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LATERAL PILE DESIGN FOR MAIN SPAN PIER E2 AND SKYWAY STRUCTURE

SAN FRANCISCO-OAKLAND BAY BRIDGE EAST SPAN SEISMIC SAFETY PROJECT

Prepared for

CALIFORNIA DEPARTMENT OF TRANSPORTATION

March 2001

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February 28, 2001
EMI Project No. 98-145

California Department of Transportation
Engineering Service Center
Office of Structural Foundations
5900 Folsom Boulevard
Sacramento, California 95819-0128

Attention: Mr. Mark Willian
Contract Manager

Subject: **Lateral Pile Design for Main Span Pier E2 and Skyway Structure**
SFOBB East Span Seismic Safety Project
Contract 59A0053, Task Order 5

Dear Mr. Willian:

Transmitted is our report containing our analysis, conclusions and recommendations on Lateral Pile Design for Pier E2 and Skyway Structure for the new East-Span San Francisco-Oakland Bay Bridge (SFOBB) Seismic Safety Project.

On behalf of the project team, we appreciate the opportunity to provide geotechnical services on the subject project. If you have any questions or comments regarding this report, please contact our offices.

Sincerely,
EARTH MECHANICS, INC.
(on behalf of Fugro-Earth Mechanics, a Joint Venture)

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LATERAL PILE DESIGN
FOR MAIN SPAN PIER E2 & SKYWAY STRUCTURE
SAN FRANCISCO OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

Task Order No. 5
State Contract No. 59A0053

Prepared for:

CALIFORNIA DEPARTMENT OF TRANSPORTATION

Submitted by:

FUGRO-EARTH MECHANICS
A JOINT VENTURE

February 28, 2001

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INTRODUCTION

1.0 INTRODUCTION

1.1 GENERAL

The proposed N6 alignment for the new East Span San Francisco-Oakland Bay Bridge is approximately 4.0 km long from the Yerba Buena Island Tunnel to the Toll Plaza on the Oakland Mole. The entire alignment is divided into the following four segments;

- YBI transition structure from the tunnel portal to the cable suspension bridge
- a self-anchored cable suspension bridge, extending offshore from Yerba Buena Island
- the Skyway Structure, linking the cable suspension bridge to Oakland Mole
- an approach structure, connecting Skyway Structure to the Toll Plaza at Oakland Mole.

The self-anchored suspension structure (also known as the Main Bridge) is 565 meters long extending offshore from the tip of the Yerba Buena Island. This signature structure will be supported on three piers denoted as West Pier (W2), Main Pier (E1), and East Pier (E2). The proposed Skyway Structure is approximately 2.1 km long, consisting of two parallel structures to carry the eastbound and westbound traffic. Both eastbound and westbound structures are supported on 14 piers (piers E3 through E16). All the piers for the Main Bridge and Skyway Structure are supported on piles. The piles at Pier W2 and Pier E1 are constructed in rock while those at Pier E2 and the entire Skyway piers are founded in soil sediments. This report has been prepared to provide recommendations for lateral pile design parameters for piers E2 through E16. Consequently, this report covers the eastern pier of the main span and the entire skyway portion of the proposed alignment.

It has been proposed in the 100-percent design plans that piers E2 through E16 will be founded on large diameter steel pipe piles. These piles are proposed to be 2.5 meters in diameter and extending down to a depth of about 90 meters from the mudline. In addition to providing lateral pile design parameters for these piles, this report documents the response of a single pile under lateral loading at pile top on a pier by pier basis. The axial pile design parameters for these piles are provided in a separate report (Fugro-EMI, 2001d).

1.2 OBJECTIVE AND SCOPE OF WORK

The main objective of this report is to develop lateral pile design parameters based on the soil stratigraphy developed from the three phases of marine site investigation works conducted during 1998 to 2000 by the Fugro-EMI joint venture. Detailed discussions on site geology and subsoil characterization are presented in the reports prepared by Fugro-EMI joint venture team (Fugro-EMI, 1998, 2001a, 2001b, 2001c, 2001f). The lateral pile design parameters are developed in terms of p-y curves, which describe the lateral load-displacement characteristics of the soil material surrounding the pile. The p-y curves are developed for single piles on a pier by pier basis. The p-y curves used in the seismic response analyses of the bridge structure presented in this report are also used to develop lateral capacity of the pile subjected to any external forces, including temperature loading and construction loading. The lateral response of a pile can be affected by pile group effects and cyclic degradation of the surrounding soil. Information (both experimental and theoretical) available in the technical literature have been reviewed, and a detailed discussion together with our recommendations is presented. For dynamic loading of pile, implementations of damping as well as added mass from surrounding soil are discussed and our recommendations are provided. In addition, single pile models were developed at each pier location and lateral push-over analyses were performed to evaluate single pile response under lateral loading conditions. Pile response was characterized in terms of displacement, bending moment and shear, and the results are presented in this report. Some pile caps are embedded in the Bay mud which will provide additional resistance against lateral movement. Load-deformation characteristics of the pile cap are also presented. Pile group stiffness matrices were provided to the structural engineers for modeling the foundation sub-structure without explicitly including individual piles. Two different sets of stiffness matrix were provided due to the different nature of loading condition (service and seismic load).

1.3 BACKGROUND

During the 30-percent design phase, only a limited number of marine borings were performed. To aid the structural designers at the time, three representative soil profiles denoted as A, B and C were developed based on the limited subsoil information available at that time. Much of the foundation parameters, including p-y curves and pile stiffness matrices, for the 30-percent design were based on these profiles.

Phase I marine drilling started in February, 1998, and subsequently the soil stratigraphy was refined into five representative profiles for the purpose of developing seismic design criteria. These representative profiles were designated as profiles A through E which provided the basis for 45-percent design, including foundation capacity calculations and much of the parametric studies. In order to avoid confusion with earlier grouping in the 30-percent design phase, the soil profiles were called A2 through E2 where applicable. The extents of each profile are approximated as follows:

Profile A: Western 1/3rd of Skyway Alignment, outside (south) of recent paleo- channel

Profile B: Western 1/3rd of Skyway Alignment, within flank of recent paleo- channel

Profile C: Eastern 2/3rd of Skyway Alignment, outside (south) of recent paleo- channel

Profile D: Eastern 2/3rd of Skyway Alignment, within flank of recent paleo- channel

Profile E: Main Span East Pier

Phase II marine drilling with the associated laboratory testing was completed in November 1998. This information allowed further refinement on soil stratigraphy to a degree that idealized soil profiles were developed separately for each pier. These pier specific soil profiles were used in the final design (65 % to 100 %). The results presented in this report are based on idealized soil profiles developed at each pier location.

1.4 ORGANIZATION OF THE REPORT

This report is divided into four sections. Section 1 contains introductory comments, and describes the scope and objective of the report. Subsoil conditions and soil stratigraphy have been described in Section 2. In Section 3, the procedure for developing lateral pile response parameters has been presented. Section 4 summarizes pier by pier lateral pile design data and presents the results of pier specific lateral pushover analysis.

SECTION 2.0

SECTION 2.0

SECTION 2.0
SUBSURFACE CONDITIONS AND STRATIGRAPHY

2.0 SUBSURFACE CONDITIONS AND STRATIGRAPHY

2.1 INTRODUCTION

Subsurface investigation for the East Span SFOBB was conducted in three phases by the Fugro-EMI joint venture team during 1998 to 2000. The investigation program included marine and land borings, cone penetration testing, 2-D and 3-D geophysical surveying, shear wave velocity sounding and extensive laboratory and in-situ testing. The following reports are the most relevant documents produced by the Fugro-EMI JV describing the site conditions at the marine piers:

Fugro-EMI (1998) Subcontractor Report, Phase I Site Investigation,

Fugro-EMI (2001f) Subcontractor Report, Phase II Site Investigation,

Fugro-EMI (2001b) Final Marine Geotechnical Site Investigation and

Fugro-EMI (2001c) Final Marine Geophysical Survey.

2.2 SITE GEOLOGY AND SOIL STRATIGRAPHY

The proposed alignment for the new bridge from Yerba Buena Island to Oakland Mole is designated as the N6 alignment and is shown in Plate 2-1 and Plate 2-2. The borehole locations are also shown in these figures. Four different cross-sections showing subsoil stratigraphy along the N6 alignment are presented in Plate 2-4 through Plate 2-8. The main geologic formations that underlie the N6 alignment in the descending sequence are:

- Young Bay Mud (YBM)
- Merritt-Posey- San Antonio Formation (MPSA)
- Old Bay Mud (OBM)
- Upper Alameda Sediments (UAM)
- Lower Alameda Sediments (LAA)
- Franciscan Formation(FF)

Brief descriptions of each geological unit are given in the following sections.

2.2.1. Young Bay Mud (YBM)

Young Bay Mud is a marine clay sediment that was deposited within last 11,000 years. This layer occurs over the entire length of the alignment with depths varying approximately from 8 to 25 meters along the skyway alignment. Deeper deposits of YBM are usually associated with paleochannels. Because of the meandering nature of the paleochannels, the thickness of the deposit is found to vary in both, east-west and north-south directions. YBM consists of very soft to firm fat clay with low undrained shear strength. The undrained shear strength of the deposit is found to be increasing with depth.

2.2.2. Merritt-Posey-San Antonio Formation (MPSA)

This formation, consisting of layered deposit of sands and clays, underlies YBM, and occurs along portions of the N6 alignment. The thickness of the deposit varies along the alignment with maximum thickness of about 6.0 m. The deposit is completely absent within the paleochannels. Although the elevation of top of the deposit varies due to erosion and channeling, the elevation of base of the deposit is less variable. MPSA consists of dense to very dense sand with layers of stiff to very stiff clay and sandy clay.

2.2.3. Old Bay Mud (OBM)/Upper Alameda (UAM) Sediments

These sediments consist primarily of thick deposits of stiff to hard clays and underlie the MPSA or YBM deposits. Within the limits of the skyway structure the thickness of this deposit is more or less constant, and is about 55 to 60 meters. The undrained shear strength of this formation increases from about 125 to 175 kPa at the top to about 150 to 250 kPa at the bottom of the sequence. The borings show that this formation typically includes multiple crustal layers with higher undrained shear strengths. Due to the presence of the crustal layers, the undrained shear strengths could increase locally by about 25 to 50 kPa. Although this formation primarily composed of stiff to hard marine clays, some sand layers were also encountered. These dense to very dense sand layers were found to occur below El. -55 to 60 meters.

2.2.4. Lower Alameda Sediments (LAA)

This sediment consists of primarily alluvial deposits of dense to very dense granular materials. These sediments underlie the OBM/UAM formations and extend down to the Franciscan bedrock formation. Although the sediment consists primarily of granular deposits, layers of hard clay deposit were also encountered. The thickness of the deposit increases from west to east along the alignment. Towards the eastern end of the skyway the thickness of this formation was found to be about 60 meters.

