Soils Exploration and Design Considerations for the Greater New Orleans Expressway

I. Exploration and Testing

JAMES H. SCHAUB,[1] *Assistant Professor of Civil Engineering, Virginia Polytechnic Institute*

● AT the present time work is progressing on the construction of what will be the world's longest highway bridge. This structure forms the main element in the Greater New Orleans Expressway and will join the parishes of Jefferson and St. Tammany across Lake Pontchartrain. Figure 1 shows the location of the project in relation to New Orleans and the area adjoining the route of the expressway. The Greater New Orleans Expressway extends from a southern connection with U. S. Route 90 northward to the shores of Lake Pontchartrain. It crosses the lake on a 24-mile-long prestressed concrete bridge, and joins U. S. Route 190 and Louisiana Route 34 near Mandeville. Figure 2 indicates the position of the project within the existing highway network of the Central Gulf states.

The investigation, design, and supervision of construction of the Greater New Orleans Expressway are under the direction of the consulting engineering firm of Palmer & Baker, Inc., of Mobile, Alabama. Construction is being performed by the Louisiana Bridge Company, a joint venture of the Brown and Root Co., and the T. L. James Co. The Resident Engineer for the consultant is Brig. Gen. J. J. Twitty, CE, USA (Ret'd). Mr. J. E. Walters is the Project Manager for the Contractors.

Completion of the expressway will establish a direct route for automobile traffic between New Orleans and U. S. Route 90 to the south and west, and Jackson and Mississippi Route 27 to the north. Time-consuming detours around Lake Pontchartrain will be eliminated. Expansion of the city of New Orleans will also be facilitated by the project.

The Greater New Orleans Expressway is a toll revenue project jointly sponsored by the terminal parishes of Jefferson and St. Tammany. Funds were raised by the Expressway Commission with the sale of a $46,000,000 bond issue. Additional funds were made available from the collection of automobile registration fees in the six parishes in the vicinity of New Orleans. Authorization for the use of the latter funds was granted by Act No. 90 of 1952, an amendment to the Constitution of Louisiana.

GEOLOGY AND SITE CONDITIONS

Lake Pontchartrain is an inland body of water formed by the enclosure of a coastal lagoon by the expanding delta of the lower Mississippi River. The lake is subject to tidal action with a mean range of 1 foot. Storms and infrequent high water cause water level variations of 1 to 6 or more feet.

The depth of the lake is relatively uniform—generally varying from 13 to 17 feet but becoming shallower close to shore. The bottom material is composed of very soft to medium-stiff sedimentary deposits, usually clays or silts of recent origin. These and other soft deposits extend to depths of 40 to 60 feet below sea level. They are followed by stiffer clays and denser silts and sands to depths of 70 to 80 feet. Materials encountered below 80 feet are usually the stiff clays and dense sands that characterize the Pleistocene deposits in the New Orleans area. Sedimentary deposits continue to depths of 2000 feet or more below sea level.

The south shore approach road to the Lake Pontchartrain Bridge crosses the low lying areas of Jefferson Parish. Here the surface materials are soft peats and organic clays followed by a thick layer of soft and compressible clay.

[1] Formerly Laboratory Director, Palmer & Baker, Inc., Mobile, Alabama.

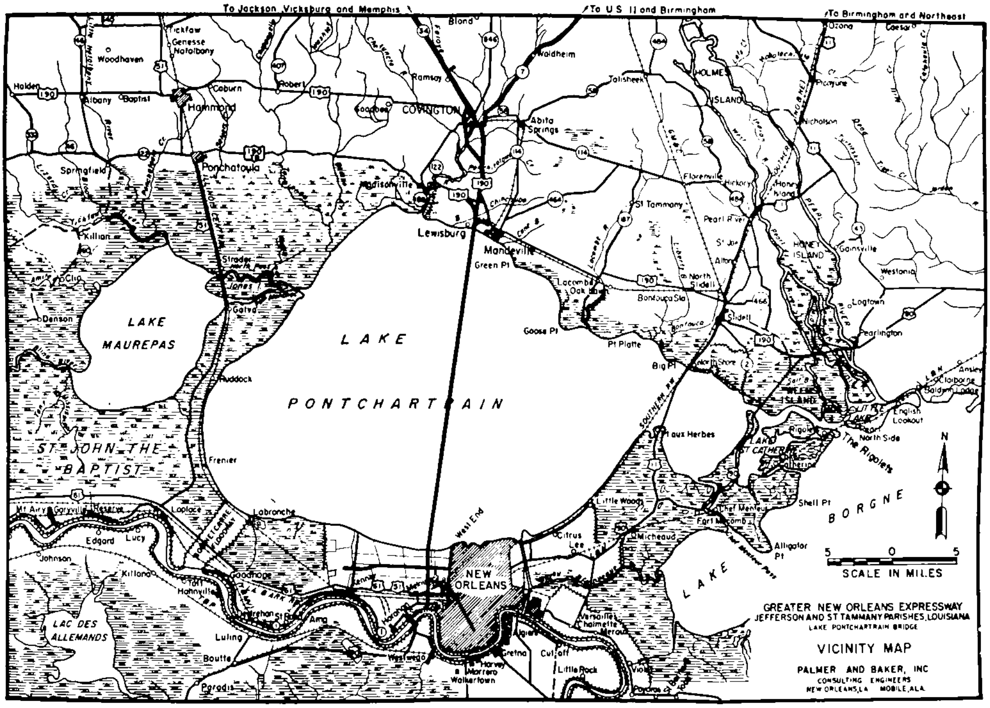

Figure 1. Vicinity map.

