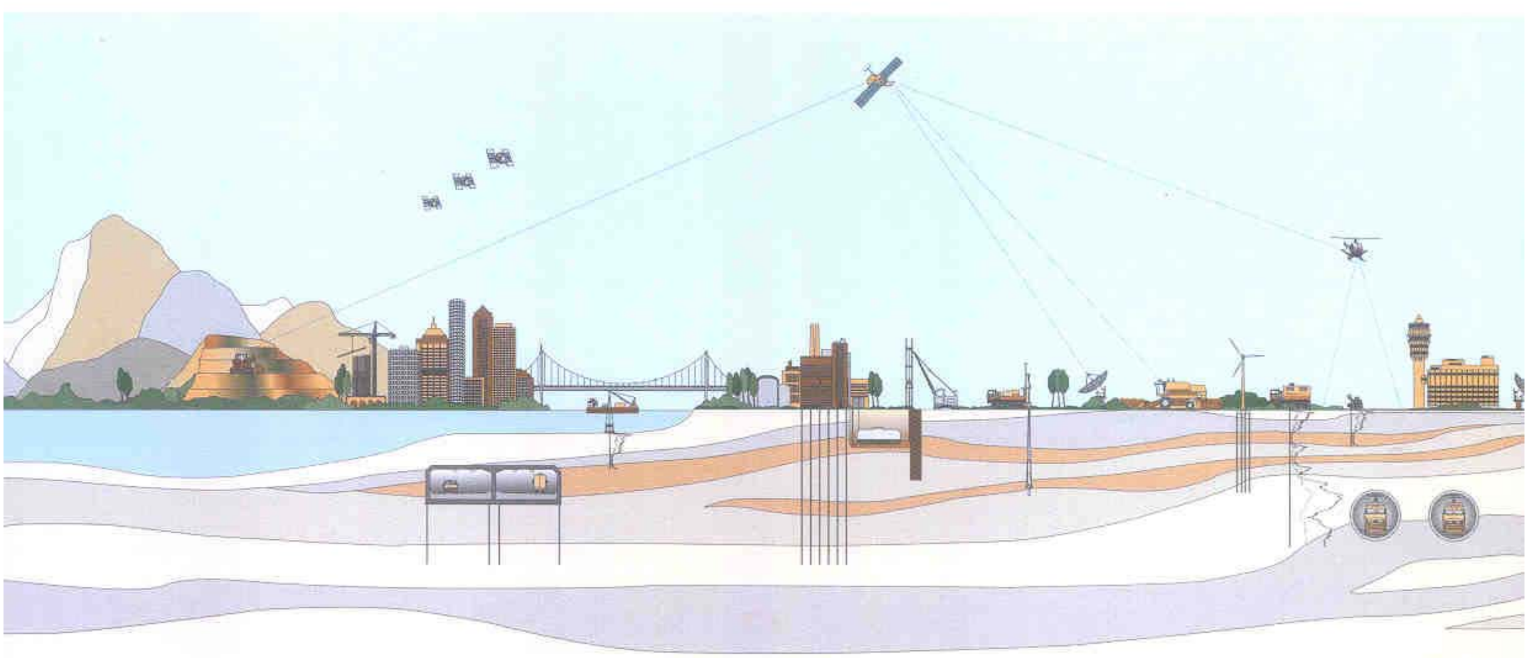
FUGRO SOUTH, INC.

GEOTECHNICAL STUDY (PART II OF II)
GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

SHINER MOSELEY AND ASSOCIATES, INC.
CORPUS CHRISTI, TEXAS



Report No. 0602-1316
Part II of II
January 7, 2003

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Attention: Mr. Dan Heilman, P.E.

Geotechnical Study (Part II of II)
Gulf Shoreline Stabilization Project
Rockefeller Refuge
Cameron Parish, Louisiana

Introduction

Fugro South, Inc. is pleased to present this final report of our geotechnical study for the above-referenced project. Mr. Dan Heilman, P.E., with Shiner Moseley and Associates, Inc. (SMA), requested this study during a telephone conversation with Mr. David W. Duhon, P.E. of Fugro South, Inc., on March 20, 2002. Mr. Neil McLellan, P.E., with SMA, authorized this study via memorandum e-mailed to Mr. Duhon on May 29, 2002. We performed this study in general accordance with our Proposal No. 0602-1316, dated March 25, 2002.

The first report (Part I of II), issued August 8, 2002, was submitted at the request of the client to aid with the conceptual designs of various shoreline stabilization structures. The major design concepts included and discussed in the first report were allowable soil bearing capacity and construction considerations. Twenty exploratory soil borings were performed for this study and the Boring Logs are presented in the first report (Part I) along with discussions of the subsurface conditions encountered, our field activities, and our laboratory-testing program. We understand that based on comments from the first report, the stabilization concept deemed most likely feasible will be a broad crested breakwater, termed a *reef breakwater*. The anticipated *reef breakwater* profile provided by SMA is included on Plate 1 of this report. Our consolidation tests are complete and we have performed settlement analyses based on this information. The results of our settlement analyses are presented in this report.

Project Description

We understand that due to extensive coastal erosion over the past several years, the Louisiana Department of Natural Resources, along with the Rockefeller Wildlife Refuge, is planning to construct a shoreline stabilization structure from Joseph's Bayou westward about 10 miles to the west boundary of the Rockefeller Refuge along the existing shoreline. The project site is essentially located in the southeast corner of Cameron Parish, Louisiana, which is bordered to the south by the Gulf of Mexico. A *Site Vicinity Map* and *Plan of Borings* are provided on Plates 1 and 2, respectively, of the first report (Part I).

Compressibility Characteristics

We measured the compressibility characteristics of the subsurface soils by performing eleven (11) incrementally-loaded consolidation tests. Due to the very soft consistency of the upper clays, we were unable to perform any consolidation tests on materials representative of the upper 20 ft at this site. We performed each test with a rebound-reload cycle near the samples estimated preconsolidation pressure. Natural moisture contents, Atterberg Limits, and dry unit weights were determined as routine portions of the consolidation tests. Consolidation test results are presented as plots of effective vertical pressure versus strain on Plates 2 through 12 of this report.

Reef Breakwater Settlement

We understand that the *reef breakwater* will have a base width of 50 ft, a crest width of 30 ft, and an overall height of approximately 5 ft. The height will vary depending upon the existing mudline elevation; however, we understand the height will be no more than 5 ft. The proposed top elevation of the breakwater will be EL +1 NAVD 88. Reportedly, the breakwater will be constructed in the Gulf of Mexico just off the beach.

Since the type of material that the breakwater will be constructed of has not been selected, our settlement analyses are based on various load values and not a particular levee section. Estimation of settlement for the very soft clays encountered at this site is difficult. Collection and testing of the in-situ soils proved onerous without developing significant sample disturbance. The following settlement estimates are based on available consolidation data, other engineering test values, judgment, and our past experience with similar soils. We performed the analyses using our in-house computer program SETANL. This program first computes net stress changes at selected locations and depths beneath loaded areas using Boussinesq theories of stress distribution. The program then uses soil compressibility parameters to evaluate the change in thickness of individual layers and compute the overall movement at the selected locations. Soil compressibility parameters used in our analyses were developed using laboratory consolidation test data presented on Plates 2 through 12 of this report. The following assumptions were also used to calculate settlement due to grade raise:

- soil stratigraphy is assumed to have infinite lateral extent,
- settlement is only under the load of the material used to raise site grade, and

- significant disturbance to the in-situ soils will not occur during construction.