2.2.5. Franciscan Formation (FF)

The Jurassic/Cretaceous-age Franciscan Formation forms the bedrock for Yerba Buena Island and underlies the Lower Alameda Sediments along the skyway portion. The bedrock contact can be found near elevation –110 m at the western end of Skyway. The bedrock descends toward east and can be found near elevation –140 m at the eastern end of Skyway. The strata of the Franciscan Formation are composed predominantly of graywacke sandstone with a few zones of interbedded, siltstone and claystone. The shear wave velocity of Franciscan Formation ranges from 1,500 to 3000 meters per second.

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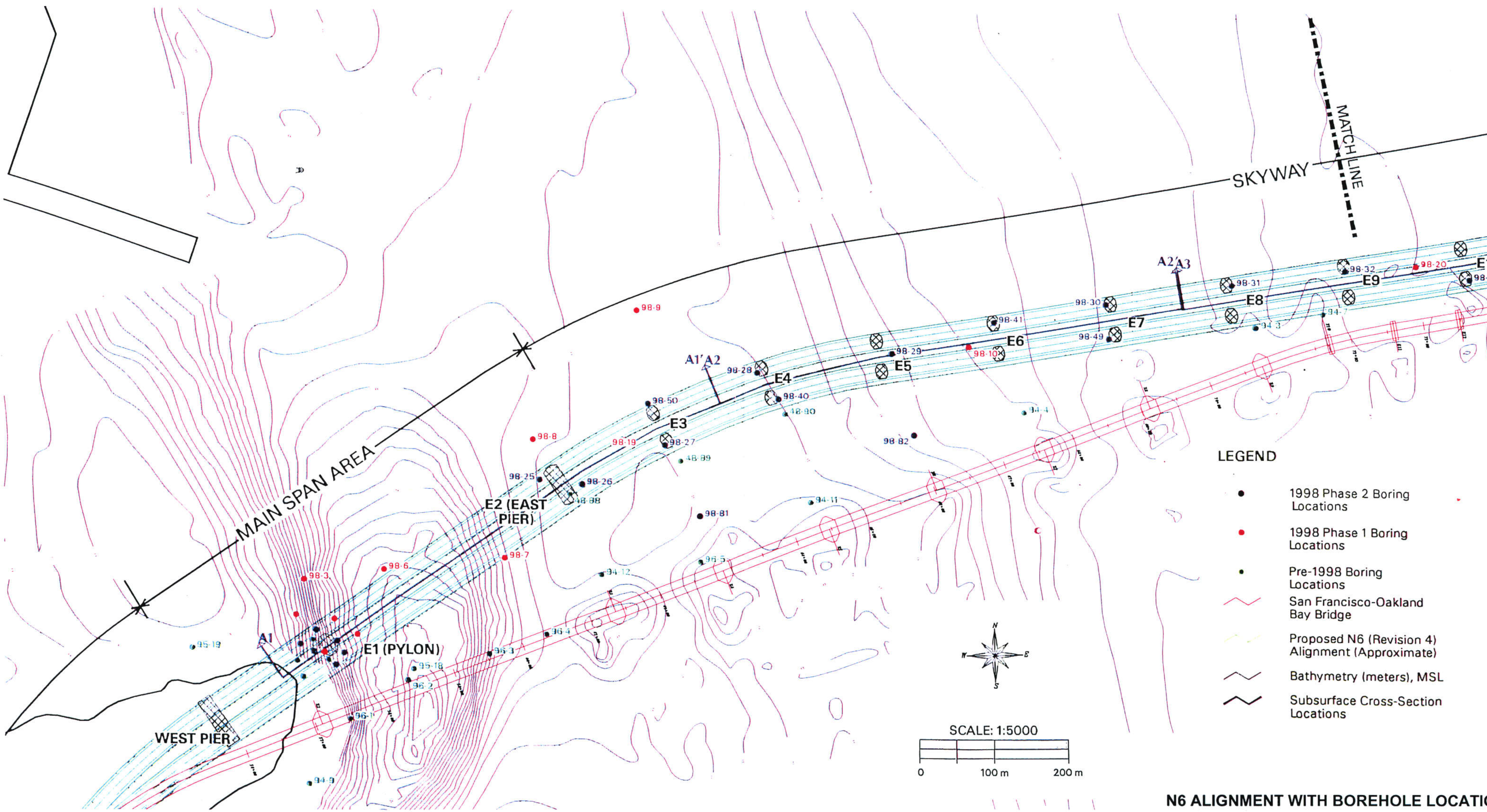

N6 ALIGNMENT WITH BOREHOLE LOCATIONS
SFOBB East Span Seismic Safety Project

PLATE 2-1

Earth Mechanics
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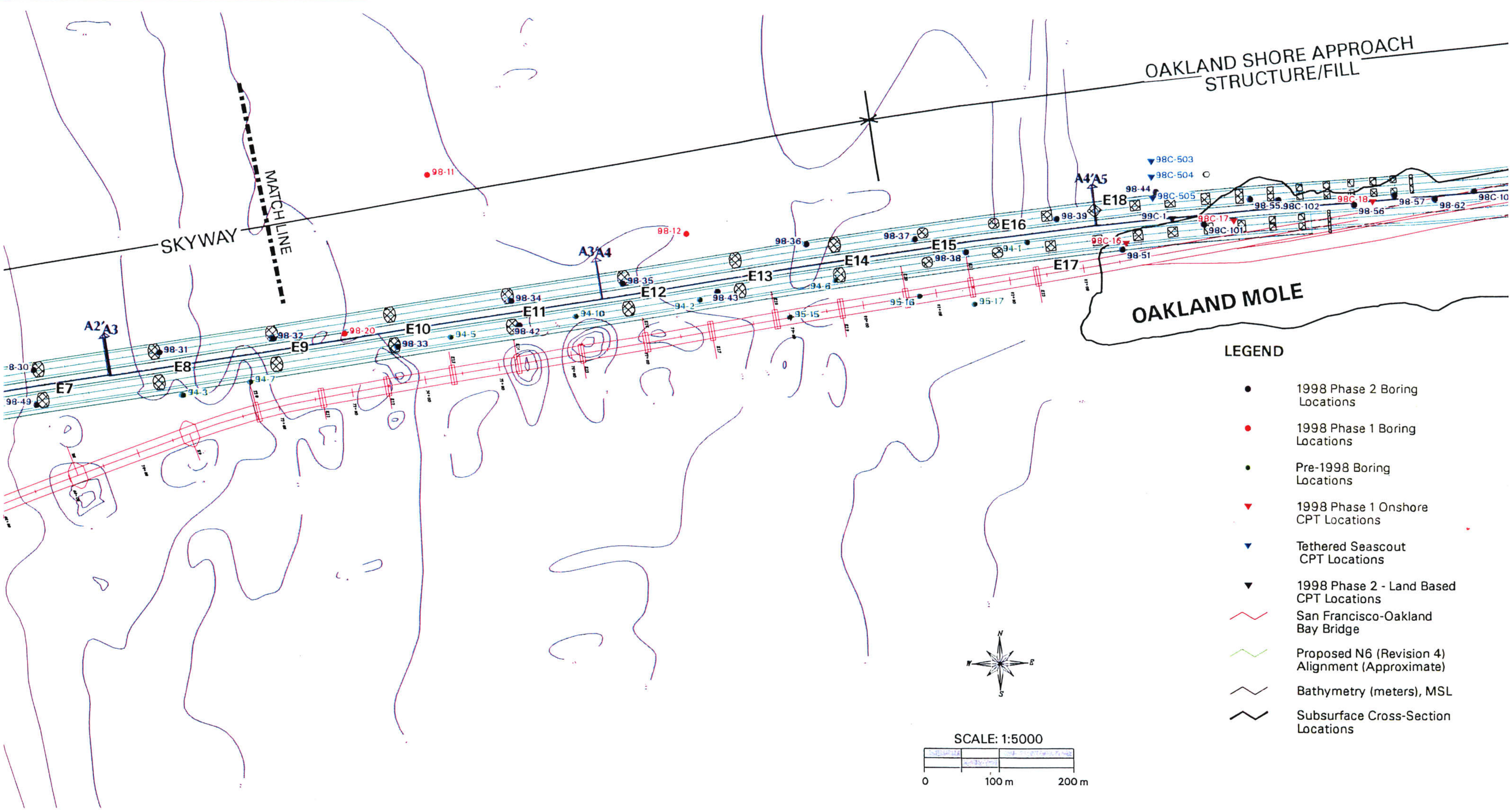
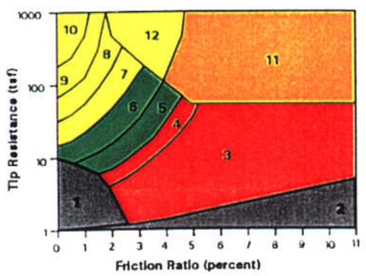


N6 ALIGNMENT WITH BOREHOLE LOCATIONS
SFOBB East Span Seismic Safety Project

PLATE 2-2



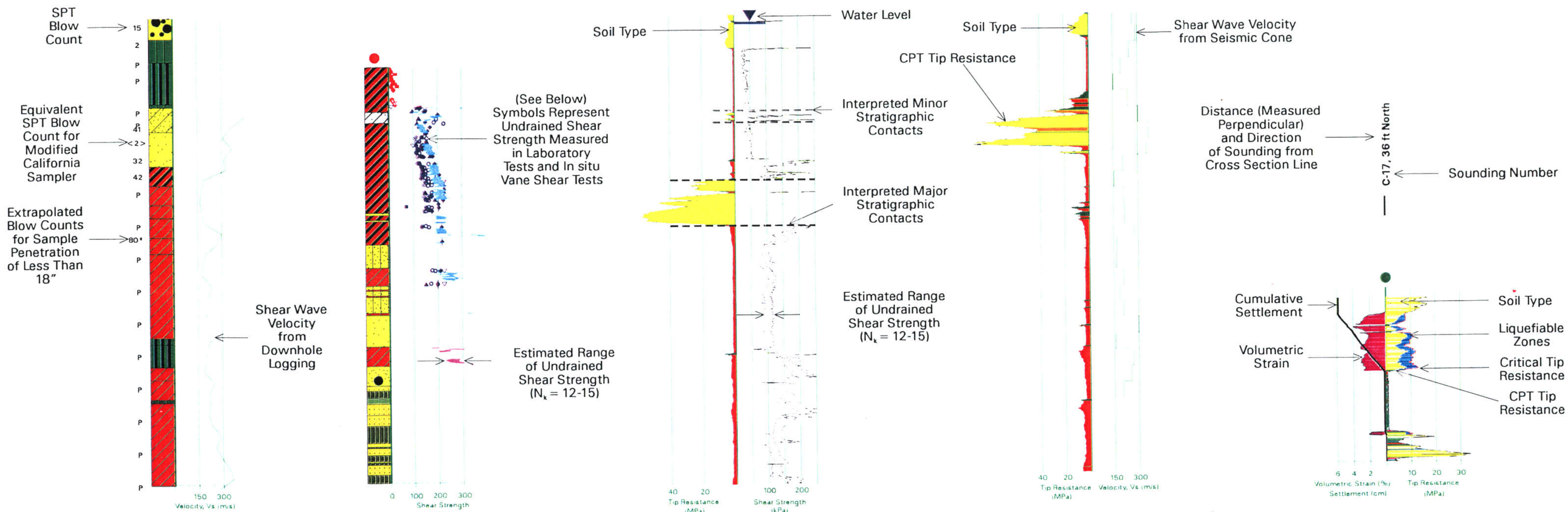
Zone	Soil Behavior Type	U.S.C.S.
1	Sensitive Fine-grained	OL-CH
2	Organic Material	OL-OH
3	Clay	CH
4	Silty Clay to Clay	CL-CH
5	Clayey Silt to Silty Clay	MH-CL
6	Sandy Silt to Clayey Silt	ML-MH
7	Silty Sand to Sandy Silt	SM-ML
8	Sand to Silty Sand	SM-SP
9	Sand	SW-SP
10	Gravelly Sand to Sand	SW-GW
11	Very Stiff Fine-grained *	CH-CL
12	Sand to Clayey Sand *	SC-SM

