COMPACTED COHESIVE TEST EMBANKMENT —
DESIGN, INSTALLATION AND OPERATION OF
FIELD INSTRUMENTATION

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BY

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PURDUE UNIVERSITY AND

INDIANA STATE HIGHWAY COMMISSION

Interim Report

COMPACTED COHESIVE TEST EMBANKMENT - DESIGN, INSTALLATION AND OPERATION OF FIELD INSTRUMENTATION

TO: J. F. McLaughlin, Director February 8, 1973
Joint Highway Research Project
Project: C-36-5F

FROM: H. L. Michael, Associate Director
Joint Highway Research Project File: 6-6-6

The attached Interim Report titled "Compacted Cohesive Test Embankment - Design, Installation and Operation of Field Instrumentation" by W. L. DeGroff of our staff is submitted on the HPR Part II Research Study "Long-Term Deformation of Clay Embankments". The research is directed by Dr. William Perloff of our staff.

The report describes the design, installation and operation of the field instrumentation for the forty foot high test embankment on SR 37 near Bloomington, Indiana. Photographs and descriptions of detailed features of the installations are included.

The Report is presented to the Board for acceptance in partial fulfillment of the objectives of the Study. It will be forwarded to the ISHC and the FHWA for similar review, comment and acceptance.

Respectfully submitted,

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INSTALLATION AND OPERATION OF FIELD INSTRUMENTATION

by

W. L. De Groff

Joint Highway Research Project

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and the

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The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Purdue University
West Lafayette, Indiana
February 8, 1972

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SUMMARY

This report describes the design, installation and operation of field instrumentation for a forty foot high test embankment on SR 37 near Bloomington, Indiana. Photographs and descriptions of detailed features of the installation are included for guidance of those who may make similar installations in the future.

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INTRODUCTION

This report describes certain features of a test embankment constructed in conjunction with a continuing research project on long-term deformation of compacted cohesive soil embankments at Purdue University. The objective of this research program has been to isolate and examine the variables which affect the long-term deformation behavior of compacted cohesive soils and to incorporate these parameters into a rational procedure predicting the deformations of embankments composed of such material.

A major part of this research was to conduct a field study to verify the degree to which the procedures, developed from work to date, can predict long-term deformations of compacted cohesive embankments. The following report describes the field instrumentation installed within and beneath the embankment, as well as pertinent details of the installation procedures and operation of the instruments. Presentation and interpretation of the data obtained will be given in a subsequent report.

The test embankment selected jointly by research project staff and the Indiana State Highway Commission (ISHC) personnel is part of the state highway system. The test section is the area from Sta 789 + 00 to Sta 790 + 00 by 250 feet left and right of center line of state highway project No. STF-92, the Monroe reservoir interchange on State Route 37, near Bloomington, Indiana.

SITE CONDITIONS

The site lies within the Mitchell plain physiographic region of Indiana, characterized by almost level to undulating topography. The

test embankment is located on a shallow lacustrine plain in the Clear Creek valley. The glacial lake-bed sediments present are, in places, overlain by fine-grained alluvium resulting from flooding of Clear Creek, which traverses the area of interest.

Logs of a series of test borings made at the site are shown in Figure 1 along with the interpreted stratigraphic profile.

FIELD INSTRUMENTATION

The test embankment was constructed at the site described, under the supervision of ISHC, with the cooperation of Joint Highway Research Project (JHRP) personnel of Purdue. The test section is approximately 40 feet high, and composed entirely of locally available compacted cohesive soil.

Installation of the field instrumentation was carried out by the contractor under the joint direction of ISHC and the Purdue personnel. Figures 2 - 7 show the instrumentation locations superimposed on cross-sections of the embankment.

A scale model of the test embankment, shown in Figure 8, was made to aid in visualizing the spatial relationships in the total project. The sides of the model were of clear plexiglass; aluminum rods and bars were used for pipes and trenches. The back side of the model and different types of instruments were color coded to assist in the planning process. This approach was found to be helpful to project personnel in interpreting results.