On the north side of the lake, the surface materials are generally of a better nature. The soft organic deposits, when they are present, are usually confined to thin surface layers or areas of limited size.

PURPOSE OF THE INVESTIGATIONS

The presence of known deposits of soft and very compressible materials indicated the necessity for extensive subsurface exploration. Though numerous boring records were obtainable for the New Orleans area, little information was available concerning the details of stratification and the engineering properties of the soils underlying the lake. Specific answers were needed to the questions of length, bearing capacity, and possible settlement of the piles proposed for the foundation of the bridge. Information was required concerning the magnitude and duration of the possible settlement of the plazas to be constructed at the bridgeheads. Additional knowledge of the soft surface materials along the alignment of the approach roads was needed to facilitate the design of a satisfactory method of construction through these areas.

EXPLORATION

The original alignment proposed for the Lake Pontchartrain Bridge is shown as the westerly line on Figure 3. The subsurface explorations were started on this line during the latter part of April, 1953. The explorations at the south plaza and at the location of the proposed artificial island turnaround followed shortly after the completion of the original line.

One hundred borings were made along the bridge center line. These borings were spaced at approximately ¼-mile intervals. Three borings were located at the sites of each of the two bascule spans and were carried to depths of 200 feet below the water surface. Approximately every fourth boring was continued to a depth of 140 to 160 feet below the surface of the lake. The remainder of the lake borings were 100 feet deep. The depth of the borings was subject to change at the

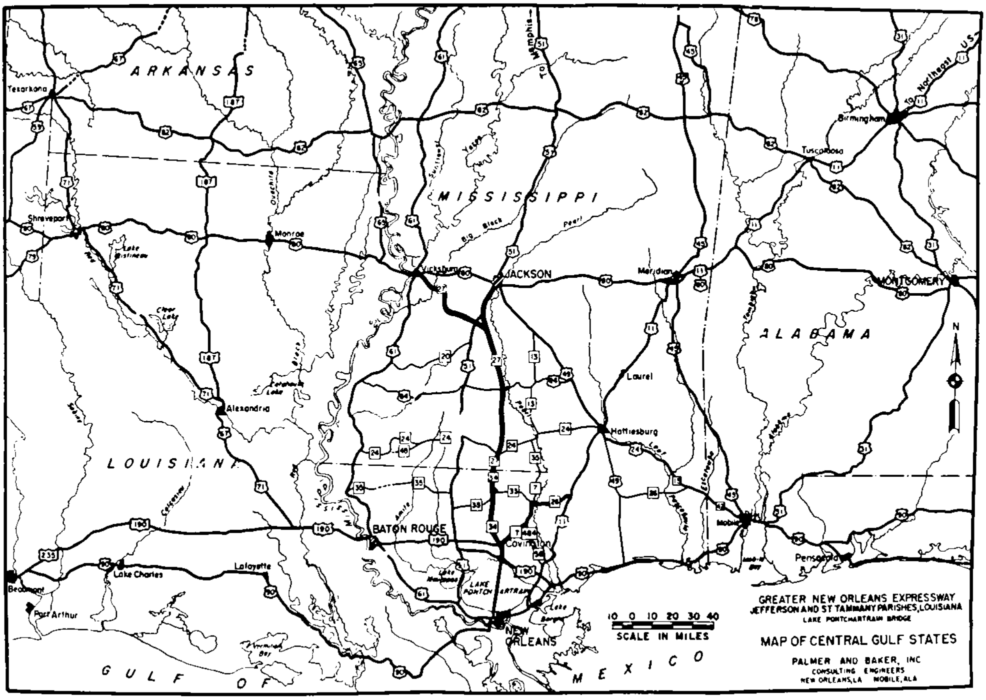

Figure 2. Map of Central Gulf states.

discretion of the engineer in charge of explorations.

All of the exploratory borings were made with rotary dilling equipment. A combination of casing and drilling mud was used to keep the holes open. Drilling operations were carried out from barges. The drill rig operated either through an opening in the center of the barge, or over one end. Normal operations utilized two drill rigs and twenty-four-hour work schedules were routine.

The choppy wave action and sudden squalls typical of the Lake Pontchartrain area introduced some difficulty. At times all work was stopped by weather conditions. On at least two occasions, drilling barges were torn from their anchors and beached by storms.