* overconsolidated or cemented

CPT CORRELATION CHART (Robertson and Campanella, 1984)

KEY TO CROSS SECTIONS

- Well graded GRAVEL (GW)
- Poorly graded GRAVEL (GP)
- GRAVEL with sand (GP or GW)
- GRAVEL with clay (GP-GC)
- Clayey GRAVEL (GC)
- GRAVEL with silt (GP-GM)
- Silty GRAVEL (GM)
- Well graded SAND (SW)
- Poorly graded SAND (SP)
- SAND with gravel (SP or SW)
- SAND with clay (SP-SC)
- Clayey SAND (SC)
- SAND with silt (SP-SM)
- Silty SAND (SM)
- Fat CLAY (CH)
- Sandy fat CLAY (CH)
- Lean CLAY (CL)
- Sandy lean CLAY (CL)
- Silty CLAY (CL-ML)
- Elastic SILT (MH)
- SILT (ML)
- Sandy SILT (ML)
- Clayey SILT (ML/CL)
- Highly Plastic ORGANICS (OH)
- Low plasticity ORGANICS (OL)
- SANDSTONE (Rx)
- SILTSTONE (Rx)
- CLAYSTONE (Rx)
- Interbedded Rock Strata (Rx)
- CONGLOMERATE (Rx)
- Rock Fragments
- PAVEMENT



SOIL BORING LITHOLOGY WITH SHEAR WAVE VELOCITY

SOIL BORING LITHOLOGY WITH UNDRAINED SHEAR STRENGTH

CPT SOUNDING WITH UNDRAINED SHEAR STRENGTH AND INTERPRETED LITHOLOGY

CPT SOUNDING WITH SHEAR WAVE VELOCITY

CPT SOUNDING WITH LIQUEFACTION EVALUATION

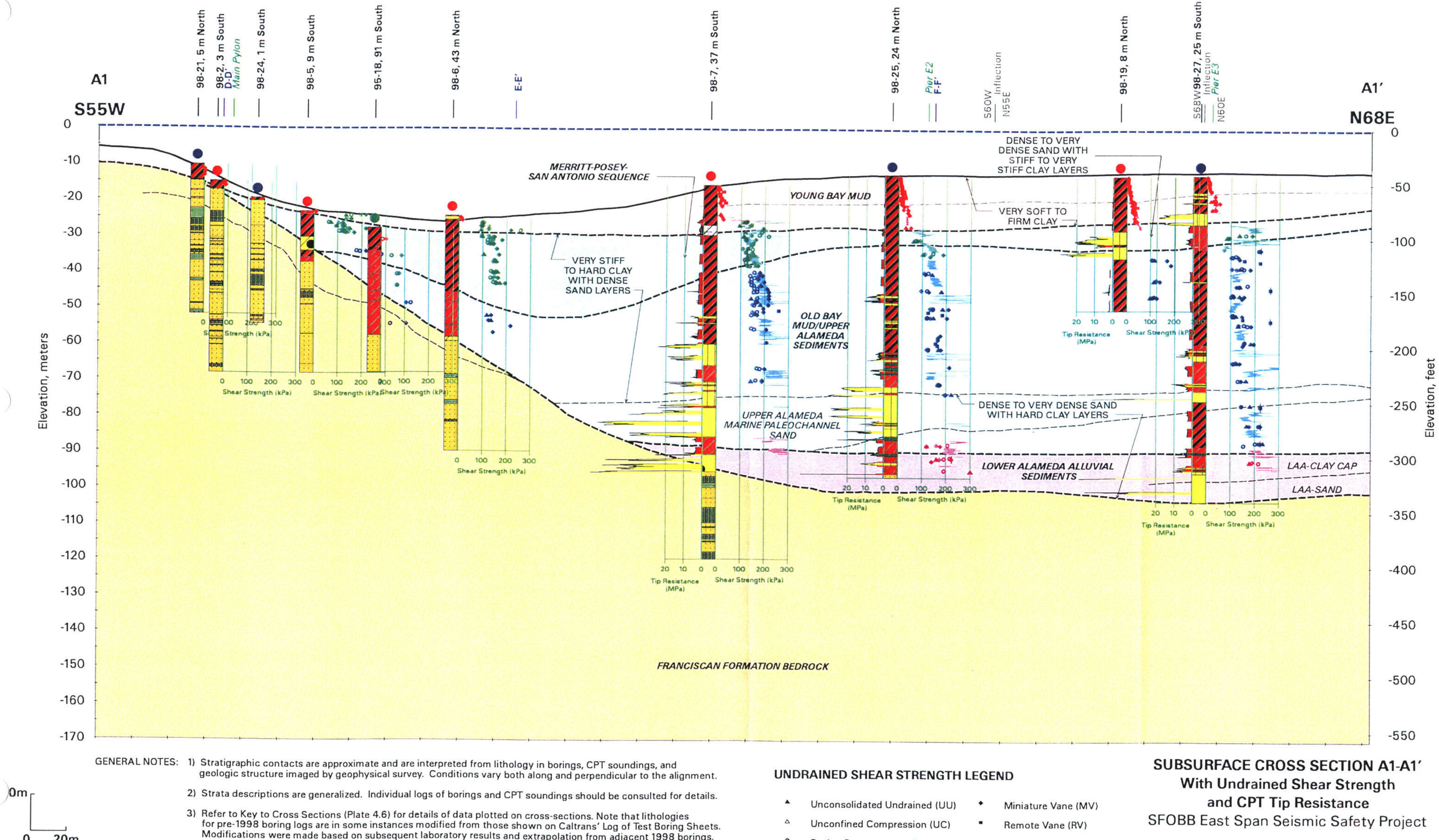
Key to Undrained Shear Strength Symbols

- ▲ Unconsolidated Undrained (UU)
- ◆ Miniature Vane (MV)

KEY TO CROSS SECTIONS

SFOBB East Span Seismic Safety Project

Earth Mechanics
FUGRO



GENERAL NOTES:

1) Stratigraphic contacts are approximate and are interpreted from lithology in borings, CPT soundings, and geologic structure imaged by geophysical survey. Conditions vary both along and perpendicular to the alignment.
2) Strata descriptions are generalized. Individual logs of borings and CPT soundings should be consulted for details.
3) Refer to Key to Cross Sections (Plate 4.6) for details of data plotted on cross-sections. Note that lithologies for pre-1998 boring logs are in some instances modified from those shown on Caltrans' Log of Test Boring Sheets. Modifications were made based on subsequent laboratory results and extrapolation from adjacent 1998 borings.

UNDRAINED SHEAR STRENGTH LEGEND

- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◆ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A1-A1′
With Undrained Shear Strength and CPT Tip Resistance
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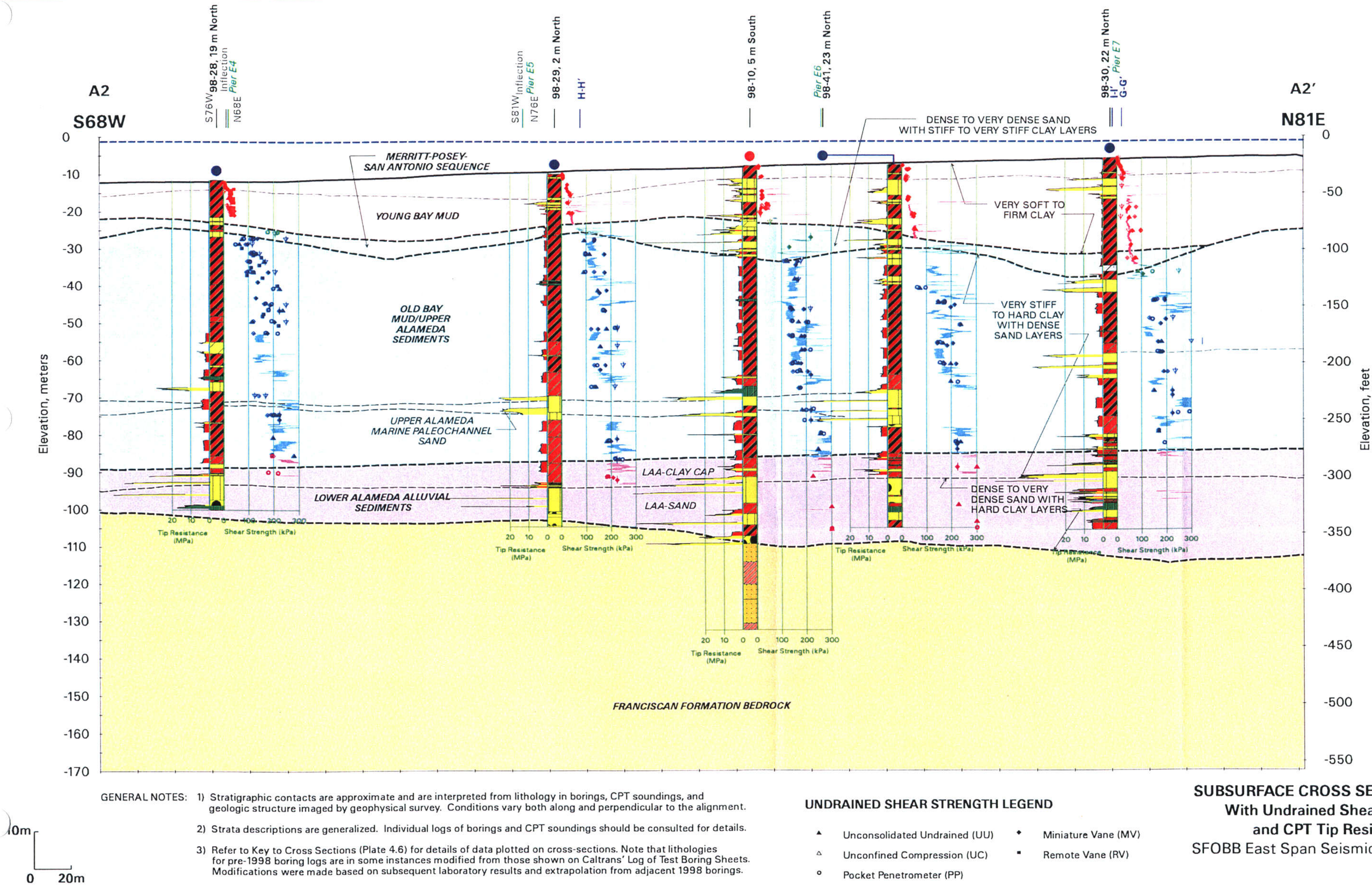