The addition of the breakwater to the site was modeled as a raise in site grade and the pressure selected to estimate settlement will depend on the type of material used for the breakwater, the amount of material considered to be above the water level and below the water level, and the height of material placed. We understand that the entire area over which the breakwater will be constructed was previously emergent land with a ground surface elevation of at least EL +1 NAVD 88. Due to erosion, the ground surface has been reduced to about EL -4 NAVD 88. The loss of soil has resulted in a decrease of applied load to the underlying soils in the immediate area of the proposed breakwater. Based on this previous loading history and the laboratory densities obtained for this study, we recommend the total applied load to the soils in the breakwater area be reduced by a value of 140 psf to determine the net applied load for settlement determination. For example, if the effective total load (buoyant) from the new breakwater is 400 psf, we recommend reducing this value to 260 psf for the net applied load and using this value to determine magnitude of settlement. The following table presents the results of our analyses:

Net Applied Pressure Change (ΔP), psf	**One-Dimensional Consolidation**	
	Estimated Center Settlement, feet	Estimated Edge Settlement, feet
100	1.1 ~ 1.1	0.7 to 0.8
150	1.4 to 1.5	1.0 ~ 1.0
200	1.7 to 1.9	1.2 to 1.3
250	2.0 to 2.2	1.4 to 1.5

We understand the use of lightweight aggregate may be included within the breakwater section to reduce total applied load. Test should be performed on the final selected material to verify unit weight; however, we typically use a total saturated weight of 72 pcf for locally available lightweight aggregate. Once submerged, the effective unit weight is typically taken as 9 pcf. Similar breakwaters in Louisiana have been successfully completed using shell or lightweight aggregate as the core. Care must be exercised during placement to protect the lightweight aggregate from wave action both during placement and after construction. Typically, a geo-fabric such as Mirafi 600X, or equivalent, is placed by hand on the mudline, lightweight aggregate is deposited by a barge and dredge line, a new geo-fabric is placed atop the lightweight aggregate and rip rap is placed to a determined thickness atop the upper fabric. We expect that a line of barges or similar wave break could be utilized for protection during placement. In addition, it may be feasible to place the lightweight aggregate within a geo-tube to protect losses during and after construction.

A detailed slope stability analysis was beyond our scope of work for this project. Slope as well as base stability of the reef breakwater should be analyzed. Due to the presence of very soft clays to a depth of about 30 ft to 40 ft, base failure will likely govern the height of the structure. Hydraulic stability of the breakwater must also be analyzed.

Construction Considerations

The following sections, which provide discussions relative to lateral soil displacement due to material placement, construction equipment, construction sequence, a field test section, and construction monitoring, are provided again due to their importance to the overall success of this shoreline stabilization project. **{**tc \l 1 "CONSTRUCTION CONSIDERATIONS"**}**

Lateral Soil Displacement. The upper soils encountered in the exploratory borings consisted primarily of very soft clays. These clays extend from the existing shoreline (mudline) to a depth of about 40 ft. It is possible that a lateral soil displacement (mudwave) could be created in these upper soils when soil or rock is dropped on them. It is difficult to determine the magnitude of a lateral soil displacement. The lateral extent of the displacement will depend on the height from which the construction material is dropped as well as the total height of the breakwater. *Reducing the height from which the materials are dropped into the water will help to reduce the extent of lateral displacement*. In our opinion, it would be prudent to gently place the breakwater material on the prepared subgrade (after the geofabric is installed) as opposed to dropping the material.

Construction Equipment. Any construction equipment used on the beach should be carefully selected and should impart very low bearing pressure on the subgrade soils. Remolding of the soils and continued operation of the construction equipment may further reduce the bearing capacity of the soils. Construction equipment may sink in the very soft clays at this site unless it is supported by mats or other properly prepared subgrade. We do not recommend running any construction equipment on the subgrade in the area of the breakwater. It should be noted that the allowable bearing capacity given in the Part I report is an average across the site and localized areas may have as much as 30 percent lower bearing capacity.

Construction Sequence. We recommend that the sequence of the breakwater construction be such that the entire breakwater is constructed in relatively uniform lifts. Significant (more that about 1.0 ft) differences in height during construction should be avoided to reduce the potential for slope/base failures. Slope/base failure issues of the breakwater should also be evaluated.

Field Test Section. We strongly recommend that consideration be given to constructing a field test section. The very soft clays at this site are prone to create a mudwave, which will be very difficult to contain or remediate. Construction of a test section will give valuable information on whether the breakwater can be constructed to its intended height, settlement and creep of the soils, and will aid in developing construction sequence and techniques.

Construction Monitoring. We recommend that a geotechnical engineer, or qualified representative, be present on-site to observe the construction of shoreline protection structures. On-site observations may aid in recognizing and reconciling any unanticipated soil or groundwater condition and to check that design recommendations are appropriate and properly implemented during construction. During the construction phases, we can provide construction surveillance to: (1) observe compliance with the design concepts, specifications, and recommendations; and (2) observe subsurface conditions during construction.

* * *

The following illustrations are attached and complete this report:

Closing

We appreciate the opportunity to be of continued service to Shiner Moseley and Associates, Inc, and look forward to working with you again in the near future. Please call us if you have any questions or comments concerning this part of the study or when we may be of further assistance.

Sincerely,

FUGRO SOUTH, INC.

Don Dugas, III, P.E.
Project Manager

John T. Juenger, P.E.
Engineering Manager

Copies Submitted: Addressee (5)