The earth fill used in the test embankment was a locally available limestone residual silty clay, carried to the site and placed by scrapers (Figure 9). The fill was compacted, near optimum water

BORING LOGS

	Sta. 789+55	250' LT	Sta. 789+45	125' LT	Sta. 789+55	£	Sta. 789+45	125' RT	Sta. 789+55	250' RT
0	Brown Soft Silty Clay	▽ G.W.T.	Brown Medium Silty Clay	▽ G.W.T.	Brown Stiff Silty Clay	▽ G.W.T.				
5	Brown Very Soft Silty Clay Trace of Organic Matter	▽ G.W.T.			Brown and Gray Stiff Silty Clay		Brown Soft Silty Clay			▽ G.W.T. Brown and Gray Medium Stiff Silty Clay with Trace of Organic Matter
10	Gray Soft Sandy Clay Trace of Organic Matter and Sand Seams		Gray Very Soft Silty Clay				Brown and Gray Soft Silty Clay			
15	Gray Loose Medium Sand		Gray Medium Stiff Sand Clay Trace of Organic							
20	Brown Medium Dense Clayey Gravel		Gray Very Soft Silty Clay		Gray Loose Clayey Sand and Gravel		Gray Stiff to Soft Silty Clay			Gray Medium Stiff Silty Clay Gray Medium Sandy Gravel
25	Gray Very Soft Silty Clay		Gray Medium Silty Gravel		Gray Very Soft Silty Clay		Soft Silty Clay			Gray Medium Stiff Silty Clay
	Gray Medium Dense to Dense Clayey Sand and Gravel		Gray Medium Silty Gravel		Gray Medium Silty Gravel		Gray Dense Silty Gravel			
30	Gray Medium Silty Gravel		Auger Refusal		Auger Refusal		Auger Refusal			Gray Medium Silty Gravel Auger Refusal

STRATIGRAPHIC PROFILE

FIGURE 1-BORING LOGS AND STRATIGRAPHIC PROFILE AT TEST EMBANKMENT SITE

FIGURE 2 - SPIRAL - FOOT LOCATION

FIGURE 3-PIEZOMETER LOCATIONS

FIGURE 4-SLOPE INDICATOR 3-7 LOCATIONS AND PRESSURE PLATE LOCATIONS

FIGURE 5- BENCHMARK AND HORIZONTAL DISPLACEMENT GAUGE LOCATIONS

FIGURE 6- HYDRAULIC SETTLEMENT GAUGE LOCATIONS

**FIGURE 7- SPIRAL-FOOT NUMBER 13 AND SLOPE INDICATORS
NUMBER 1 AND 2**

FIGURE 8 - MODEL OF EMBANKMENT AND INSTRUMENT LOCATIONS

FIGURE 9- HAULING FILL TO EMBANKMENT SITE

content by paddle foot rollers (Figure 10). A detailed description of the subsurface soils, compacted fill and construction conditions will be given in a subsequent report.

This report is concerned primarily with the instrumentation, its installation and use. Critical comments concerning these features are provided as guidance for others who may undertake similar field studies. All such comments are subject to the caveat that they are based on experience at a specific site. Details of the installation procedures are given in the Appendix.

Bench Marks

There was no structure close enough to the test section to serve as a reference bench mark. Therefore, installation of bench marks was required. The type installed were similar to those described by Bozozuk et al (1962).

The bench mark is a datum rod which extends from solid base material to the surface. The datum rod is protected inside a casing extending from within two feet of the datum rod base to ground surface. This was the first item installed after obtaining soil samples. All following installations were then referenced from the bench marks. The location of the bench marks is shown in Figure 5. A cross-section of a typical installation is given in Figure 11. Figure 12 shows a bench mark being installed.

FIGURE 10-COMPACTION OF TEST EMBANKMENT FILL

FIGURE II- CROSS-SECTION OF BENCH MARK INSTALLATION

FIGURE 12- INSTALLING BENCH MARK

Spiral-Foot Settlement Gauges

The spiral-foot gauge was used to measure vertical movements of points within and below the embankment.

Figure 13, based on Bozozuk (1968), shows the spiral foot and a cross-section of the installed gauge; the datum rod is shown extending to the surface. Figure 14 shows the foot, casing and handle to turn the foot into the soil. The gauge is installed by drilling a hole to within six inches of the desired measurement depth. The gauge is then screwed into the soil for the remaining six inches.

When the installation of the gauge is complete, oil is pumped down the inside of the datum pipe and out the holes above the foot, filling the casing with oil. The subsoil was very soft at this location so on the installation 16 feet below grade, water was pumped down the pipe first to help loosen any soil pushed in the pipe when it was placed. Locations of the gauges are shown in Figures 2 and 7, and installation procedures are illustrated in Figures 15 and 16. As the embankment was constructed, the datum rod and casing were extended with the fill.