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- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◆ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A2-A2′
With Undrained Shear Strength
and CPT Tip Resistance
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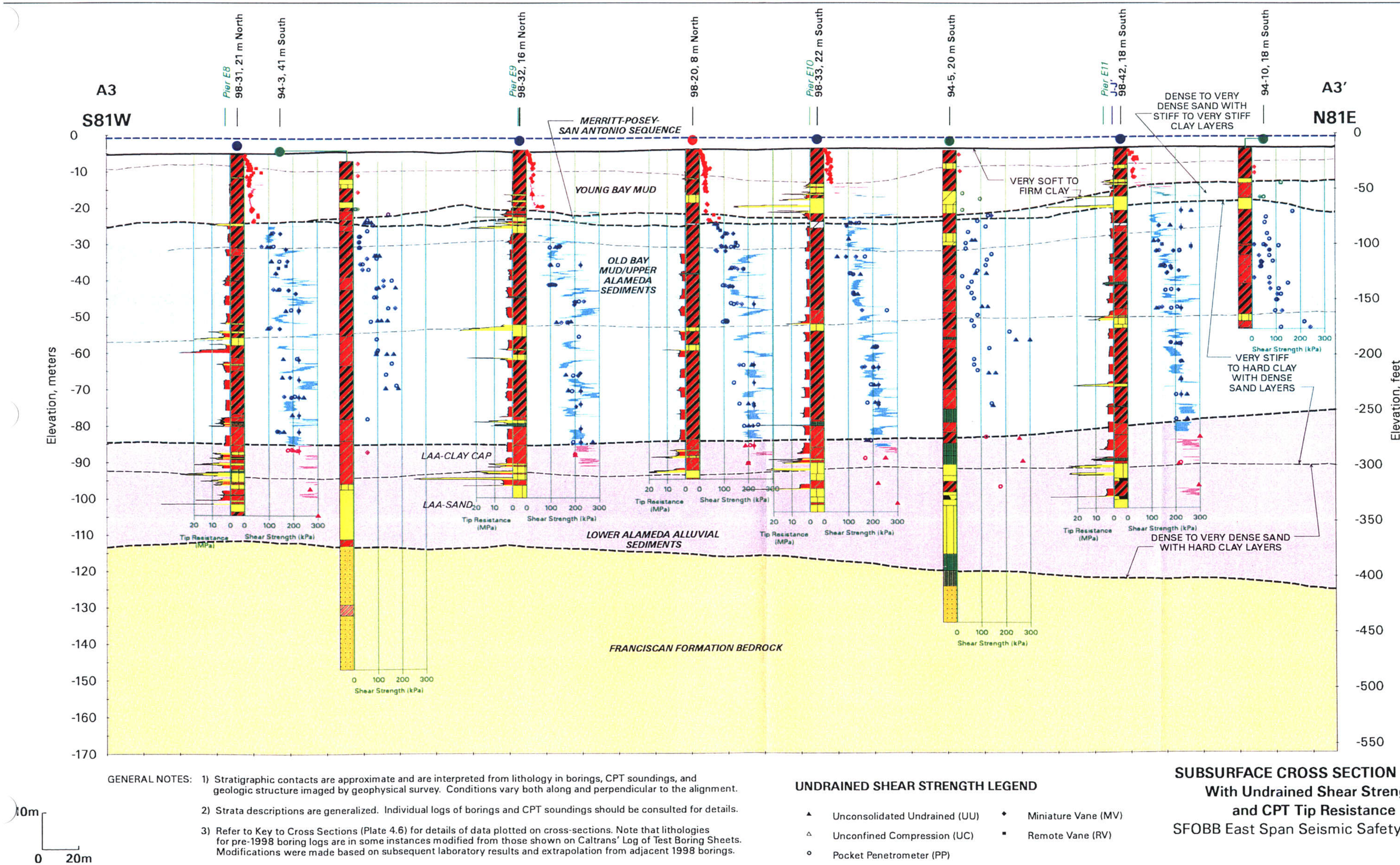

GENERAL NOTES:

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UNDRAINED SHEAR STRENGTH LEGEND

- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◆ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A3-A3′
With Undrained Shear Strength
and CPT Tip Resistance
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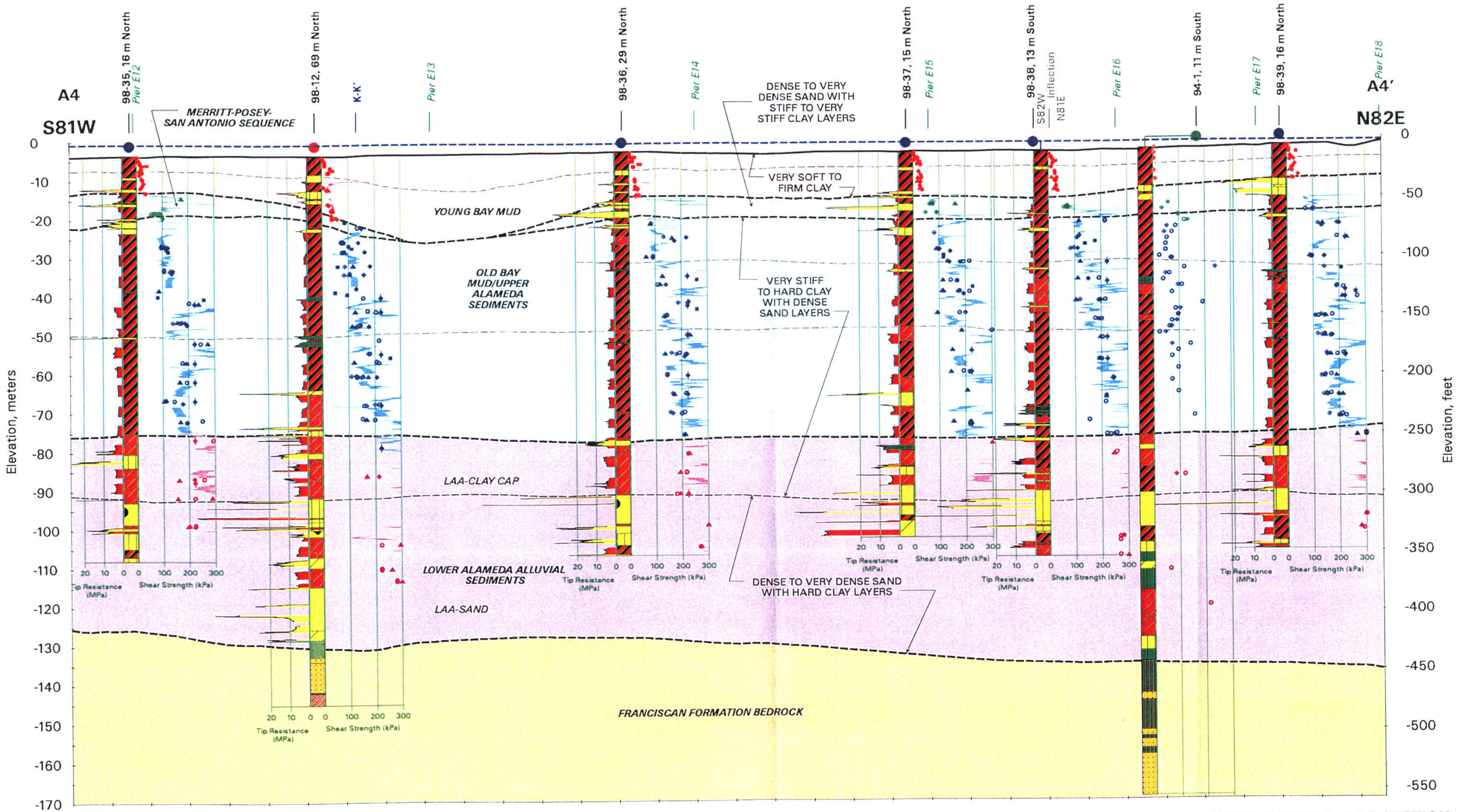

GENERAL NOTES:

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UNDRAINED SHEAR STRENGTH LEGEND

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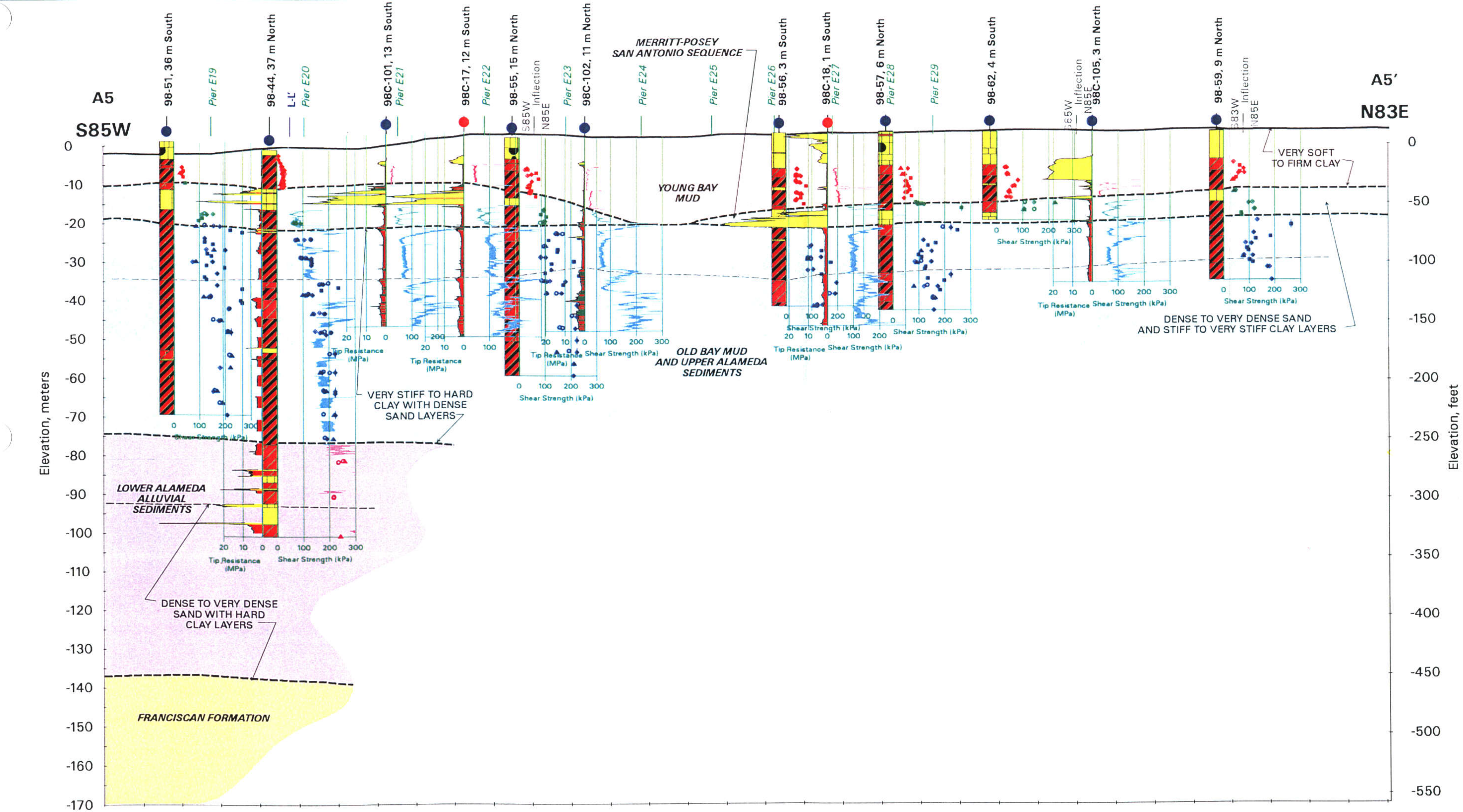
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◆ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A4-A4′
With Undrained Shear Strength and CPT Tip Resistance
SFOBB East Span Seismic Safety Project