Samples were not required at depths of less than 40 feet unless the material encountered was noticeably different from the usual soft bottom muck. Below depths of 40 feet, samples were required at every change in soil type and at intervals of not more than 10 feet. Samples were taken with a 3-inch Shelby Tube Sampler utilizing the hydraulic drawdown of the drilling equipment to force the sampler into the soil. Samples of the granular materials encountered were obtained from the split spoon after the performance of a Standard Penetration Test.

Samples were removed from the sampling tubes in the field immediately after being recovered. Following a visual inspection and classification of the soil, two sections, each approximately 6 inches long, were cut from the core. These sections were wrapped carefully in waxpaper and sealed into half-gallon waxed cardboard liquid containers. In addition to the two undisturbed sections, one pint-jar disturbed sample was retained from each sample tube to permit visual inspection of the material at the laboratory.

As each boring was completed, samples were transported by the consultant's field force to the soils laboratory in Mobile, Alabama. Inspection of several hundred undisturbed sections did not indicate any harmful effects from the method of handling and transporting the samples. Several sections prepared in this manner were opened recently. Surface drying

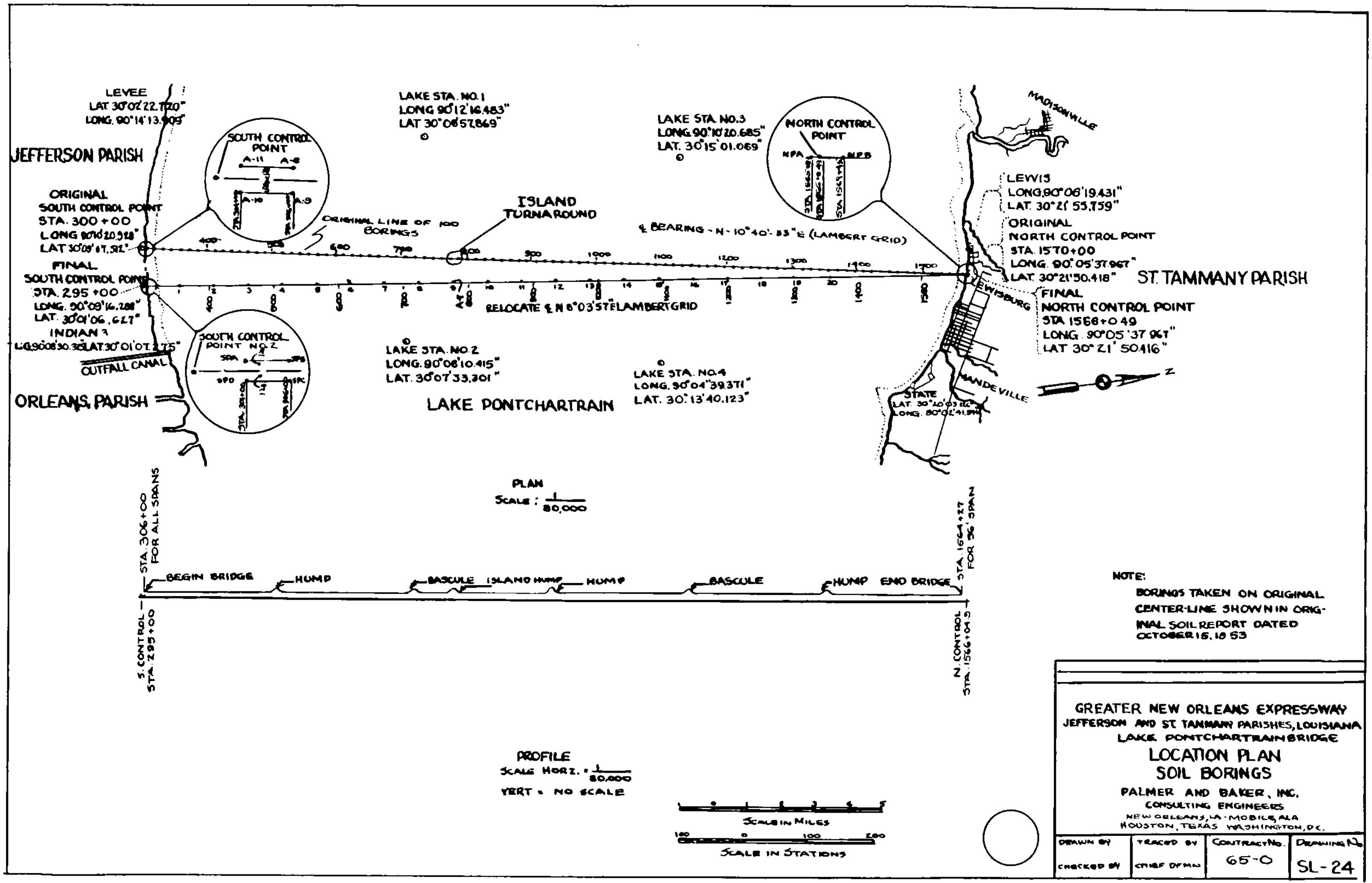

Figure 3. Location plan.

was apparent but there was very little change in the water content of the interior of the sample.