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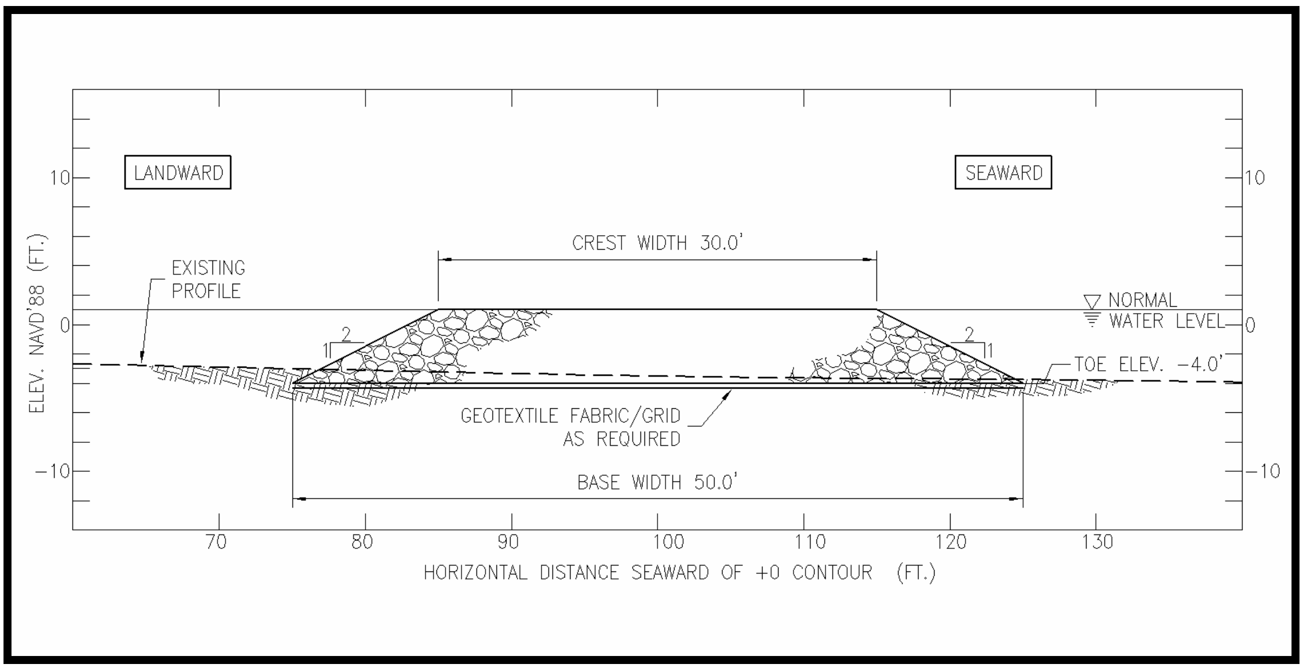
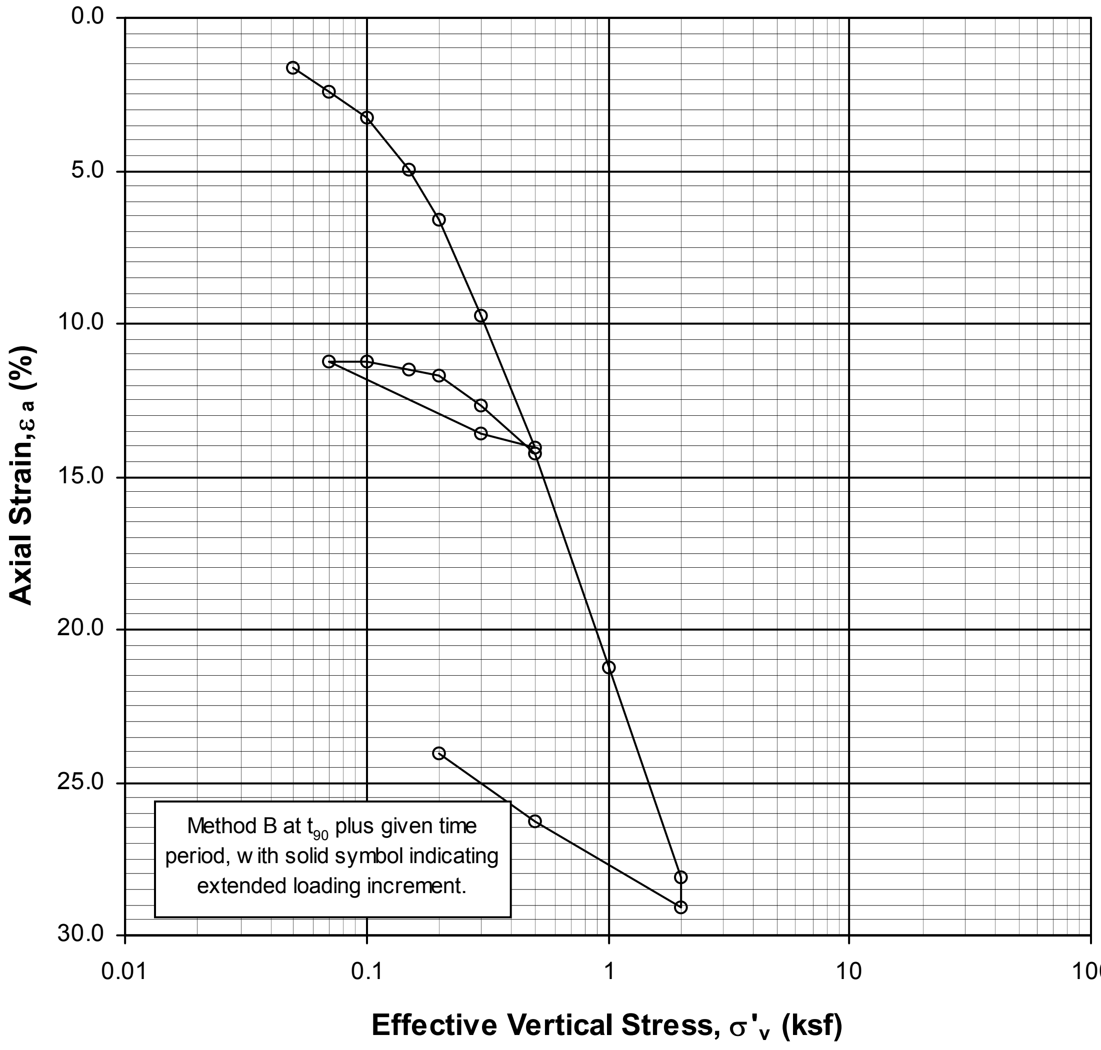


Drawing Provided by Shiner Moseley and Associates, Inc. December 20, 2002.

BROADCRESTED "REEF BREAKWATER"
PROFILE
Not-to-Scale

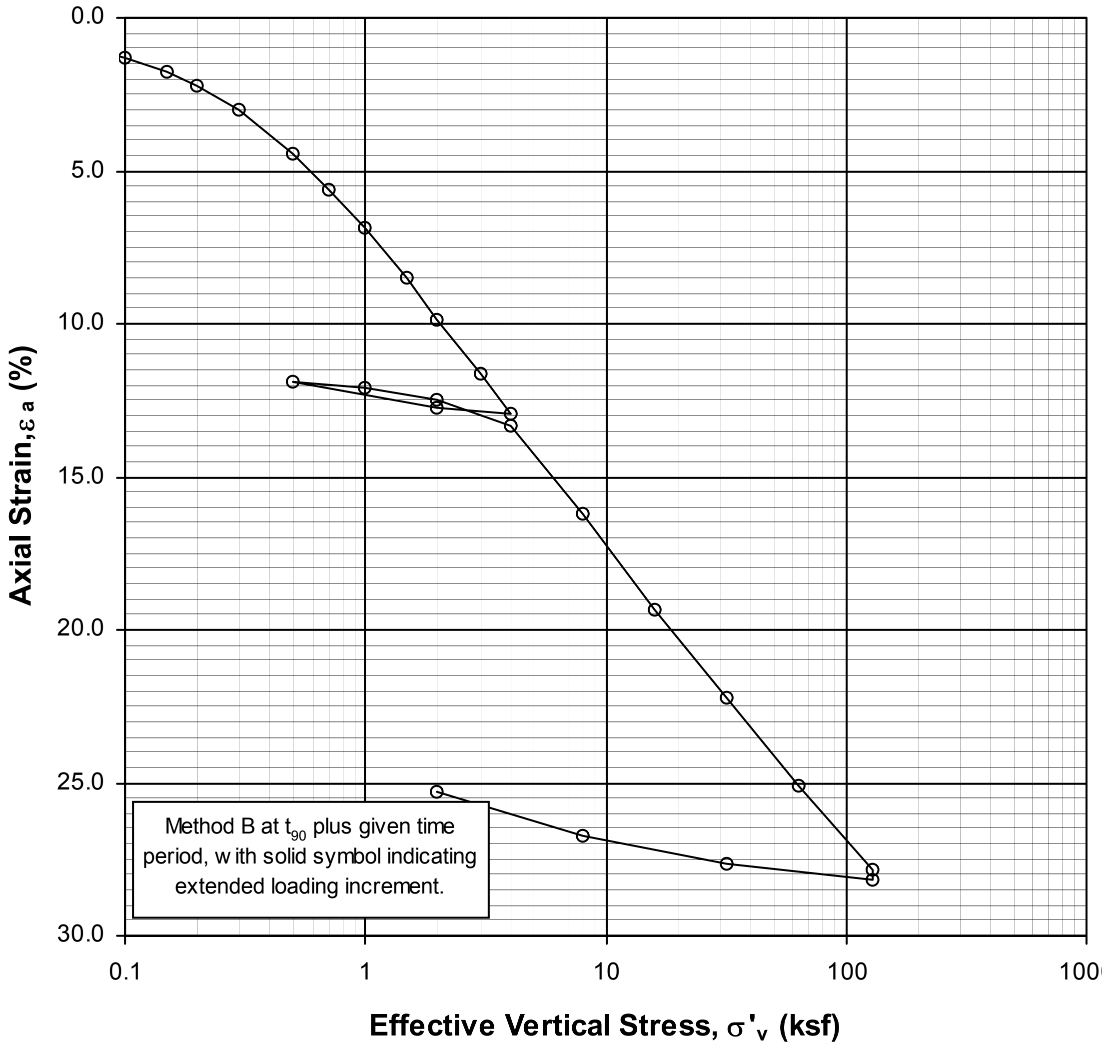
BORING: B-2
PENETRATION: 20.0 Feet
MATERIAL: CLAY, very soft to soft, gray
DRY UNIT WEIGHT: 42.5 pcf
WATER CONTENT: 111.4 %
LIQUID LIMIT: 100
PLASTICITY INDEX: 72
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 3.029