GENERAL NOTES:
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UNDRAINED SHEAR STRENGTH LEGEND

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- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ♦ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A5-A5′
With Undrained Shear Strength
and CPT Tip Resistance
SFOBB East Span Seismic Safety Project

SECTION 3.0
LATERAL PILE DESIGN PARAMETERS

3.0 LATERAL PILE DESIGN PARAMETERS

3.1 BRIEF DESCRIPTION OF STRUCTURE

The proposed N6 alignment of the East Span SFOBB between Yerba Buena Island and Oakland Mole is shown in Plate 2-1 and Plate 2-2. The alignment is comprised of the following structural features:

- A 560-meter-long transition structure that transitions from a double-decked structure at the tunnel portal on Yerba Buena Island to a parallel side by side structure.
- A 620-meter-long self-anchored suspension cable signature structure that extends offshore from Yerba Buena Island.
- An approximately 2.1-km-long Skyway structure that extends eastward from the signature structure to Oakland.
- An approximately 600-meter-long approach structure that joins skyway structure to Oakland Mole.

The focus of this report is on the Skyway Structure and the eastern pier of the signature structure. The proposed skyway structure will consist of two parallel structures that will carry eastbound and westbound traffic. There will be a total of 28 piers (Pier E3 through E16, eastbound and westbound) to carry the structures.

3.2 DESCRIPTION OF FOUNDATION

It is proposed that the skyway piers will be founded on 2.5-meter-diameter steel pipe piles. Typical layout of pile foundations is shown in Plate 3-1 and Plate 3-2. Four different pile group configurations are proposed as shown in these figures: one for pier E2, one for piers E3 through E6, one for piers E7 through E14, and one for piers E15 and E16. The upper section of the piles will be filled with reinforced concrete. The current design indicates that the wall thickness of the pipe piles will vary with depth. As explained later in Section 4, pile group stiffness matrices were computed for two different loading conditions: static and seismic. Different sectional properties of the pile were used for modeling these two conditions. The sectional properties of the piles were provided by T. Y. Lin, and they are tabulated in Table 3-1a and Table 3-1b. The static load case examines structural component stresses during erection sequence and temperature shrinkage and hence, Table 3-1a is consistent with gross sectional properties. The values presented in Table 3-1b are based on effective sectional properties expected during earthquake loading and 50%-corroded dimensions.

Table 3-1a. Sectional Properties for Seismic Condition

Piers	Cut-off Elevation (m)	Bottom of Pile Cap (m)	Elevation (m) From	Elevation (m) To	Axial Stiffness (AE) (MN)	Flexural Stiffness (EI) (MN-m^2)
E2	-	-2.7	-2.7	-12.7	296100	187200
			-12.7	-13.9	290300	181800
			-13.9	-16.9	188600	94380
			-16.9	-22.0	220400	118800
			-22.0	-55.0	195900	101600
			Below -55.0		69400	52400
E3 thru E6	+2.25	-3.5	-3.5	-32.75	210000	88800
			-32.75	-47.75	202000	87800
			-47.75	-62.75	186000	81800
			Below -62.75		78400	58500
E7	-6.75	-12.5	-12.5	-41.75	210000	88800
			-41.75	-56.75	202000	87800
			-56.75	-71.75	186000	81800
			Below -71.75		78400	58500
E8	-5.55	-11.3	-11.3	-40.55	210000	88800
			-40.55	-55.55	202000	87800
			-55.55	-70.55	186000	81800
			Below -70.55		78400	58500
E9	-5.15	-10.9	-10.9	-40.15	210000	88800
			-40.15	-55.15	202000	87800
			-55.15	-70.15	186000	81800
			Below -70.15		78400	58500
E10	-6.00	-11.75	-11.75	-41.00	210000	88800
			-41.00	-56.00	202000	87800
			-56.00	-71.00	186000	81800
			Below -71.00		78400	58500

Table 3-1a (Cont'd)

Piers	Cut-off Elevation (m)	Bottom of Pile Cap (m)	Elevation (m)		Axial Stiffness (AE) (MN)	Flexural Stiffness (EI) (MN-m^2)
			From	To		
E11	-3.85	-9.60	-9.60	-38.85	210000	88800
			-38.85	-53.85	202000	87800
			-53.85	-68.85	186000	81800
			Below -68.85		78400	58500
E12	-6.85	-12.60	-12.60	-41.85	210000	88800
			-41.85	-56.85	202000	87800
			-56.85	-71.85	186000	81800
			Below -71.85		78400	58500
E13	-8.75	-14.50	-14.50	-43.75	210000	88800
			-43.75	-58.75	202000	87800
			-58.75	-73.75	186000	81800
			Below -73.75		78400	58500
E14	-10.25	-16.00	-16.00	-45.25	210000	88800
			-45.25	-60.25	202000	87800
			-60.25	-75.25	186000	81800
			Below -75.25		78400	81800
E15	-4.75	-10.50	-10.5	-30.5	232000	99600
			-30.5	-50.5	202000	87800
			-50.5	-70.5	186000	81800
			Below -70.5		78400	58500
E16	-5.25	-11.0	-11.0	-30.75	232000	99600
			-30.75	-50.75	202000	87800
			-50.75	-70.75	186000	81800
			Below -70.75		78400	58500

Table 3-1b. Sectional Properties for Static Condition

Piers	Cut-off Elevation (m)	Bottom of Pile Cap (m)	Elevation (m) From	Elevation (m) To	Axial Stiffness (AE) (MN)	Flexural Stiffness (EI) (MN-m^2)
E3 thru E6	+2.25	-3.5	-3.5	-32.75	224000	113200
			-32.75	-47.75	202000	103000
			-47.75	-62.75	194000	97200
			Below -62.75		78400	58800
E7	-6.75	-12.5	-12.5	-41.75	224000	113200
			-41.75	-56.75	202000	103000
			-56.75	-71.75	194000	97200
			Below -71.75		78400	58800
E8	-5.55	-11.3	-11.3	-40.55	224000	113200
			-40.55	-55.55	202000	103000
			-55.55	-70.55	194000	97200
			Below -70.55		78400	58800
E9	-5.15	-10.9	-10.9	-40.15	224000	113200
			-40.15	-55.15	202000	103000
			-55.15	-70.15	194000	97200
			Below -70.15		78400	58800
E10	-6.00	-11.75	-11.75	-41.00	224000	113200
			-41.00	-56.00	202000	103000
			-56.00	-71.00	194000	97200
			Below -71.00		78400	58800
E11	-3.85	-9.60	-9.60	-38.85	224000	113200
			-38.85	-53.85	202000	103000
			-53.85	-68.85	194000	97200
			Below -68.85		78400	58800
E12	-6.85	-12.60	-12.60	-41.85	224000	113200
			-41.85	-56.85	202000	103000
			-56.85	-71.85	194000	97200
			Below -71.85		78400	58800

Table 3-1b (Cont'd)

Piers	Cut-off Elevation (m)	Bottom of Pile Cap (m)	Elevation (m) From	Elevation (m) To	Axial Stiffness (AE) (MN)	Flexural Stiffness (EI) (MN-m²)
E13	-8.75	-14.50	-14.50	-43.75	224000	113200
			-43.75	-58.75	202000	103000
			-58.75	-73.75	194000	97200
			Below -73.75		78400	58800
E14	-10.25	-16.00	-16.00	-45.25	224000	113200
			-45.25	-60.25	202000	103000
			-60.25	-75.25	194000	97200
			Below -75.25		78400	58800
E15	-4.75	-10.50	-10.5	-30.5	242000	121200
			-30.5	-50.5	202000	103000
			-50.5	-70.5	194000	97200
			Below -70.5		78400	58800
E16	-5.25	-11.0	-11.0	-30.75	242000	121200
			-30.75	-50.75	202000	103000
			-50.75	-70.75	194000	97200
			Below -70.75		78400	58800

3.2.1. Development of p-y Curves

The lateral movement of pile is resisted by lateral resistance generated within the soil that surrounds the pile. Generally, the soil reaction is described in terms of its characteristic p-y curves where p is the soil reaction per unit length of the pile, and y is the pile displacement at that particular location. For this report, p-y curves for the piles are developed according to the guidelines provided in American Petroleum Institute (API) RP 2A (API, 1993).

3.2.2. Brief Description of p-y curves

Guidelines for developing p-y curves for different soil materials, such as clay and sand, are provided in the API document mentioned above. The brief description of the methodology is presented here.

p-y Curves for Clay. The ultimate lateral bearing capacity of clay material is given as a function of undrained shear strength, S_u, depth below the ground surface, z, and pile diameter, D. For a depth, z, that is less than the critical depth, z_r, the ultimate soil reaction is given by

$$p_u = \left(3S_u + \gamma z + J\frac{S_u z}{D} \right) D \tag{3-1}$$

and for depths greater than z_r, the ultimate soil reaction is given by

$$p_u = 9S_u D \tag{3-2}$$

where γ is the effective unit weight of the soil and J is a dimensionless empirical factor usually taken as 0.5. The critical depth z_r is given by

$$z_r = \frac{6D}{\frac{\gamma D}{S_u} + J} \tag{3-3}$$

The soil reaction to lateral pile movement does not vary linearly with pile displacement. The p-y curves describe the soil behavior by a nonlinear relationship between soil reaction, p and pile displacement, y. The normalized p-y curve for clay material is presented in Table 3-2. The soil reaction, p and displacement, y are normalized with respect to ultimate soil resistance, p_u, and reference pile displacement, y_c, respectively. The reference displacement, y_c is equal to $2.5\varepsilon_c D$ where ε_c is the axial strain measured at half the maximum stress in laboratory undrained compression tests on undisturbed soil sample.