Boring operations were completed on the original line in late July, 1953. The total time required for this phase of the explorations program was approximately 3 months. During this period, 100 borings with a lineal footage of 11,567 feet were completed. More than 950 samples of the Shelby Tube and the split spoon types were recovered.

A second phase of the original location exploration consisted of borings at the site of the south bridgehead plaza and at the site of the proposed artificial island turnaround. Four borings were made to a depth of 60 feet below ground surface at the former location. Sampling and drilling methods were similar to those used for the bridge center line borings. The borings at the plaza site were to determine the stratification in this area and to obtain samples for consolidation and shear strength testing. The explorations confirmed earlier opinions that the design and construction of the plaza fill would be complicated by the very soft material present in this area.

At the site of the proposed artificial island turnaround, four borings were made to a depth of 60 feet below the water surface. Samples were taken in the usual manner. These borings were to determine the suitability of the site. Three additional borings were made to a depth of 70 feet at locations east of the center line to explore this area for suitable hydraulic fill material. No samples were obtained from these borings. The unsuitable character of the material was obvious from the field classification.

The two phases of the original location exploration consisted of 12,390 lineal feet of borings. The unit price for this work varied from $5.50 to $7.50. Later explorations were accomplished at lower unit prices. The variation is believed to have been caused by the unknown factors involved in work of this nature on a treacherous body of water.

An adjustment in the alignment of the Lake Pontchartrain Bridge necessitated additional exploration work. The new and final alignment is shown as the easterly line in Figure 3. The alignment change consisted of moving the south bridgehead 1.1 miles to the east while maintaining the north bridgehead at the original location. Twenty borings at intervals of 1 mile were made along the new center line. Four borings at the relocated south plaza site, and two borings at the site of the north plaza also were made. These borings were completed during the month of February, 1954.

The method of boring, sampling, and handling of samples was similar to that used in the earlier series of borings.

The two borings located at the bascule span sites were carried to a depth of 200 feet, while the remainder were stopped at 100 feet below the water surface. The depth of the borings at the plaza sites was 100 feet. This depth was 40 feet greater than the plaza borings of the original exploration program.

The additional exploration required for the adjusted location of the Lake Pontchartrain Bridge consisted of 2740 lineal feet of boring. Approximately 260 undisturbed and Standard Penetration Test samples were recovered.

The total cost of explorations for the Lake Pontchartrain Bridge, including both the original and the final locations, amounted to slightly less than 0.3 percent of the contract cost of the structure.

Among the foundation designs proposed for the Lake Pontchartrain Bridge was one that contemplated the use of two 54-inch hollow prestressed concrete piles per bent. Piles of this type, but of a smaller size, had been used previously with a great deal of success. In order to better judge the feasibility of this design proposal, a test pile was considered necessary. The test pile was manufactured by the Raymond Concrete Pile Company and driven approximately 7400 feet from the south shore on the original alignment of the bridge.

In conjunction with the driving and loading of the test pile, which will be discussed in Part II of this paper, two borings were made at the site. One boring was made from the test pile platform. This boring recovered disturbed samples only. Its purpose was to obtain general stratification information. A second boring was made from the instrument platform and continuous undisturbed samples were obtained with a 2-inch Shelby Tube Sampler. Both borings were advanced by hand methods but utilized a power driven cathead to handle the drill stem and to push down the sample tubes. These borings were made by the Raymond Concrete Pile Company.