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

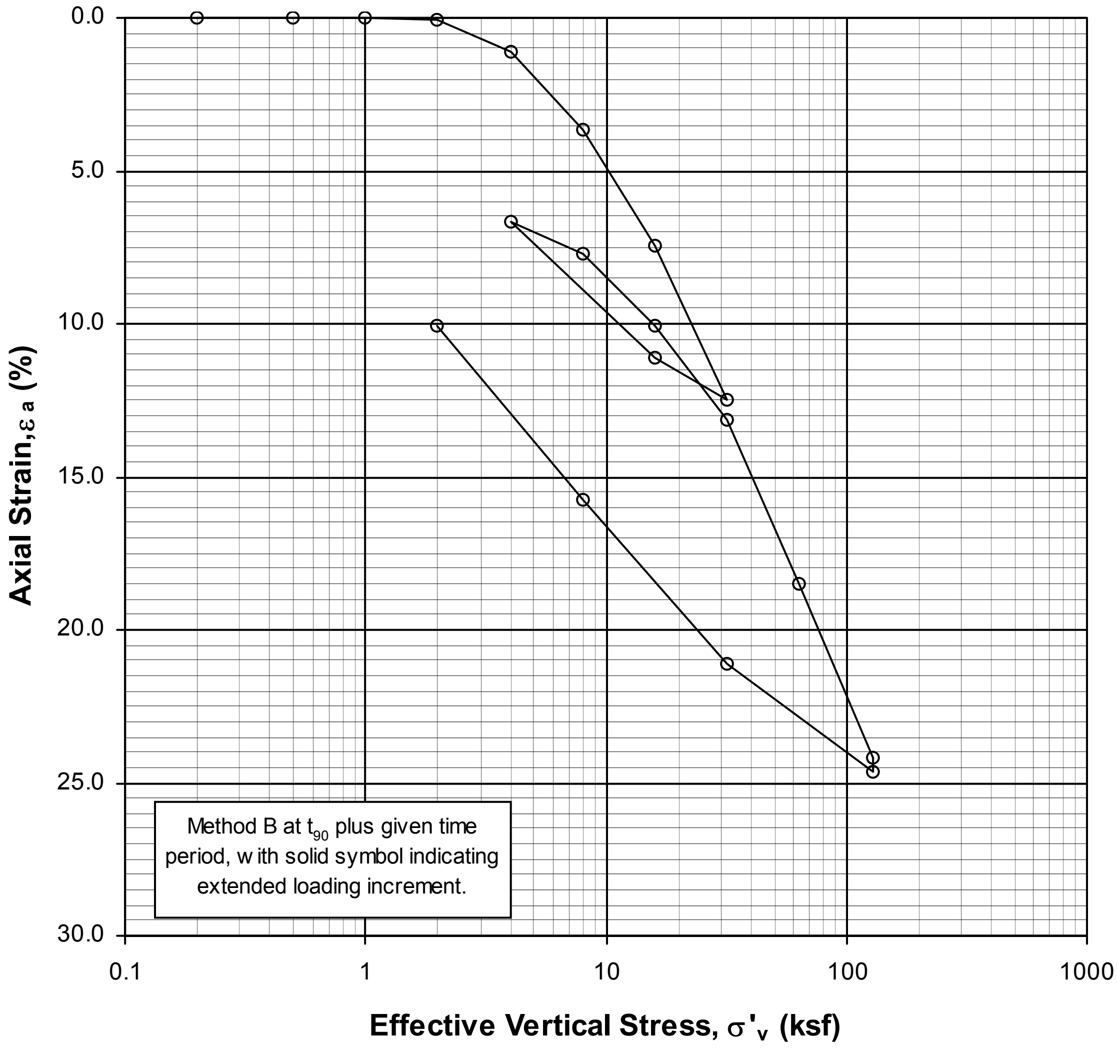
BORING: B-3
PENETRATION: 40.0 Feet
MATERIAL: CLAY, soft to firm, gray with shell fragments and sand pockets
DRY UNIT WEIGHT: 88.7pcf
WATER CONTENT: 33.3 %
LIQUID LIMIT: 39
PLASTICITY INDEX: 24
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 0.932



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

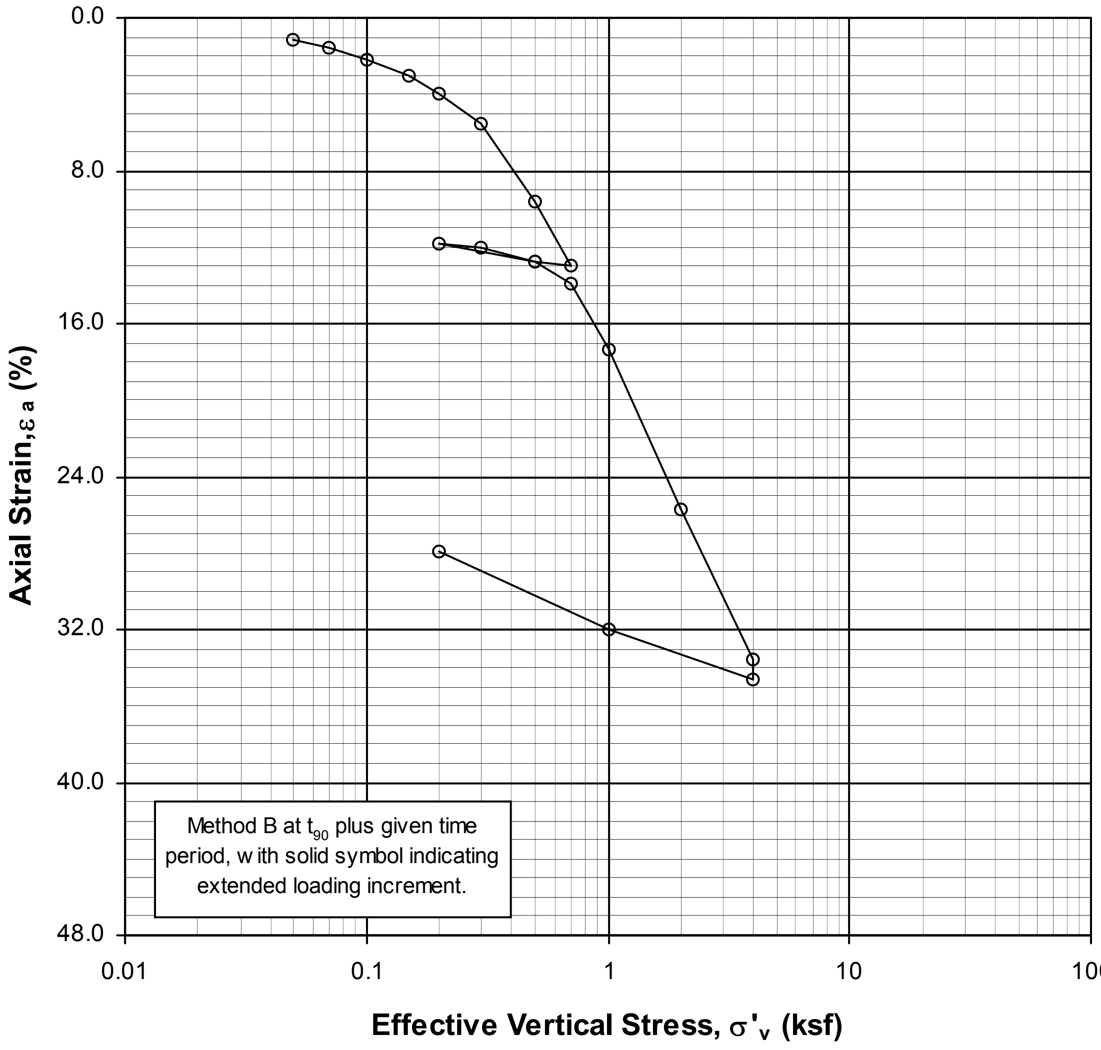
BORING: B-3
PENETRATION: 70.0 Feet
MATERIAL: CLAY, firm to stiff, yellowish-red and brown with sand partings
DRY UNIT WEIGHT: 84.4pcf
WATER CONTENT: 38.1 %
LIQUID LIMIT: 79
PLASTICITY INDEX: 56
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 1.03