Horizontal Movement Plates

The horizontal movement plate pictured in Figure 17 transmits the lateral movement of a point within the fill. Steel plates were buried on vertical planes in the fill at selected locations, shown in Figure 5. A plan showing the position of the horizontal movement plates in a horizontal plane is given in Figure 18. A cable connected to a plate is encased in tubing extending out of the fill (Figure 19) and enters the instrument house at the side of the fill. The cable is pulled

GROUND MOVEMENT GAUGE ASSEMBLY

FIGURE 13- SPIRAL FOOT SETTLEMENT GAGE INSTALLATION

FIGURE 14 - TYPICAL SPIRAL-FOOT GAUGE BEFORE INSTALLATION

FIGURE 15 - WASHING SPIRAL FOOT GAUGE INTO POSITION

FIGURE 16 - FILLING SPIRAL-FOOT GAUGE CASING WITH OIL

FIGURE 17 - HORIZONTAL MOVEMENT PLATE WITH CONNECTING CABLE

FIGURE 18 - GENERAL PLAN OF INSTALLATION FOR HORIZONTAL MOVEMENT PLATE.

FIGURE 19 - HORIZONTAL MOVEMENT PLATE INSTALLED IN TRENCH

tight by a window sash spring. A reference marker is placed on the cable at the measuring point. Figure 20 shows a station for reading cables coming into the instrument house from elevation 520 feet.

A plate is located on the centerline of the embankment as a reference for movement of plates installed left and right of centerline. A cathetometer is used to measure the difference in elevation of the marks on various plate cables; reference is always made to the plate on the centerline.

The row of plates at elevation 515 were below the instrument house. The cables were brought up to the house via a pulley box buried at elevation 515 directly below the reading station in the instrument house (Figure 21).

The plastic tube encasing the cables should be laid as straight as possible. This helps the accuracy and reduces friction. An attempt was made to use the tubing in a curve and the friction was large enough to prevent the cable from moving. The pull on the cables and the size of the protective tubing should be increased when the distance from plates to measuring point become large.

Piezometers

The piezometer measures the pore water pressure in the vicinity of a point. Piezometers were installed within the fill and subsoil. The locations are shown in Figures 3 and 5.

The piezometers selected for this project were a diaphragm type manufactured by the Slope Indicator company. This type of piezometer has a diaphragm between the pore fluid and air supplied under pressure through tubing from the readout device. The diaphragm controls a ball valve which is open when the return line pressure is lower than

**FIGURE 20- STATION FOR READING DISPLACEMENT OF
HORIZONTAL MOVEMENT PLATES**

FIGURE 21- PULLEY BOX TO BRING LOWER HORIZONTAL DISPLACEMENT PLATE CABLES UP TO INSTRUMENT HOUSE

the pore pressure. When the return pressure equals the pore pressure the ball valve is closed and the return line pressure is not allowed to increase. The arrangement of the ball valve and diaphragm is shown in Figure 22. The supply and return line from the piezometer are connected to the readout pressure gauge in the instrument house. A piezometer connected to the readout box is shown in Figure 23. A typical installation is depicted in Figure 24. Steps in the installation are illustrated in Figures 25-28.

The supply and return lines are 1/8 inch nylon tubing, these tubes are both encased in a 1/2 inch polyethene tube. Four piezometers became inoperative during construction of the embankment. The performance of these four suggested that two of the failures were due to the 1/8 inch line being bent, and the other two were due to dirt in the ball valve system. Therefore care should be taken to avoid these problems when installing the connecting line.

The time spent taking readings is reduced by using a manifold system and air supply tank. The toggle valve board to select a piezometer, the air tank to pressure the input line, and the readout box are shown in Figure 20.

Total Pressure Plates

The total pressure plates determine the average total normal pressure acting on a plane at a "point" within the embankment. The Gloetzi type pressure plates, manufactured by Terrametrics, Inc., consist of a double diaphragm cell filled with oil (Figure 29). This cell is loaded by the soil and the pressure developed goes to one side of a

FIGURE 22-PIEZOMETER ASSEMBLY DRAWING

FIGURE 23- PIEZOMETER CONNECTED TO READOUT EQUIPMENT

FIGURE 24-PIEZOMETER INSTALLATION.

