in the sand to clayey sand between the soft mud and stiff mud layers. Typical excess hydrostatic pressure data obtained are shown in Figures 10 to 12.

During the period between installing the piezometers in the soft mud and the placing of the roadway prism, a slight decrease, less than 0.1 ton per sq ft, in excess hydrostatic pressure occurred. During the placing of the roadway prism, the loading on centerline was increased 0.6 ton per sq ft. This increase in weight was reflected by a 0.5- to 0.6-ton per sq ft increase in excess hydrostatic pressure on centerline and about 0.2-ton per sq ft increase in excess hydrostatic pressure 75 to 80 ft from centerline, but with no noticeable effect under the mud wave. After completion of the roadway prism, the excess hydrostatic pressure at centerline decreased slowly from about 2 to less than 1 ton per sq ft at the present time. The excess hydrostatic pressure outside the toe of the roadway prism, 75 to 80 ft from centerline, decreased at a slower rate than the excess hydrostatic pressure at centerline until the two were about equal, then they both decreased at about the same rate. The decrease in excess hydrostatic pressure under the mud wave has been small, 0.1 to 0.2 ton per sq ft, and has been very erratic. These erratic readings are believed due to tidal effects. The tide action has now destroyed all of these piezometers. The piezometers placed in the sand to clayey sand layer between the soft mud and stiff mud layers indicate a constant excess hydrostatic pressure of about 0.2 ton per sq ft in this layer.

The piezometers often indicated pressures that were in excess of the loading due to the fill directly above them. Before placing the roadway prism, the loading within 100 ft of the piezometers was investigated, and it was found that the piezometers tended to indicate the maximum pressure due to the working table within this distance. The result was a fairly uniform excess hydrostatic pressure that was not reflecting the extremes of the soft mud displacement.

The excess hydrostatic pressure measurements indicate that a rapid decrease in pressure occurred after placing the roadway prism in areas of large mud displacement until the pressures were about equal to the pressures below adjacent smaller mud displacement areas. Then the excess hydrostatic pressure in the two areas decreased at about the same rate. This effect appears to exist over an area of 100 to 200 ft and is not reflected in the rate of consolidation as measured by the vertical movements. It appears that two actions may be occurring that are affecting the settlement and excess hydrostatic pressure measurements. The excess hydrostatic pressures are being transferred in a horizontal direction up to 200 ft and the fill is acting as an arch or bridge for a distance of about 200 ft in the locations of small mud displacement.

CONCLUSIONS

The primary object of the two experimental sections at Candlestick Cove was to determine how to construct a stable fill across the open water section of this road. It was found that a 200-ft wide working table would successfully support the roadway prism without failures when the soft mud was displaced to elevation −20 or below.

During the early stages of construction the fill was placed without regard for the amount of soft mud being displaced. With this method of operation varying amounts of soft mud were trapped below the working table. A method of placing the fill was developed that effected almost total displacement of the soft mud by the fill. This total mud displacement was accomplished by controlling the shape of the nose, rate of placing and advancing the fill, elevation to which the working table was constructed, and height of the mud wave by mud blasting.

Differential settlement has occurred as a result of variable amounts of soft mud remaining below the working table. This differential settlement has produced a wavy pavement surface where large variations of the amount of soft mud exist. Where total mud displacement was obtained, only small differential settlement occurred.

ACKNOWLEDGMENTS

Acknowledgment is made to the Materials and Research Department, which is under the supervision of F. N. Hveem, and to District IV, under the supervision of J. H. Skeggs, retired, of the California Division of Highways, under whose direction this project was constructed. The author wishes to acknowledge the assistance given by A. W. Root, T. W. Smith, and W. Travis in conducting and planning the work presented.