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

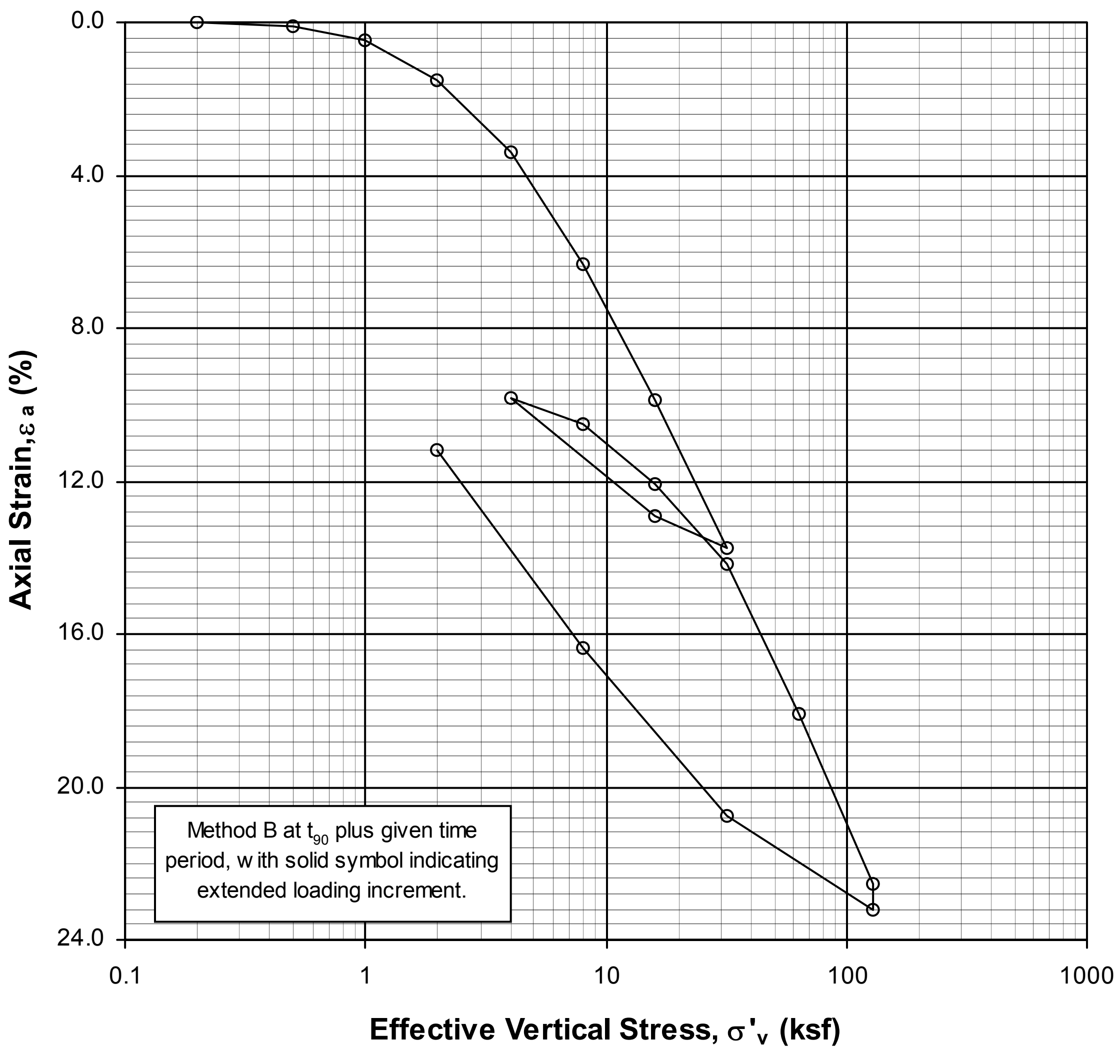
BORING: B-4
PENETRATION: 20.0 Feet
MATERIAL: CLAY, very soft to soft, gray
DRY UNIT WEIGHT: 44.2pcf
WATER CONTENT: 105.4 %
LIQUID LIMIT: 91
PLASTICITY INDEX: 66
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 2.881



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

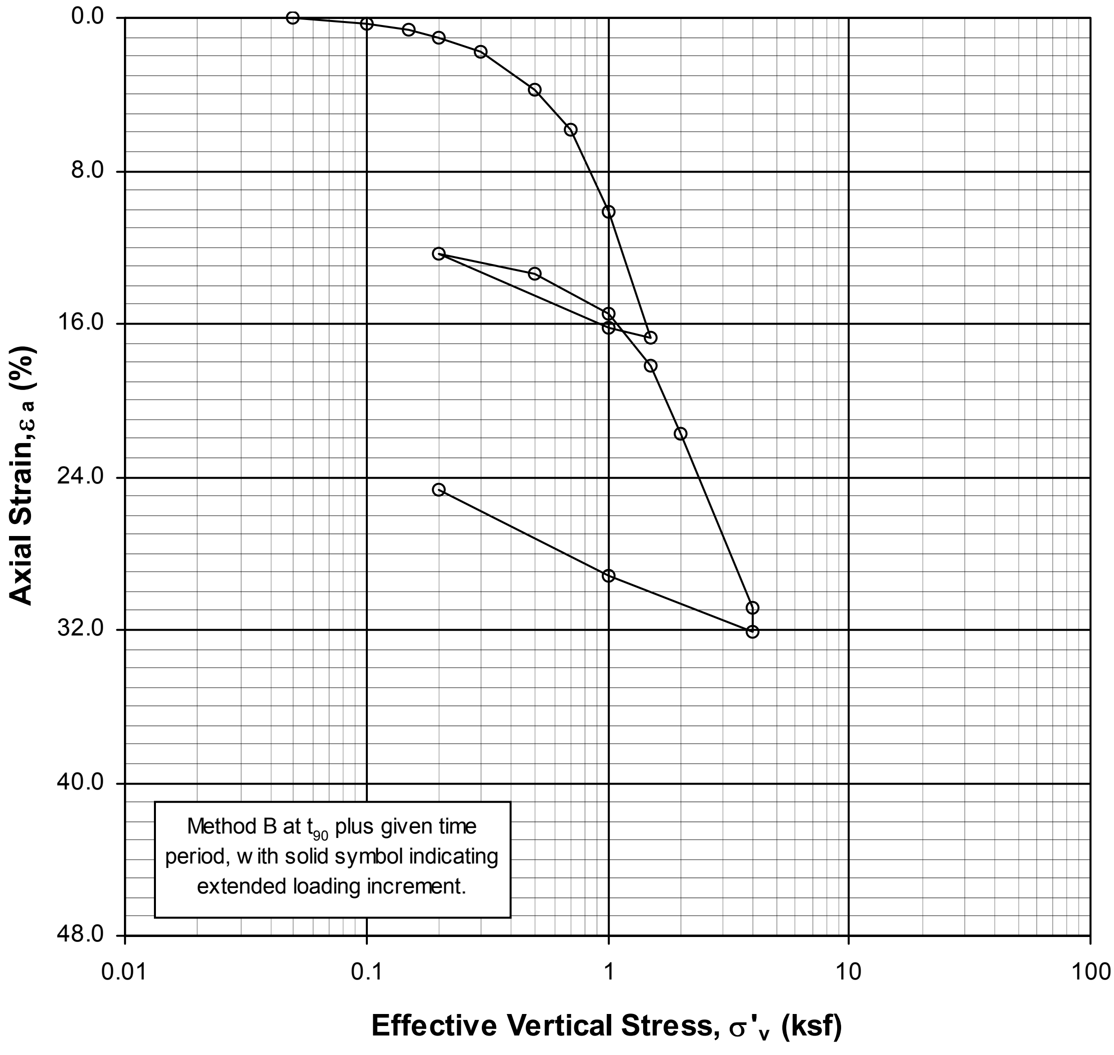
BORING: B-6
PENETRATION: 35.0 Feet
MATERIAL: CLAY, stiff, greenish gray with slickensided and sand partings
DRY UNIT WEIGHT: 87.1pcf
WATER CONTENT: 35.2 %
LIQUID LIMIT: 83
PLASTICITY INDEX: 62
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 0.966