FIGURE 25- PIEZOMETER BEING PLACED IN CASING

FIGURE 26 - OTTAWA SAND BEING POURED AROUND PIEZOMETER

FIGURE 27- DROPPING BENTONITE BALLS DOWN PIEZOMETER CASING

FIGURE 28 - HAMMER FOR COMPACTING BENTONITE SEAL

FIGURE 29 - TOTAL PRESSURE CELL ASSEMBLY

flexible diaphragm. The other side of the diaphragm is pressured by oil passing through an orifice which is opened and closed by the movement of the thin diaphragm. A greater cell pressure closes the diaphragm cutting off flow from the input line to the return line; when the input line pressure reaches the cell pressure the diaphragm will open permitting flow to the return line. Thus, the maximum input line pressure is the pressure in the cell. A pressure cell is shown connected to the readout gauge and pump in Figure 30.

Calibration of the pressure plates placed in a sand medium indicated that the sand transmitted the pressure applied, and that the plates recorded this pressure correctly. Initial readings for each cell must be determined before installation, and be corrected for elevation differences between the readout device and the cells.

The locations of groups of three pressure plates are shown in Figure 4. Three non-parallel plates are installed at one location so that the complete stress field in the plane normal to the axes of the plates can be determined. A template is used to insure correct alignment of the pressure cells (Figure 31). A typical installation in the fill, with the cells embedded in sand pocket to provide good contact, is shown in Figure 32. Other steps in installation are shown in Figures 33-35.

In two locations, pressure cell groups were installed both parallel and perpendicular to the embankment axis so that the complete three-dimensional stress state could be determined. The pit containing one of these groups is shown in Figure 36.

FIGURE 30 - PRESSURE PLATE CONNECTED TO READOUT DEVICE

FIGURE 31-PRESSURE PLATES AND TEMPLATE FOR INSTALLATION

FIGURE 32-TEMPLATE AND PRESSURE PLATES PLACED IN SAND POCKET

FIGURE 33-FILLING PRESSURE PLATE LINES WITH FLUID

FIGURE 34- PRESSURE PLATES COVERED BY SAND

FIGURE 35 - PRESSURE PLATE TUBING IN TRENCH

FIGURE 36- PIT WITH PRESSURE PLATES PERPENDICULAR AND PARALLEL TO CENTER LINE

Slope Indicators

Slope Indicators were installed to measure lateral movement. The Slope Indicator manufactured by the Slope Indicator Company consists of a sensing torpedo, readout device and grooved tubing, as shown in Figure 37.

The grooved tubing is installed vertically from the surface to bedrock, and socketed three feet into the rock. The tubing was installed in insitu material before construction of the embankment; five foot sections were added during construction to extend the tubing to final grade elevation.

There are two sets of perpendicular grooves in the installed casing to guide the torpedo. Inclination readings relative to a plumb line are taken at different elevations, one set parallel and another perpendicular to the centerline of the highway. A profile of the casing in the two directions can be plotted. The Torpedo used to make the inclination measurements is able to read inclinations which correspond to less than 1/16 inch horizontal movement.

Readings are taken at various time intervals so that different profiles with time are obtained. The profiles are compared to define the rate of movement of the fill.

The slope indicator casing was made up of 5 foot lengths and 12 inch couplings. These were fastened together with pop rivets. A six inch long sleeve is left between the 5 foot length so that settlement of the fill would not lead to crushing of the casing. The installation sequence is illustrated in Figures 38-42.

FIGURE 37- SLOPE INDICATOR, TUBING, SENSING TORPEDO AND READOUT DEVICE

FIGURE 38- DRILLING HOLE FOR SLOPE INDICATOR CASING

FIGURE 39 - HAMMERING CONSTRUCTION CASING TO ACHIEVE SEAL AT BASE

FIGURE 40-POP RIVETING SLOPE INDICATOR CASING

**FIGURE 41- PLACING PREASSEMBLED SLOPE INDICATOR CASING
IN HOLE .**

FIGURE 42- READING SLOPE INDICATOR

Hydraulic Settlement Gauges

The hydraulic settlement gauge is used to measure vertical settlements along a line inside a material mass. The system employed is similar to that described by Bozozuk (1969). A one inch tube is installed at the desired elevation to measure deflection, as shown in Figure 43. The desirable feature about this type of installation is the capability to measure settlements continuously along the tube and the accessibility of measurement during construction.