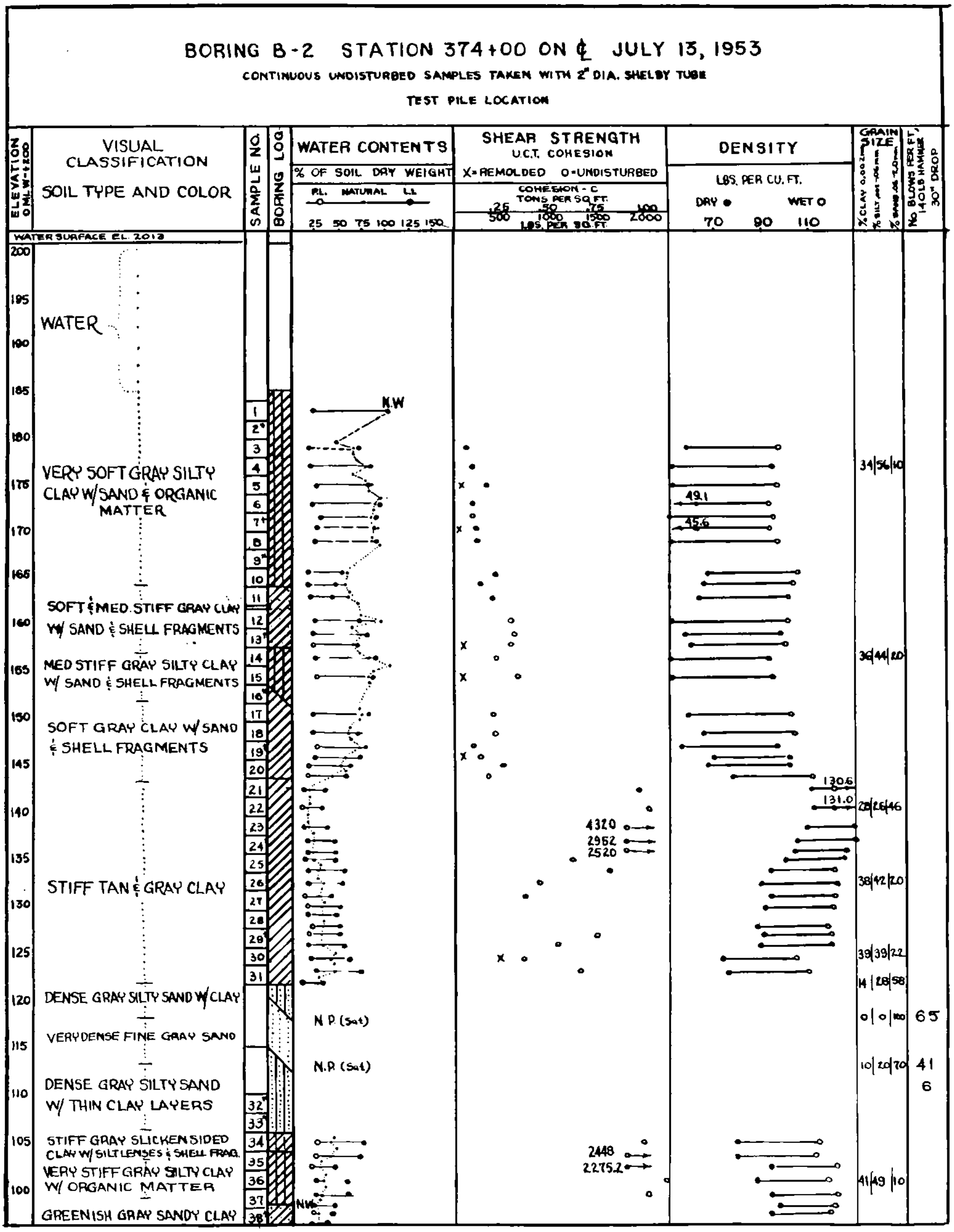

Figure 4. Test pile boring log.

The samples were ejected from the Shelby Tube Samplers in the field and handled as previously described. An exception was made in the case of two samples which were sealed in the tubes for shipment to the laboratory. It is interesting to note that there was no apparent difference in the test results obtained from the samples ejected from the tubes in the field and those removed from the sampler in the laboratory. Figure 4 shows the results of the testing on the continuous undisturbed sample boring.

LABORATORY INVESTIGATIONS

The laboratory program consisted primarily of classification testing, shear strength determinations, and consolidation testing. One of the two undisturbed sections received from each sample tube was tested. The other section was retained unopened for a recheck of the test values or later visual inspection. In some cases a poor sample or the occurrence of a change of strata within a sample necessitated opening the second section. The quantity of samples arriving in the laboratory made it essential that all testing be performed as swiftly as possible. All laboratory personnel were organized on a production line basis. Each individual or group was made responsible for certain testing operations.

The testing methods used were those generally accepted throughout the United States. Water contents were expressed as a percentage by weight based on the weight of the oven-dried sample. Liquid limits were determined by the use of a three-point curve plotted on semi-log paper. Each point represented the average of two number-of-blow determinations. Laboratory procedure required that the two number-of-blow determinations for each point check within one blow of each other. Plastic limits were computed as the average of two separate determinations that were in substantial agreement with each other. The lowering of the water content for both liquid and plastic limit tests was accomplished by air drying and kneading of the soil. Dry soil was not added in the effort to reduce water content. Grain size determinations were made by use of the hydrometer analysis, wet sieving, or a combination of both. The method used in each case was selected after consideration of the particle size of the material being tested. Shear strength values were established by the unconfined compression test on samples trimmed to a diameter of 1.4 inches and a length of 2.8 inches. Test specimens were loaded hydraulically. Loads were measured by means of calibrated proving rings and deformations were established with extensometers. For those samples that showed a plastic type failure, the failure load was considered to be that corresponding to 20 percent strain. A limited number of unconfined compression tests were made on samples remolded at the natural water content to establish the sensitivity ratio.

All consolidation tests were performed on specimens of 2.5-inch diameter and 0.5-inch thickness in floating ring type consolidometers. The consolidation samples were loaded initially to a load approximately equal to the existing overburden pressure. Subsequent loading was by increments to a maximum load of 12.8 tons per square foot. All load increments were maintained until the dial reading versus time curve showed a straight line. In general, each load increment was maintained for a period of 24 hours. Wet unit weights were computed from volume and weight measurements made on the samples immediately after opening the sealed sections.