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

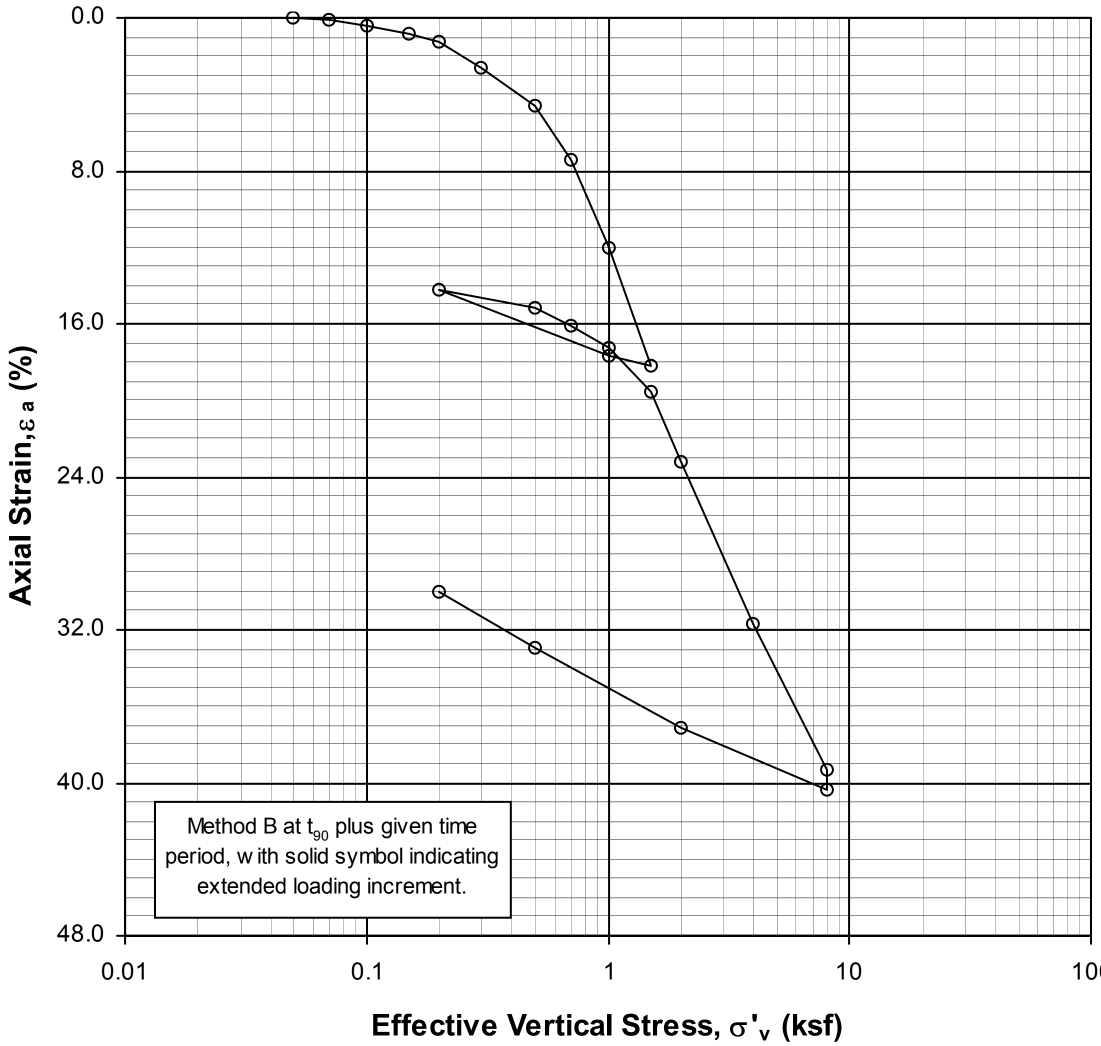
BORING: B-8
PENETRATION: 30.0 Feet
MATERIAL: CLAY, very soft to soft, gray
DRY UNIT WEIGHT: 43 pcf
WATER CONTENT: 108 %
LIQUID LIMIT: 106
PLASTICITY INDEX: 79
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 2.984