It may be mentioned that according to API recommendations, a p-y curve for clay material is defined by 5 data points instead of 6 as shown in Table 3-2. The point No. 2 is introduced here to reflect initial stiffness of soil response at a small displacement level. The initial soil stiffness, as given in this modified p-y curve, was essentially estimated on the basis of a soil subgrade modulus of $400S_u$. This relationship between soil subgrade modulus and undrained shear strength has been suggested by Poulos and Davis (1980). They suggested that the tangent modulus of soil, E_s can be within a range of $250S_u$ to $400S_u$.

It is our understanding that the committee for API is currently considering to implement an additional point on API p-y curve similar to Point No. 2 in Table 3.2. However, the final recommendations on p-y curve from API are not yet available at this time.

TABLE 3-2. P-Y CURVE DATA FOR CLAY

Point	p/p_u	y/y_c
1	0.0	0.0
2	0.25	0.125
3	0.5	1.0
4	0.72	3.0
5	1.0	8.0
6	1.0	∞

p-y Curves for Sand. The ultimate lateral bearing capacity for sand is found to vary considerably with depth. API recommends that the ultimate bearing capacity should be taken as the smaller of p_{us} (for shallow failure mechanism) and p_{ud} (for deep failure mechanism) calculated by the equations

$$p_{us} = (C_1 z + C_2 D)\gamma z \qquad (3\text{-}4)$$

and

$$p_{ud} = C_3 D \gamma z \qquad (3\text{-}5)$$

where C_1, C_2, and C_3 are coefficients that can be calculated as function of angle of internal friction, ϕ, of sand. Plate 3-3 shows variations of these three coefficient with ϕ.

Like p-y curves for clay, the p-y curves for sand are also nonlinear. The nonlinear relationship between p and y is given by a hyperbolic equation as

$$p = A p_u \tanh\left(\frac{kzy}{A p_u}\right) \qquad (3\text{-}6)$$

where k is the initial subgrade modulus having an unit of (F/L^3), and A is factor to account for cyclic or static loading conditions. The p-y curves for sand are represented using seven points. Because of the way the p-y curves for sand is formulated, normalized p-y curves are not unique. However, they can be approximately expressed as those given in Table 3-3.

TABLE 3-3. P-Y CURVE DATA FOR SAND

Point	p/p_u	y/y_u
1	0.0	0.0
2	0.10	0.03
3	0.46	0.17
4	0.76	0.33
5	0.91	0.50
6	1.0	1.0
7	1.0	∞

3.3 GROUP EFFECTS AND CYCLIC LOADING

Because of close proximity, piles in a group interact with each other. Such pile to pile interaction and the resulting effect on individual pile response is commonly termed as group effect. Another important factor that can influence individual pile behavior is the degradation of the surrounding soil under cyclic loading from the piles. Some of the experimental results related to pile group effects that are available in the technical literature are discussed below.

Group effects and the effect of cyclic loading on p-y curve have been studied by Bogard and Matlock (1983). They performed a series of static and cyclic lateral load tests on circular pile group at Harvey, Louisiana. According to them zones of soil loaded by the individual piles could overlap forming larger zones of stress in the soil surrounding the pile group, depending on the spacing between individual piles in a pile group. Integrating the lateral strains that arise from the superposition of individual pile stress bulbs would yield an increased pile group deflection as compared to the isolated piles, for a same level of lateral resistance. This would mean that for same load level, the piles in a group would deflect more than a single isolated pile. Accordingly, the p-y curves for an individual pile in a pile group would be softer, and can be regarded as a "stretched" version of p-y curve for a single isolated pile.

The results of the cyclic lateral load tests indicted that the initiation of cyclic degradation in resistance occurred. Near the surface, the losses in soil resistance are associated with vertical soil heave and with the separation of pile and soil, or gapping. At depths, where the soil movement is restricted to the horizontal plane due to confinement, the losses in soil resistance are normally associated with soil remolding which is initiated by reversal of plastic strain and slip in the soil. The effects of cyclic degradation are most severe in the soil immediately adjacent to the pile, with the severity of effects decreasing rapidly with radial distance.

If the piles in a group are separated by sufficient distance, the local heave and gap formation will be confined to the soil very near the individual piles. As the gap form around individual piles, the lateral resistance would be reduced which in turn would reduce the stress transferred to the soil and adjacent piles. Thus, little group action will be observed. If the piles in the group are closely spaced, the surface gaps initiated around individual piles could overlap and join forming a continuous gap around the entire pile group.

A full scale study in sand was conducted on a closely spaced group of piles arranged in a 3x3 configuration at the University of Texas (Brown, et. al., 1987, Brown, et. al., 1988). The test results indicated that most significant group effect is associated with the phenomenon called "shadowing", in which the soil resistance of a pile in a trailing row is reduced because of the presence of the pile ahead of it. The p-y curves for the piles of the leading row were slightly softer than those for the single pile. The reduction in soil resistance in the trailing row piles was quite significant. The researchers concluded that a convenient way of expressing the loss of soil resistance due to group effect is by using a p-multiplier, a constant used to "squash" p-y curves for an isolated single pile.

Cyclic loading on similar (3x3) pile group in sand did not produce a great loss of soil resistance. This observation was in contrary to the experimental results in stiff clay. It seemed that soil response was quite sensitive to load history. Small cyclic load produced substantial densification, which appeared to improve the soil resistance at subsequent larger loads. Some softening of the response of the piles in the group was observed at large loads. Other experimental studies on pile group behavior are:

> Centrifuge testing of 3x3 pile groups at three-diameter (3D) and five-diameter (5D) spacing by McVay, et. al. (1995) which shows that the experimental results can be simulated using a p-multiplier approach. The p-multiplier values suggested by them ranges from 0.3 to 0.85.
>
> Static and statnamic tests on 3x3 full-scale pile groups in clays by Peterson and Rollins (1996) indicate that piles in closely spaced groups (3D) may be expected to displaced 2 to 3 times more than an isolated pile under the same average load. Dynamic tests (statnamic) show a 15% to 25% higher load capacity for individual piles due to the contribution from damping and inertia forces.
>
> Full-scale lateral load testing of pile groups in liquefied soil inducted by blast loading by Ashford and Rollins (1999) where cyclic loading was conducted before and after blasting to understand subgrade reaction relationships for non-liquefied and liquefied sand.

From a review of all the research studies described above, it appears that group effects and cyclic degradation are highly nonlinear and inelastic behavior. It is very difficult, if not impossible, to mimic each of these physical behaviors in the p-y curve model. This hypothetical p-y curve may well be dependent on location of the pile within the group and loading path, which, among other things, could mean updating the p-y curve at each time step which becomes impractical for design. In view of this scenario, we have elected to adopt a p-multiplier of 0.5 as a constant to "squash" the conventional API type p-y curves for all the piers along the skyway structure to collectively account for group effects and cyclic degradation without further refinement. These sets of p-y curves with a p-multiplier of 0.5 represent a benchmark scenario for the seismic load case (Load Case No. 7).

3.4 CONSIDERATION OF P-Y CURVE FOR SPECIAL LOAD CASE

Besides seismic load case, the structural designers requested for our recommendations on p-y curve that would be appropriate for dealing with mechanisms associated concrete shrinkage and temperature loading (Load Case No. 3). Since this type of loading is essentially monotonic, we elected to recommend a p-multiplier of 1.0 as an upper bound scenario to portray somewhat stiffer soil supports. These p-y curves can be used to evaluate possible staging of construction and to examine structural distress for the service load case scenario.

3.5 LATERAL PUSHOVER AND SOIL-STRUCTURE INTERACTION ANALYSIS

The main objectives of developing p-y curves are to utilize them 1) in lateral pushover analyses to evaluate member stresses in pile and 2) in kinematic pile-soil interaction analyses to define effective seismic loading on the superstructure. In addition, the p-y curves are intended to be used by structural engineers in the global model of bridge structure for dynamic analysis. Individual piles and non-linear soil springs could be included in such models.

For different types of analyses mentioned above, the pile needs to be discretized with lumped P-Y springs attached at discrete nodal points. For kinematic and dynamic analyses it is also necessary to apply the ground motions to the piles through the lumped P-Y springs. Capital letters are used for lumped springs to distinguish them from p-y springs which represent soil reaction per unit length of the pile. Lumped springs are obtained by multiplying p-y springs by appropriate nodal tributory length as shown in Plate 3-4. The ground motions at different elevations are obtained from site response analysis. Therefore, the pile discretization scheme needs to match the discretization scheme adopted for the site response analyses. Different aspects of site response analyses have been discussed at length in a separate report prepared by Fugro-EMI joint venture (Fugro-EMI, 2001e). The discretization scheme adopted for site response analyses is described here briefly.

3.5.1. Discretization Scheme

The typical discretization scheme adopted for the ground response analysis is shown in Plate 3-4, as mutually agreed upon by the structural engineers and EMI. The soil column that was analyzed for ground response extended down to MSL El. -95.0 m. From the ground surface down to a depth of 45 meters, the soil column was divided into 3.0-meter-thick layers, and below 45 meters, the layers were 6.0-m thick. The length of the last layer was adjusted so that the tip of the pile is at -95.0 m elevation. It may be noted that the pile nodes are closely spaced (at 3.0 meter interval) near the ground surface, and the spacing is increased with depth. The reason for adopting such a scheme is due to the fact that under lateral loading, significant soil-pile interaction takes place within a depth of about 10 to 12 pile diameter from the ground surface. It may also be noted that the length of the pile model extends down to an elevation of -95.0 m from the ground surface. Although the actual pile length may vary from pier to pier, for lateral pushover and kinematic interaction analyses the pile length is kept constant because of two reasons. First, the soil column used for the site response analyses extended down to an elevation of -95.0 m, the elevation at which level firm ground motion has been defined. It has been mentioned in the previous section that for kinematic soil-structure interaction analysis, the pile nodes need to match the discretization scheme used for the ground response analysis. Secondly, this variation from the actual condition is thought to be insignificant in determining pile response, because most of the soil-pile interaction would be limited to a zone near the ground surface.