The highly organic surface soils from the south approach road area were tested in an effort to determine the pH and organic content. The pH value was established from a suspension of the soil by the use of a Beckman type pH meter. The organic content determination was expressed as the percentage loss of weight on ignition of a sample of oven-dried soil. The question of the classification of soils with high organic contents was a source of extensive discussion. An arbitrary classification system was finally adopted. This system utilized the Atterberg Limits and the percentage of organic matter indicated by the loss on ignition.

Upon arrival in the laboratory, the disturbed samples from each sample tube were visually classified and a testing program prepared for the boring. In general, one undisturbed section from each tube was used to determine the natural water content, Atterberg Limits, wet unit weight, and unconfined compressive strength of the sample. Selected samples were tested for grain size distribution, remolded compressive strength, and consolidation characteristics. The individual samples were tested for the natural water content, wet unit weight, and unconfined compressive strength, immediately upon being opened. The scraps from the trimming operation that shaped the unconfined compressive strength specimens were used for limit testing and for the grain size determinations. Concurrently with trimming, a detailed examina-

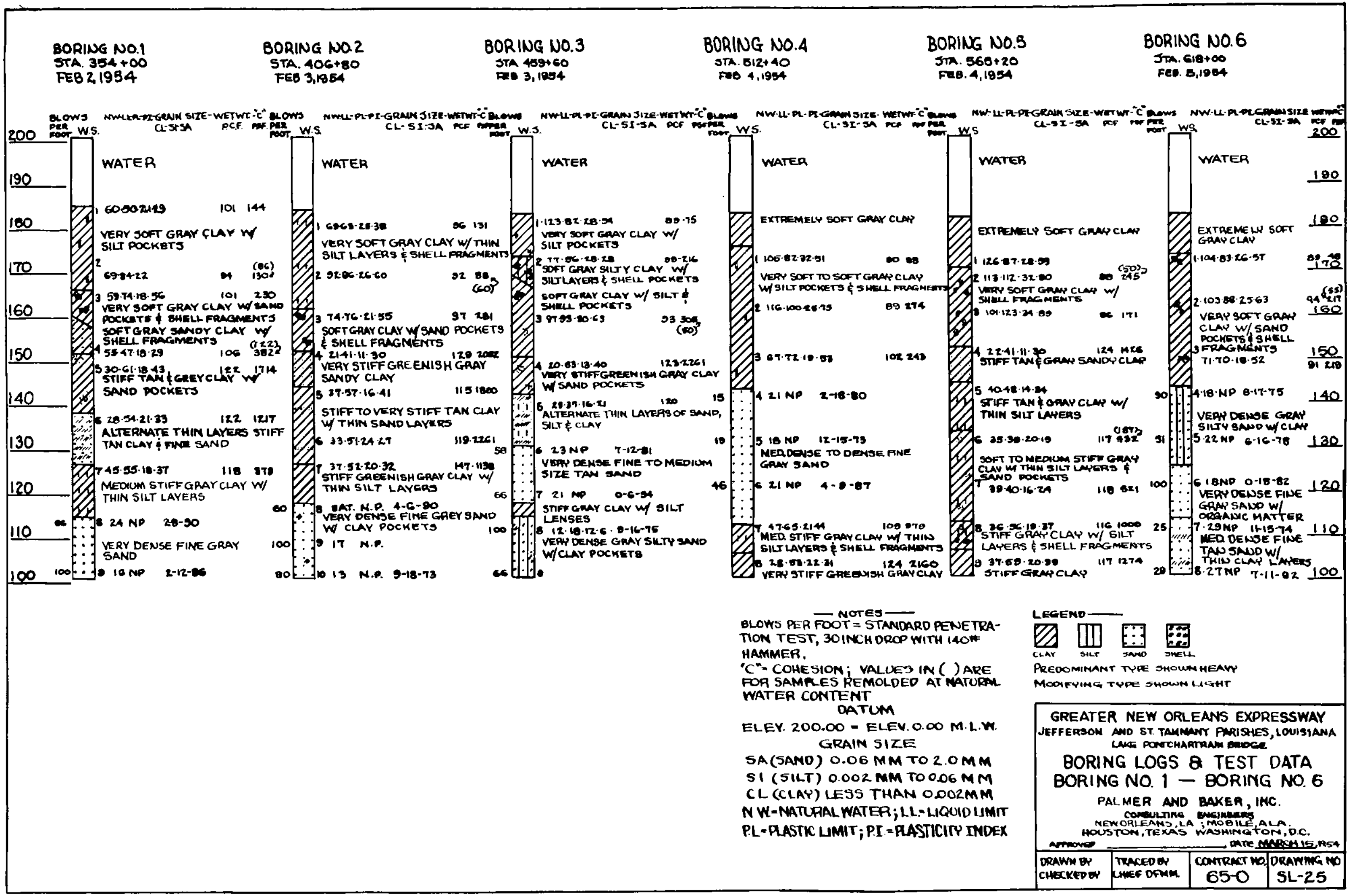

Figure 5. Boring logs and test data.

tion and visual classification of the sample was made.