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

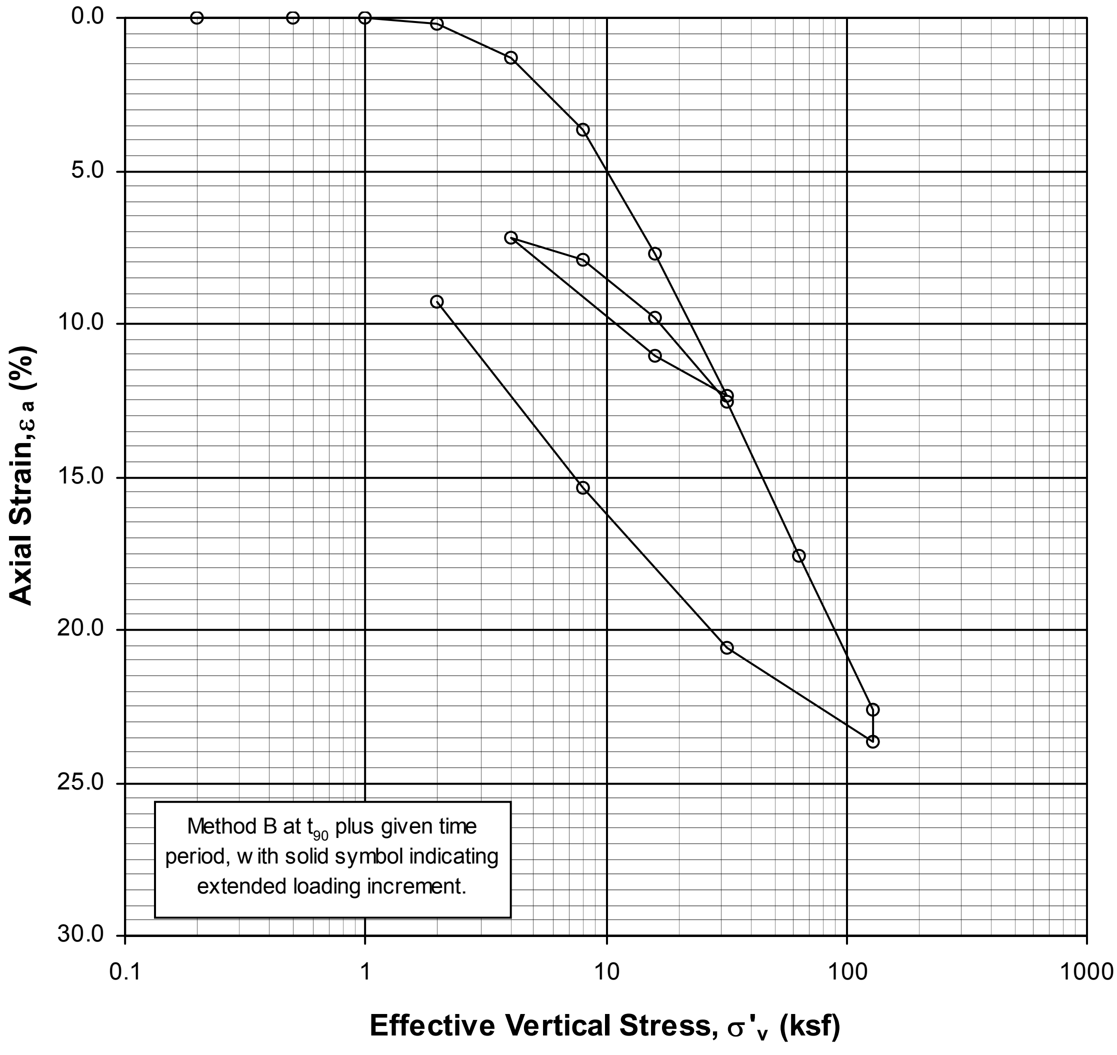
BORING: B-10
PENETRATION: 40.0 Feet
MATERIAL: CLAY, soft, gray
DRY UNIT WEIGHT: 42.4 pcf
WATER CONTENT: 109.9 %
LIQUID LIMIT: 113
PLASTICITY INDEX: 85
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 3.046



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

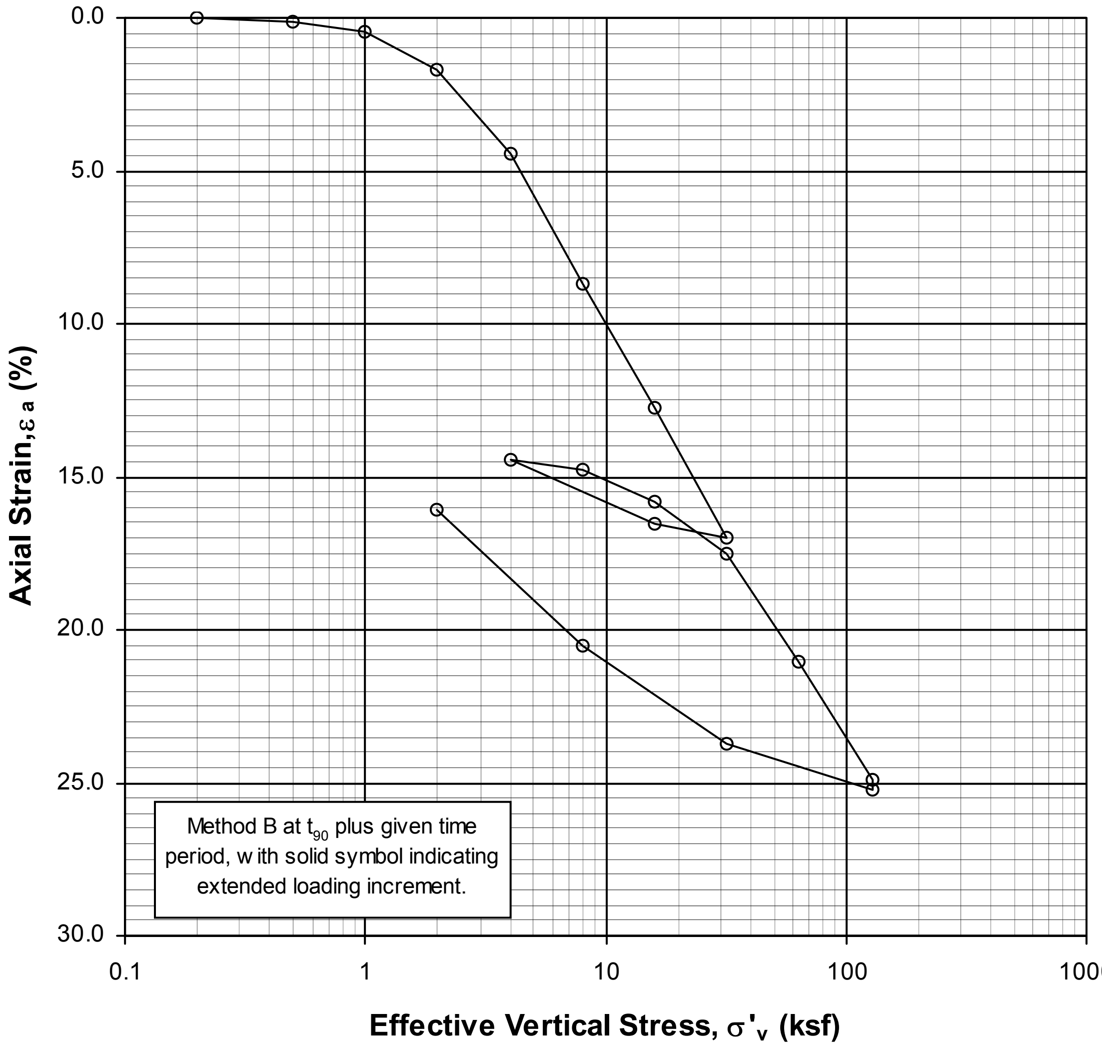
BORING: B-12
PENETRATION: 50.0 Feet
MATERIAL: CLAY, very stiff, brown and gray
DRY UNIT WEIGHT: 90.5 pcf
WATER CONTENT: 32.5 %
LIQUID LIMIT: 89
PLASTICITY INDEX: 70
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 0.893