One inch diameter tubes were installed in trenches through the embankment at four elevations (Figure 6). The tubes were filled with ethylene glycol and allowed to overflow reservoirs at both ends of the tube (Figure 44). A pressure transducer was pulled through the tube to measure the head relative to the overflow elevation. From the pressure measurements, elevations of the tube can be calculated.

The settlement tube was installed in a trench cut into the fill as shown in Figure 45. After the tube was placed, the trench was backfilled with sand (Figure 46).

This installation experienced a number of problems. The first was insufficient slope in the tube to eliminate entrapped air. The slope should be at least 1:100 to allow air to flow out when the tube is filled with ethylene glycol. A second problem was the effect of drag on the pressure readings due to pulling the transducer through the tube. The most difficult problem, was the effect of temperature fluctuation of the fluid. This caused a thermal zero shift equal to $.01\%FS/^{\circ}F$ and thermal sensitivity shift of $.01\%FS/^{\circ}F$. In addition, the Statham transducer used also exhibited a nonlinearity and

- 1 Reservoir - Overflow
- 2 Electric Wire - Distance Marked
- 3 1" Internal Diameter P.V.C. Pipe
- 4 Pressure Probe - Housing
- 5 Stainless Steel Wire
- 6 Reservoir
- 7 Antifreeze
- 8 Boxes for Reservoirs

SETTLEMENT GAUGE
SALIENT FEATURES

FIGURE 43 - TYPICAL HYDRAULIC SETTLEMENT GAUGE SYSTEM

FIGURE 44- SETTLEMENT GAUGE RESERVOIR

FIGURE 45 - TRENCHING FOR HYDRAULIC SETTLEMENT GAUGE INSTALLATION

FIGURE 46-BACKFILLING HYDRAULIC SETTLEMENT GAUGE TRENCH AFTER INSTALLATION

hysteresis error of 0.75%FS. The effect of temperature on the measured pressure at the active face of the transducer is shown in Figure 47.

In the field, elaborate methods would have to be used to control the temperature of the solution or to measure the temperature of the instrument while readings are being taken within the body of the embankment. If temperatures were measured, it would be necessary to wait at each reading until the instrument temperature equilibrated. Suitably accurate transducers without the temperature sensitivity are not currently available.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations concerning the installation and operation of the field instrumentation are based on experiences at a single test site. When viewed in this light, they may be helpful guides in future field instrumentation programs:

1. The bench marks and spiral-foot settlement gauges were installed without major problems and have performed satisfactorily. No change in design of these elements is recommended.
2. When horizontal movement plates extend more than approximately 150 feet from the reading station tubing must be larger and less flexible than that employed in this study to reduce frictional binding of the measurement wires. A suggested scheme is to use 3/4 inch PVC pipe in 20 foot sections joined by slip couplings of the same material.

Error for 1° Temp. Change

FIGURE 47 - TRANSDUCER ERROR WITH TEMPERATURE.

3. Although the piezometers operated satisfactorily, the long lines produced considerable resistance to the flow of air. Larger tubes should be used in such cases in the future.
4. The total pressure plates have operated satisfactorily and reliably, and would be used in a similar fashion on a subsequent project.
5. The hydraulic settlement gauge has many advantageous features, but these are outweighed by the disadvantages. In subsequent applications, alternative settlement gauges would be selected.

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APPENDIX

In this appendix, details are given concerning installation procedures for the embankment instrumentation.

Installation of Bench Marks

1. A 2.5 inch auger hole 10' deep was drilled as a pilot; care was taken to make sure the hole was vertical. The auger is shown in Fig. 12 being cleaned after drilling the hole.
2. A 1/4 inch pipe (The datum pipe) was connected to the steel foot. An EX drill casing was slip fit loosely to the steel foot. The datum pipe (1/4 inch pipe) should always extend out of the EX casing.
3. The assembly was placed in the pilot hole, this is being done in Figure 10. The assembly was then driven using a 140 pound hammer free falling a distance of 30 inches striking a collar on the drill rod. Additional 1/4 inch pipe and EX casing were added when required.
4. When refusal was reached the EX casing was pulled up above the steel foot 2 feet, making sure the foot was not lifted.
5. The drill rod was filled with S.A.E. #80 oil.
6. An additional EX drill rod and 1/4 inch pipe was added while the berm elevation was brought to grade. The fill within a 3 foot radius of the EX case was compacted by hand.
7. When the final elevation was reached the contractor installed a 4" pipe casing with a steel cap. This is shown in Figure 9.