As the testing was completed for each boring, the various test results were correlated. A rough soils log was prepared to show the soil stratification, sample location and classification, and all test results. Final presentation of the soils test results and boring information was made in the form of an ink-on-linen copy of the rough log.

The largest single problem in the handling of the large quantities of samples received was that of record keeping. This difficulty was overcome in part by the experience of the technicians and by the close supervision of the various section leaders. Continual evaluation and adjustment of the testing methods and various laboratory operations were necessary. Limited storage space required handling the samples swiftly and as efficiently as possible.

Testing of the samples from the original location borings, and the preparation of the final boring log and data sheets were completed 2½ months after the conclusion of the field work. The testing for the explorations along the final alignment was completed within 30 days of the completion of the drilling.

At least one section received from each sample tube from the continuous undisturbed sample boring at the test pile site was subjected to a full series of classification and shear strength tests. The natural water content was established and a visual classification was made on all other sample sections. The results of the testing on this boring are shown in Figure 4. The reduced size of the reproduced drawing has necessitated elimination of the individual sample classifications.

The following summation of the numbers of the various tests performed is presented to indicate the magnitude of the laboratory investigations.

Atterberg Limits	1108
Unconfined compression tests	629
Grain size determinations	244
Consolidation tests	83

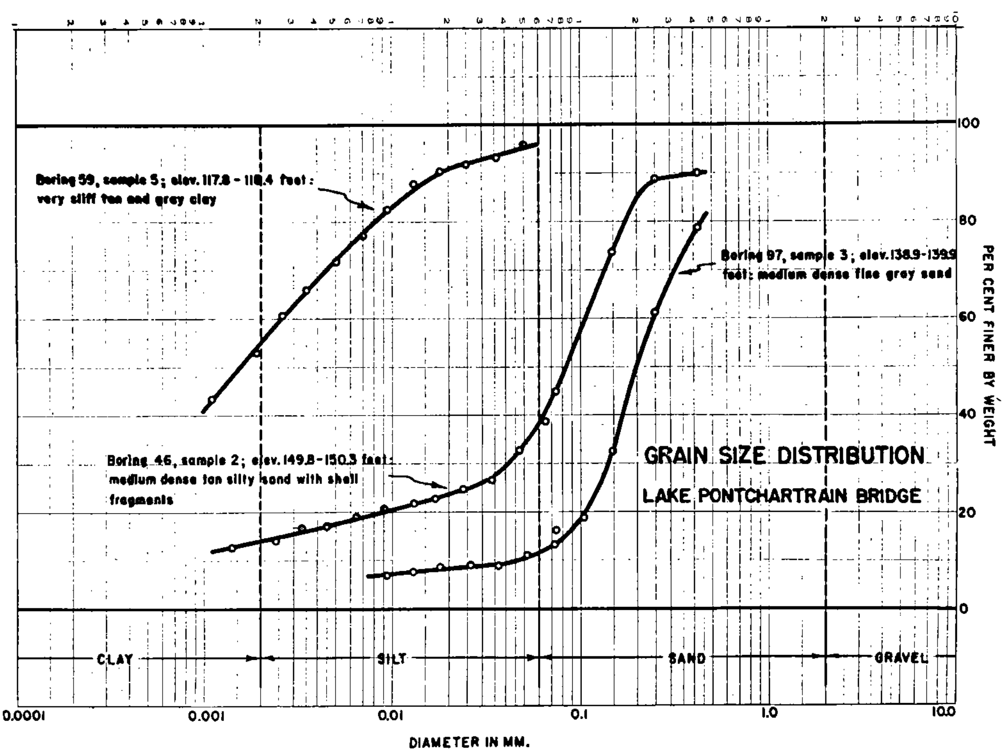

Figure 6. Typical test results.