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

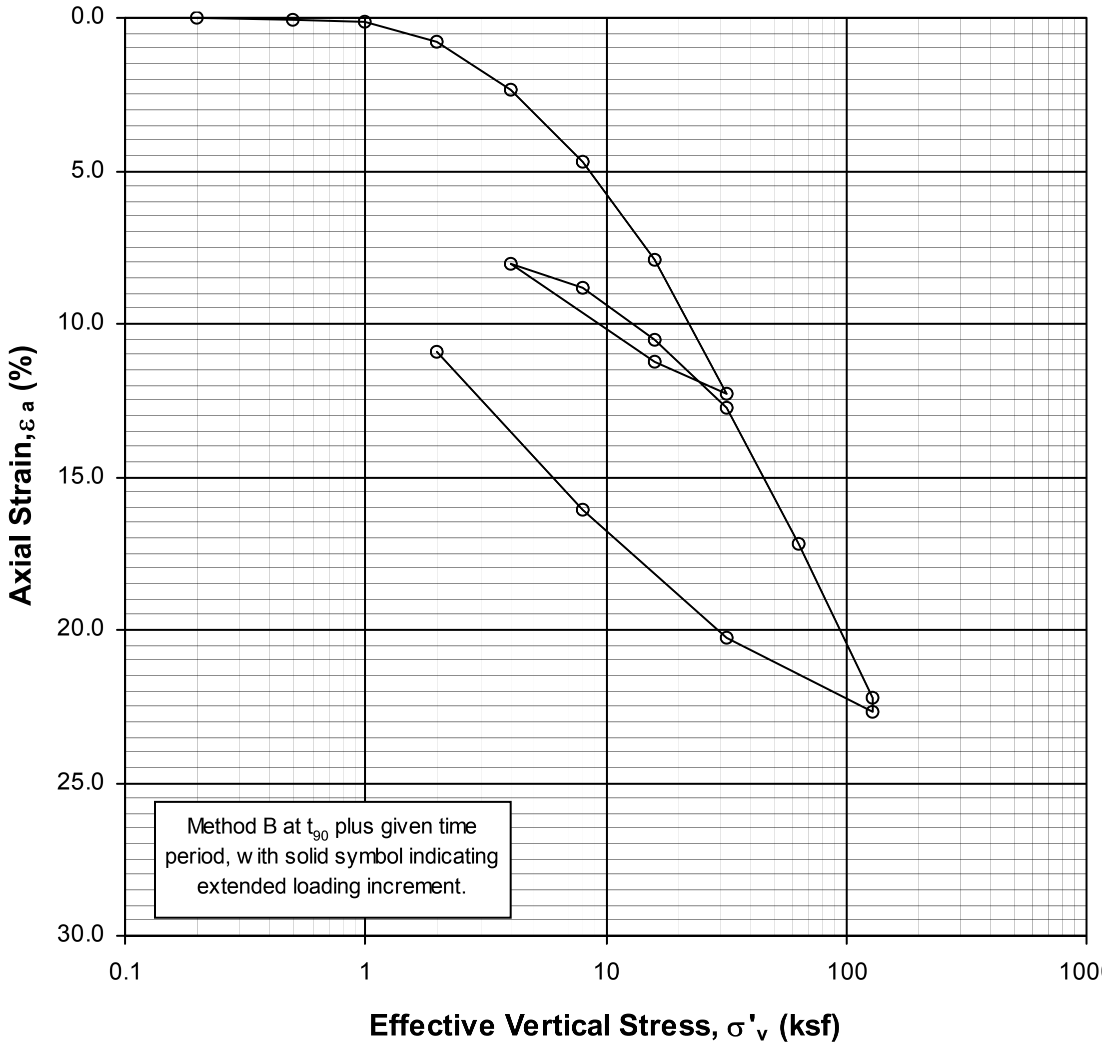
BORING: B-16
PENETRATION: 50.0 Feet
MATERIAL: CLAY, stiff to very stiff, brownish-yellow and gray
DRY UNIT WEIGHT: 88.5 pcf
WATER CONTENT: 32.9 %
LIQUID LIMIT: 73
PLASTICITY INDEX: 57
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 0.937



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

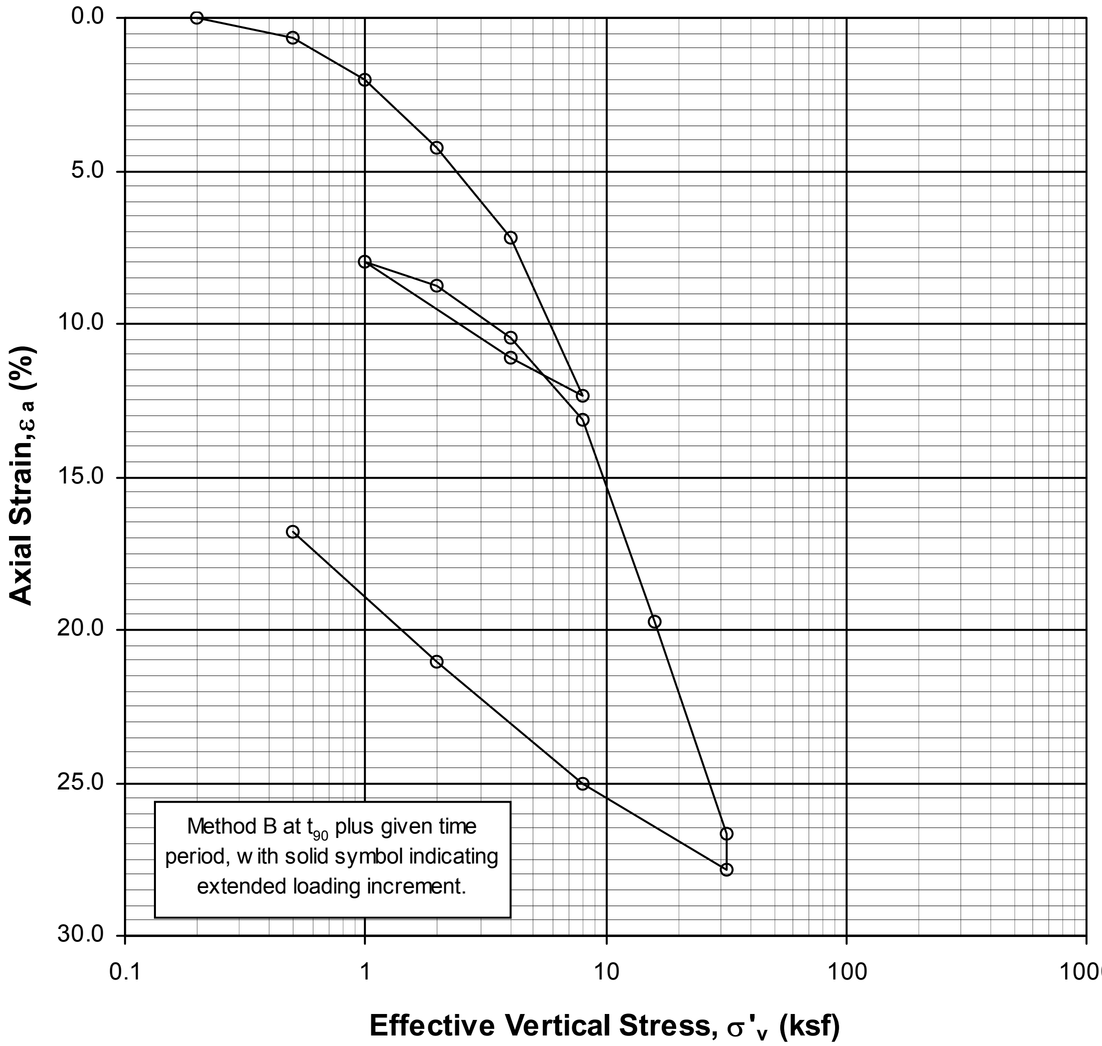
BORING: B-18
PENETRATION: 60.0 Feet
MATERIAL: CLAY, firm, brownish-yellow and gray
DRY UNIT WEIGHT: 88.2 pcf
WATER CONTENT: 34.5 %
LIQUID LIMIT: 68
PLASTICITY INDEX: 49
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 0.943



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA

BORING: B-18
PENETRATION: 95.0 Feet
MATERIAL: CLAY, soft, brown
DRY UNIT WEIGHT: 71.3 pcf
WATER CONTENT: 51.6 %
LIQUID LIMIT: 73
PLASTICITY INDEX: 51
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 1.405



INCREMENTAL CONSOLIDATION TEST RESULTS

GULF SHORELINE STABILIZATION PROJECT
ROCKEFELLER REFUGE
CAMERON PARISH, LOUISIANA