Installation of Spiral-foot Gauge

1. A 2 inch diameter auger was turned in 6 inches above the desired elevation of the spiral foot. The hole was cleaned and the auger removed.
2. The datum pipe with the foot attached and casing surrounding was pushed to the bottom of the hole. For holes deeper than 6 feet water was pumped through the inner, and out the bottom ports while pushing. This is shown in Figure 15.
3. The casing was then pulled up 6 inches and the spiral-foot screwed down 6 inches to desired elevation.
4. S.A.E. #80 oil was pumped through the inner pipe and out the ports at the bottom of the datum rod. The oil carries loose material out the top of the outside casing. Figure 16 shows the grease truck pumping oil down the datum pipe. The typical installation and path of the oil is shown in Figure 13.
5. Additional outside casing and datum rod were added as fill was brought to grade. The fill within a 3 foot radius of the Spiral-foot gauge was compacted by hand.
6. When the final grade was reached the contractor installed a 4 inch pipe casing and steel cap the same as shown for the Bench Mark in Figure 11.

Installation of Horizontal Displacement Gauge

1. The embankment was constructed to an elevation 18 inches above the elevation at which the Horizontal Displacement Plates were to be installed.

2. A trench was cut 18 inches deep by 12 inches wide from the furthest plate from the instrument house to a point below the instrument house for the installation at elevation 505. For the trench at elevation 520 the trench extends from the furthest plate to the point where it exits from the embankment slope, holding the trench bottom at the specified elevation. The bottom of the trench was tamped with a vibrating compactor.
3. The wire cable was connected to the plates and threaded thru polyethylene tubing and nylon tubing alternating. The plate connected to tubing and cable is shown in Figure 17.
4. The plate was pushed or hammered into the soil at the bottom of the trench. A plate pushed into place is shown in Figure 19. A tube carrying the wire from one other plate is also shown.
5. The cables were aligned on the bottom of the trench. The cables at elevation 505 feet were threaded into a 4 inch plastic pipe at the end of the trench nearest the instrument house. The polyethene casing extended into the 4 inch pipe 2 or 3 feet. At the other end of the pipe is a pulley box shown in Figure 21. The cables are placed around the pulleys and are threaded thru a vertical 4 inch plastic pipe carrying the cables to the instrument house. The cables at elevation 520 are fed into a 4 inch iron pipe which connects to the instrument house.
6. The trench is backfilled with sand and vibrated for compaction.
7. In the Instrument House the cables are pulled tight over a pulley system by window sash pulls.

8. A brass reference marker was placed on the cable so readings can be made with a cathetometer. This is shown in Figure 20.

Installation of Piezometers

1. A three inch diameter hole 5 feet long was drilled through the top crust for driving ease and alignment.
2. Three inch nominal galvanized pipe casing was pushed and driven three inches past the proposed piezometer tip.
3. The casing was then cleaned out with a rotary bit until the wash water was clean.
4. The casing was then pulled; if this was not possible it was hammered to the elevation of piezometer toe.
5. The hole was filled with Ottawa sand to the piezometer tip elevation, then compacted by the device shown in Figure 28.
6. The piezometer was placed in a tank to soak the stone for an hour.
7. The piezometer was lowered into the hole as shown in Figure 25.
8. The casing was pulled to an elevation 3 inches above the piezometer.
9. Ottawa sand was then added. In Figure 26 the sand is being added. The sand level was brought to an elevation 3 inches above the piezometer.
10. The casing was then pulled, or hammered another 6 inches.
11. A Bentonite seal was installed. A 15 inch seal of 5 separately compacted 3 inch lifts was placed. Figure 27 shows bentonite balls being dropped down the casing one at a time.

12. Then 2 feet of sand was compacted in the casing, and a second Bentonite seal was placed.
13. The casing was filled with sand.
14. A trench was excavated in line with the piezometers to the instrument house so the tubes leading to the instrument house could be buried.
15. Lengths of casing were remove until the top of the casing was below the bottom of the trench.
16. The tubing was placed in an "S" pattern along the trench to ensure that movement of the embankment did not break the tubing. It was necessary to install a 4 inch plastic pipe at the end of the trench connecting those piezometers which were installed in the natural subsurface material to bring the tubes up to the berm elevation.
17. The trench was backfilled with sand, and the 1/8 inch tubes were connected to the pressure manifold.