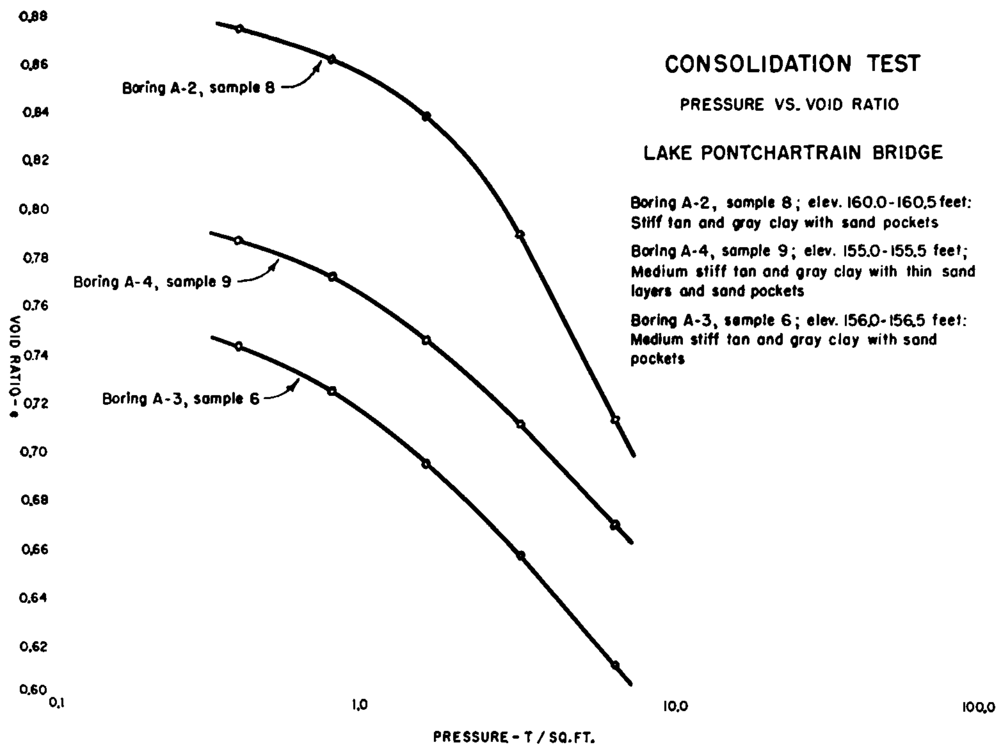

Figure 7. Typical test results.

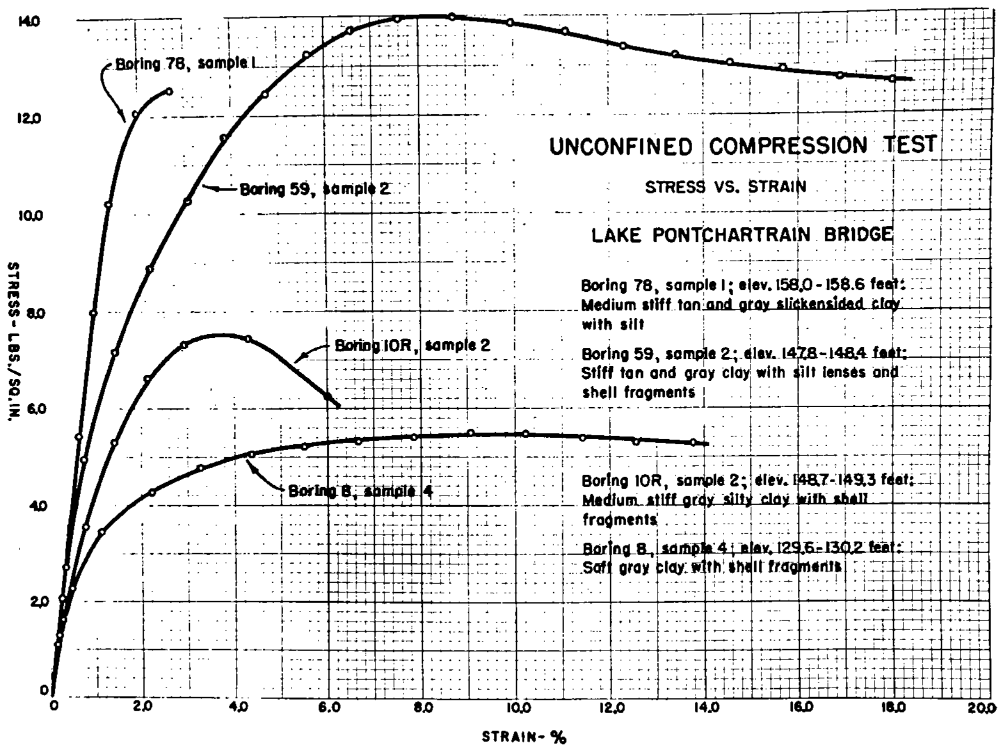

Figure 8. Typical test results.

Included in the number of unconfined compression tests reported are 46 remolded tests. The sensitivity ratios varied from a low of approximately 1.0 to a maximum of 6.5. In general, the high values of the sensitivity ratio are typical of the clays occurring at the depths of less than 60 feet below the water surface. The exception to this occurs on the northern end of the line where the Pleistocene clays appear at the higher elevations. These clays show an average sensitivity ratio of approximately 1.5.

A total cost for the laboratory investigations was estimated utilizing unit cost figures for the various soils tests. The unit cost values were derived from time-and-daily-cost studies made over a period of years. On this basis, the laboratory testing amounted to less than 0.1 percent of the contract cost of the Lake Pontchartrain Bridge.

PRESENTATION OF TEST AND EXPLORATION DATA

It was desirable that all of the soils and exploration data be made available to the designers in as complete and concise a manner as possible. The method of presentation finally adopted is illustrated by Figures 4 and 5. Typical test results were included in the final soils report in the manner illustrated by Figures 6, 7, and 8.

ACKNOWLEDGMENTS

The completion of an exploration and testing program of the scope of that performed for the Greater New Orleans Expressway requires the efforts of many people. The cooperation and encouragement of all those concerned were of great assistance. The group of laboratory technicians that were engaged on this project are to be especially commended for their unstinting efforts in the completion of the work.