3.6 DAMPING PARAMETERS FOR LATERAL LOADING

The conventional API p-y criteria modified by a p-multiplier of 0.5 to account for cyclic loading and pile group effects have been adopted for the seismic design. The p-y model used by the structural engineers in their complete model has non-linear and inelastic characteristics. When these p-y curves are implemented with proper allowance for hysteretic behavior, the strain-dependent energy dissipation mechanism is automatically simulated which explicitly accounts for material damping.

For additional damping associated with radiation of energy through the half space, elasto-dynamic solutions recommended by Gazetas et al. (1992) were used to assess the relative magnitude of radiation damping with respect to the material damping included in the non-linear p-y curves. The classical method of solving soil-pile interaction problem involving radiation damping has been based on an elasto-dynamic approach in frequency domain (Mylonakis, et. al., 1997 and Gazetas et. al., 1992). Because of the linear superposition principle in the frequency domain, soil stiffness is usually expressed as Winkler type of linear spring which would have a unit of FL^{-2} (soil resistance per unit pile length per unit pile deflection). The radiation viscous dashpot parameter given in the following equation is derived from shear wave velocity

$$c_x = 1.6\rho_s v_s d\left(\frac{\omega d}{v_s}\right)^{-\frac{1}{4}} \tag{3-6}$$

where c_x is the damping coefficient, ω is the angular frequency, D is the pile diameter, ρ_s is mass density and v_s is shear wave velocity. This radiation damping parameter would be frequency dependent.

To study the effects of viscous damping, cyclic push-over analyses were performed on a single pile supported on dashpots and nonlinear inelastic p-y springs. The viscous damping coefficients for the dashpots were determined from the above equation and the nonlinear p-y curves were estimated using the API procedure. The dashpots represent radiation damping, while the hysteretic behavior from the p-y curves simulates material damping. The dashpot coefficients were evaluated at an angular frequency corresponding to a period of 1 second For a longer period (small angular frequency) expected as the response of the skyway structure, the radiation damping coefficient estimated using the above equation would be smaller. Three sets of pushover analyses were performed: the first with dashpots in series with p-y curves, second with dashpots in parallel p-y curves, and the third with no viscous damping.

Plate 3-5 shows an arrangement of the pile supported on dashpots connected in parallel with the p-y springs. The figure also shows the representative soil profile used in the analyses which corresponds to the general soil profile representative of the western part of the skyway structure. It was realized that that small strain shear wave velocity is too high for deriving the viscous damping coefficients. Therefore, an equivalent depth-varying linear Winkler springs were derived from the p-y curve model, which was used to determine an equivalent soil modulus. Based on the estimated equivalent soil modulus, strain-compatible shear wave velocities were calculated and used to estimate the viscous damping coefficient using Eqn. (3-6).

Studies on viscous dashpots in series with non-linear p-y springs were also conducted. In fact, it is more logical to model the radiation dashpots in series with the API p-y curves from a mechanistic point of view because the radiation wave from the pile must travel through the highly strained soil-pile interaction zones before dissipating into the half space. As shown in Plate 3-6, non-linear p-y curves represent a near-field soil-pile interaction zone, while the dashpots with linear springs represent elastic behavior of far-field half space.

The solutions in terms of cyclic pile head load versus deflection are shown in Plate 3-7 through Plate 3-9 at several deflection levels. Plate 3-7 presents cyclic load-deflection solutions without radiation damping, i.e., only material damping derived from hysteretic p-y curves is included. Plate 3-8 presents the load-deformation loops with additional radiation damping where dashpots are arranged in parallel with the p-y springs. Plate 3-9 presents the solution with radiation dashpots in series with the p-y springs. It appeared that the parallel viscous dashpots added the damping effects a significant degree above the hysteretic effects, but the viscous dashpots in the series mode did not result in appreciable radiation damping. From engineering mechanics, as earlier mentioned, a dashpot in series is more realistic in representing physical behavior of the soil-pile system.

Care is required in mixing API type of nonlinear p-y curves with viscous coefficient to account for radiation damping based on elasto-dynamic approach. Recent centrifuge pile load tests conducted at the University of California at Davis to simulate transient earthquake loading indicated that the conventional API p-y curves yielded reasonable soil-pile interaction stiffness especially for clayey soils (Boulanger et al., 1998). However, viscous dashpots based on elasto-dynamic approach using small strain shear wave velocity arranged in parallel with the p-y Winkler springs resulted in exaggerated radiation damping solutions (Wang et al., 1998). Although the most common way to implement radiation dashpot is in a parallel manner for soil-pile interaction analysis, researchers at the University of California, Davis recommend to arrange the Winkler spring and the dashpot in series. This kind of arrangement ensure that forces acting at the viscous dashpot would be transmitted through the Winkler based p-y springs; thereby reducing the effect of the viscous damper.

Based on our parametric studies and the findings from other researchers, it may be concluded that the effect of radiation damping would be small compared to that of material damping. Since the material damping is already accounted for in the p-y curves, no additional radiation damping is recommended for this project.

3.7 NON-LINEAR SPRINGS FOR PILE CAP

The design plans for the skyway indicates that the pile caps for piers E07 through E16 would be placed below the mudline. For these piers, in addition to the piles, the pile caps would also offer additional resistance against lateral movement derived from passive pressure of the soil. Our recommendations for pile cap springs are presented in this section. In Table the normalized shapes of pile cap springs are tabulated. In this table, q represents the soil pressure in the units of F/L^{-2} and y represents displacement. The pressure is normalized with respect to ultimate pressure q_{ult} and the displacement is normalized with respect to reference displacement, y_c. The ultimate pressures are computed using procedures very similar to that used for calculating ultimate soil capacity for piles. The estimated values of q_{ult} depend largely on the undrained shear strength of the soil, and to some extent on the pile cap configuration, i.e., the contact dimension L and B for longitudinal and transverse loading directions, respectively. The reference displacement, y_c, was estimated as

$$y_c = I_p \varepsilon_{50} . L_c \qquad (3\text{-}7)$$

where I_p is a shape factor arising from elastic half space analysis. For I_p, values ranging from 1 to 2.5 can be found in the literature. ε_{50} is a soil strain parameter from laboratory stress-strain test and depends on the soil type. For soft surficial clay at the project site, a value of 0.02 was used for ε_{50}. L_c is the characteristic length of the embedded pile cap which for rigid foundation can be taken as the shortest dimension. For these pile caps the depth represents the shortest dimension and which was therefore considered as L_c.

3.8 ADDED MASS FOR SOIL

As regards to added mass to account for inertial effects of the soil, there is very little information available in the technical literature to draw any definite conclusions. In traditional elastic half space method of analysis, the foundation drags the soil and moves in phase with it. This, in effect, gives rise to the concept of added mass that contributes to the inertial response of the foundation system. However, the soil stratigraphy at the project site consists of deep deposit of soft bay mud layer. It is expected that at higher load levels this soft soil will yield and produce large amount of slippage between the soil and the pile than those can be expected in elastic half space analysis. Therefore, the use of added mass as suggested by elastic analysis may not be reasonable.

Recent centrifuge tests performed at UC Davis (Boulanger et al., 1999, Wang et al., 1998) consisted of pile foundations embedded in deposits of soft bay mud. The experimental results were compared with the results from the numerical analyses. The numerical model, consisted of pile mass only, and did not include any added mass of the surrounding soil. These researchers were able to obtain good match between the experimental and the numerical results without including any additional soil mass. Similar conclusion could be drawn from our simulation of Statnamic vertical pile test data with regard to added soil mass participation in the vertical direction.

We believe that the soil inertia force would be small compared to the restoring force from p-y springs especially when gapping occurs. We recommend no added mass above the pile mass and the soil plug inside the pile itself in the dynamic pile model. However, one can intuitively conclude that due to large cross-sectional area, the added soil mass may be more significant for the pile cap than for the soil-pile system. It is recommended that a sensitivity analysis may be necessary to establish the importance of added soil mass for the pile cap. Trail added mass, equal to the weight of the displaced soil, are tabulated in Table 3-5 which can be used for the sensitivity study to examine effects on the overall bridge response with and without added mass for the pile cap.

3.9 FOUNDATION SUBSTRUCTURE AND CONDENSED MATRICES

To evaluate the dynamic response of a bridge structure, it would be most desirable to create a complete analytical model of the total system including the bridge superstructure, pile cap, and the soil-pile system. Such model would account for depth varying nonlinear soil springs (p-y curves), depth varying ground motion, and inertial forces of the foundation system. However, such a model in most cases becomes cumbersome with the analysis involving a large number of degrees of freedom. The solution for keeping model size small and reducing the number of degrees of freedom is to use the method of substructuring. For bridges, the global structure can be divided into two substructures: a substructure for the foundation and a substructure for the bridge superstructure, with a convenient interface between the two substructures at the pile cap level. By using the substructuring method, the stiffness of the foundation system and the forces arising from the soil-pile interaction can be condensed at the pile cap level, which can be used by the structural engineer to analyze the response of the bridge superstructure.

3.9.2. Pile group stiffness matrix

A typical bridge problem can be considered as a multiple-input, multiple-degree-of-freedom (MDOF) system; it consists of superstructure (deck and column), pile-cap, and pile-foundation. For the purpose of discussion, the damping term is ignored and the mass matrix is based on a lumped mass system. The equations of motion for this MDOF system due to multiple-input ground motion $\{x_g(t)\}$ are written as

TABLE 3-4. NONDIMENSIONAL PILE CAP SPRINGS

q/q_{ult}	y/y_c
0.000	0.000
0.250	0.125
0.500	1.000
0.720	3.000
1.000	8.000
1.000	∝