Installation of Pressure Plates

1. The fill was constructed to an elevation two feet above the desired installation level.
2. A pit was cut 6 inches below desired elevation of the lower pressure plate and large enough to use the template shown in Figure 31. A trench was cut leading from the pits to the instrument house.
3. The nylon pressure lines are filled by the pressure tank shown in Figures 30 and 33. The tank shown was filled with fluid (90% Kerosene and 10% oil) the top was pressurize with the pump; the oil flows into the lines from the bottom.

Each plate has its own input line but the out lines return to the readout station in groups of six.

4. The bottom of the pit is covered with damp sand formed so that the plates can be located by the template as in Figure 32.
5. The Plates were covered with sand, Figure 34, and the sand was compacted.
6. The template was removed; sand was placed and compacted to a depth of 18 inches above the pressure plates.
7. The tubing was laid in the trench, in an "S" pattern, from the pit to the instrument house as shown in Figure 35.
8. The pit was sealed from the trench by a plug consisting of a mixture of clay fill and bentonite. This permitted the development and maintenance of pore pressure.
9. The tubes were connected to the manifold in the instrument house for an initial reading.
10. The remaining portion of the pit was backfilled with fill material; the trench was backfilled with sand.

Installation of Slope Indicator

1. A five inch diameter hole was drilled in the insitu material to bedrock as illustrated in Figure 38. The auger was then pulled out of the hole.
2. The hole was cased to bedrock. To seal the casing at the base it was driven with a 300 pound hammer, as in Figure 39. In one case, the hole could not be sealed by this method, and a bentonite slurry was used to stop sand from entering at the base.

3. A rock auger was put down the casing to drill a 4 inch diameter by 3 foot deep hole into the bedrock.
4. The Slope Indicator casing was assembled in 20 foot lengths on the ground and lowered into the hole. It was easier to preassemble the long section on the ground, than assembling it all when lowering the casing into the hole. The longest section preassembled was 20 feet, for this could be handled without damaging the casing. The casing was made up of 5 foot lengths and 12 inch couplings. The couplings connected the 5 foot lengths with a 6 inch gap. The couplings were connected by pop rivets which require a field drilled hole. Then the pop rivets were placed as shown in Figure 40. Figure 41 shows a preassembled length of casing being placed.
5. The casing was then aligned with the grooves perpendicular and parallel to the center line.
6. After the Slope Indicator casing was completely in place. The outer casing (construction casing) was pulled from the hole making sure not to disturb or pull the Slope Indicator casing. If the outer casing is allowed to slip back into the hole, the toe of the casing will catch the coupling on the Slope Indicator casing and shear the pop rivets.
7. Number 17 sand was then slowly poured around the casing which was gently vibrated. This was done slowly until the sand fill reached ground elevation. The sand should be checked later for additional settlement.

8. Fill was compacted in the shape of a mound around the casing. This was repeated and extensions were added to the casing with the construction of the embankment.
9. Initial readings were taken immediately after installation of casing in the insitu material.

Installation of Hydraulic Settlement Gauges

1. The embankment was constructed 18 inches above the elevation of installation of the Hydraulic Settlement Gauges.
2. A trench 18 inches deep and 12 inches wide was cut across the embankment extending out of both slopes, except for the trenches below berm grade. The lower trenches were stopped at station 230 and 220, as shown in Figure 6. The excavation of the trench is shown in Figure 45. It is advisable to have a 1 in 100 slope to the centerline to aid in filling the tube without entrapping air.
3. A one inch P.V.C. tube was laid on the bottom of the trench and extended out the ends. The two trenches below berm elevation should have enough tubing excess at both ends to reach the Berm grade.
4. The trench was backfilled with 4 inches of sand and the remaining with fill material. In Figure 46 the trench is being backfilled with sand.
5. The wire to pull the transducer through is now installed. It's end is connected to a rubber stopper with just fits the tubing. It was pushed into the tube far enough to get an air supply tube in and a construction tire repair truck was used to blow the stopper thru the tube. The wire

spool is put on a spindle to unroll the wire.

6. The reservoirs were connected to the tubes and installed on a concrete slab foundation (Figure 44).
7. The tube and reservoir were filled with ethylene glycol, and an initial reading was made.
8. A protective box was built to cover the reservoir.