TABLE 3-5. PILE CAP SPRINGS FOR DIFFERENT PIERS

Pier No.		E07 EB&WB	E08 EB&WB	E09 EB&WB	E10 EB&WB	E11 EB&WB	E12 EB &WB	E13 EB &WB	E14 EB &WB	E15 EB &WB	E16 EB &WB
Depth of Footing (m)		6.5	6.0	6.5	6.5	5.8	6.5	6.5	6.5	6.5	6.5
Added Mass (kg/m^3)		1740	1740	1740	1740	1740	1740	1740	1740	1740	1740
q_{ult} (MN/m^2)	Long. Direction	0.057	0.067	0.076	0.079	0.069	0.099	0.131	0.605	0.0732	0.0784
	Trans. Direction	0.058	0.067	0.077	0.079	0.069	0.099	0.132	0.617	0.0737	0.079
y_c (m)	Long. Direction	0.130	0.130	0.130	0.130	0.116	0.130	0.130	0.130	0.130	0.130
	Trans. Direction	0.130	0.130	0.130	0.130	0.116	0.130	0.130	0.130	0.130	0.130

$$\begin{bmatrix} [m_s] & & \\ & [m_c] & \\ & & [m_p] \end{bmatrix} \begin{Bmatrix} \{\ddot{x}_s\} \\ \{\ddot{x}_c\} \\ \{\ddot{x}_p\} \end{Bmatrix} + \begin{bmatrix} [K_{ss}] & [K_{sc}] & \\ [K_{cs}] & [K_{cc}] & [K_{cp}] \\ & [K_{pc}] & [K_{pp}] \end{bmatrix} \begin{Bmatrix} \{x_s\} \\ \{x_c\} \\ \{x_p\} \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ [K_g]\{x_g\} \end{Bmatrix} \quad (3\text{-}8)$$

where the subscript "s", "c" and "p" denote the superstructure, pile-cap and the pile degrees of freedom, respectively. The mass and stiffness are represented by the matrices [m] and [K]. The vectors $\{x_s\}$, $\{x_c\}$ and $\{x_p\}$ represent displacement of the superstructure, pile-cap, and pile degrees of freedom relative to the earth inertia reference frame (i.e, total displacements), respectively. The displacement vector $\{x_g\}$ represents the depth-varying free-field motions which can be computed from an appropriate site response study, and $[K_g]$ is the soil stiffness surrounding the piles. The pile-cap node would have 6 degrees of freedom (three translation, and three rotation). It is assumed that mass of the pile is small and can be ignored, i.e, $[m_p]=0$. Typically this is the case because inertial forces of the piles are relatively small compared to the more massive superstructure, and therefore neglecting the foundation inertial effect does not normally cause significant error. Then the system of equations become:

$$\begin{bmatrix} [m_s] & & \\ & [m_c] & \\ & & [0] \end{bmatrix} \begin{Bmatrix} \{\ddot{x}_s\} \\ \{\ddot{x}_c\} \\ \{\ddot{x}_p\} \end{Bmatrix} + \begin{bmatrix} [K_{ss}] & [K_{sc}] & \\ [K_{cs}] & [K_{cc}] & [K_{cp}] \\ & [K_{pc}] & [K_{pp}] \end{bmatrix} \begin{Bmatrix} \{x_s\} \\ \{x_c\} \\ \{x_p\} \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ [K_g]\{x_g\} \end{Bmatrix} \quad (3\text{-}9)$$

With the pile mass assumed to be zero, static condensation can be performed to eliminate the pile degrees of freedom. After eliminating the pile degrees of freedom, dynamic response analysis can be performed using the following set of equations involving the superstructure $\{x_s\}$ and the pile cap nodes $\{x_c\}$;

$$\begin{bmatrix} [m_s] & \\ & [m_c] \end{bmatrix} \begin{Bmatrix} \{\ddot{x}_s\} \\ \{\ddot{x}_c\} \end{Bmatrix} + \begin{bmatrix} [K_{ss}] & [K_{sc}] \\ [K_{cs}] & [K] \end{bmatrix} \begin{Bmatrix} \{x_s\} \\ \{x_c\} \end{Bmatrix} = \begin{Bmatrix} 0 \\ \{f\} \end{Bmatrix} \quad (3\text{-}10)$$

where [K] and {f} in the above equation are defined as

$$\{f\} = -[K_{cp}][K_{pp}]^{-1}[K_g]\{x_g\} \quad (3\text{-}11)$$

$$[K] = [K_{cc}] - [K_{cp}][K_{pp}]^{-1}[K_{pc}] \quad (3\text{-}12)$$

It is noted that Equation 3.10 contains only the pile-cap and the superstructure degrees of freedom, and in fact the solutions to this set of equations are what the structural engineers are seeking in order to determine demands for the superstructure and the pile-cap. The transformation of the original problem into a substructured system consisting only of the superstructure and pile-cap is entirely based on classical static condensation (e.g., Cook, et al., 1989). The stiffness of the pile foundation system is now represented by the 6x6 condensed stiffness matrix [K], given by Equation 3.11 and the equivalent force applied at the pile-cap represented by the 6x1 forcing function {f}, given by Equation 3.12. Both the stiffness matrix [K] (which is constant with time) and the forcing function {f} (which is time dependent and related to the time histories of the depth-varying free-field input ground motion) can be pre-calculated without knowledge of the response of the superstructure or the pile cap.

3.9.3. Pile group mass matrix

The substructuring approach using static condensation, as described above, provides rigorous solutions for massless piles. However, for piles with some limited mass, the method is only approximate and the error depends on the relative magnitude of the pile mass to the superstructure mass. The solution can be greatly improved by implementing a condensed mass to represent an inertia effect of the foundation substructure. This is to maintain the fundamental mode of vibration of the entire foundation system in the condensed substructure. One approach would be based on computation of eigenvalues for the soil-pile system representing the entire foundation. The condensed mass, [M], can be approximated by

$$[M] = \frac{1}{\omega^2}[K] \tag{3-13}$$

where [K] is the condensed stiffness matrix obtained from the substructuring approach and ω is an angular frequency. The numeric value for ω is often chosen as the fundamental frequency (1^{st} mode) for each of the six axes (3 translation and 3 rotation) of the original foundation (before condensation). By doing so, the condensed model consisting of the 6x6 mass matrix [M] and the 6x6 stiffness matrix [K] would reproduce the same 6 fundamental modes of vibration as the original foundation prior to adding the superstructure. For practical application, [M] is assumed to be diagonal to simplify the computation.

In many cases, however, computation of natural frequencies and mode shapes for a large pile group can be very time consuming. A method similar to static condensation can be employed to reduce the number of degrees of freedom for a dynamic system which minimizes the expense of computing eigenvalues and eigenvectors. This condensation algorithm is known in the literature as Guyan reduction, mass condensation, dynamic condensation, or eigenvalue economization (Cook et al., 1989). In the context of a pile foundation, free vibration characteristics of the pile-cap/pile system can be expressed as

$$\left(\begin{bmatrix} [K_{cc}] & [K_{cp}] \\ [K_{pc}] & [K_{pp}] \end{bmatrix} - \omega^2 \begin{bmatrix} [m_c] & \\ & [m_p] \end{bmatrix} \right) \begin{Bmatrix} \{x_c\} \\ \{x_p\} \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \tag{3-14}$$

In order to obtain a relation between $\{x_c\}$ and $\{x_p\}$, all the masses are temporally ignored, and thus providing the following relationship:

$$\begin{Bmatrix} \{x_c\} \\ \{x_p\} \end{Bmatrix} = [T]\{x_c\} \tag{3-15}$$

where

$$[T] = \begin{bmatrix} [I] \\ -[K_{pp}]^{-1}[K_{pc}] \end{bmatrix} \tag{3-16}$$

and [I] is an identity matrix. Substituting Equation 6.15 into Equation 6.14 and pre-multiplying by $[T]^T$ yields a condensed eigen problem as follows

$$([K] - \omega^2[M])\{x_c\} = \{0\} \tag{3-17}$$

where the reduced stiffness and mass matrices are symmetric and are given by

$$[K] = [T]^T \begin{bmatrix} [K_{cc}] & [K_{cp}] \\ [K_{pc}] & [K_{pp}] \end{bmatrix} [T] = [K_{cc}] - [K_{cp}][K_{pp}]^{-1}[K_{pc}] \tag{3-18}$$

and

$$[M] = [T]^T \begin{bmatrix} [m_c] & \\ & [m_p] \end{bmatrix} [T] \tag{3-19}$$

It can be seen that [T] plays a similar role as Ritz vectors in the Raleigh-Ritz method, and the stiffness matrix [K] is the same matrix as produced by static condensation presented in Section 3.9.2. Furthermore, it is noted the condensed mass [M] is banded and is a combination of both mass and stiffness coefficients. However, to simplify the modeling effort, only the diagonal coefficients of the mass matrix are used for bridge analyses.

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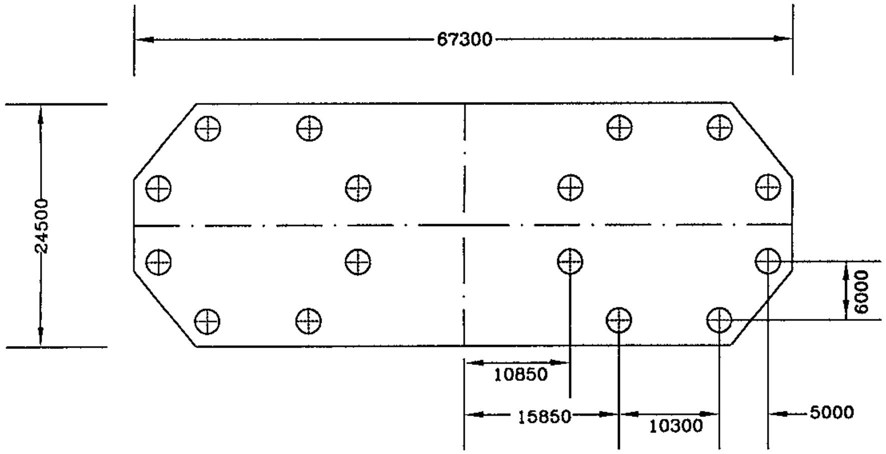
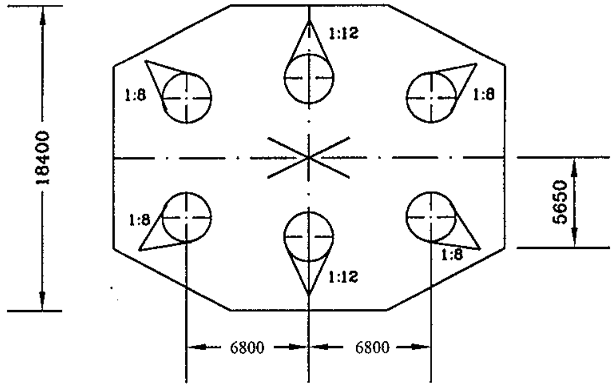
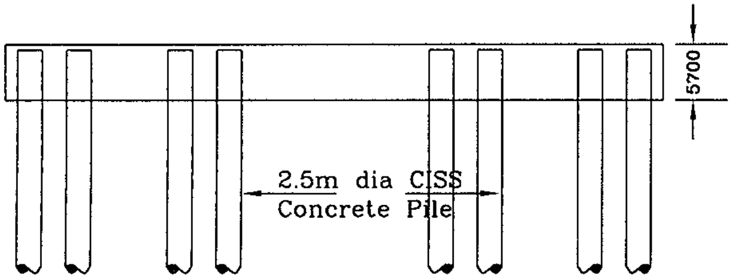
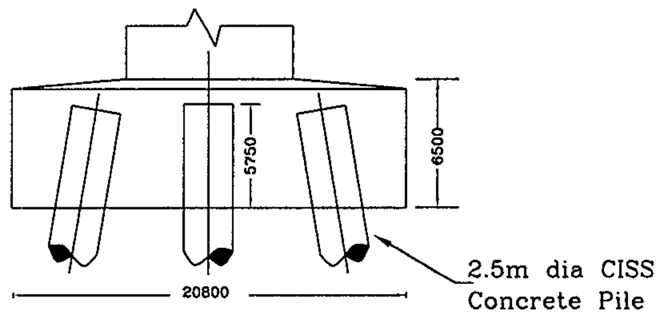




Note: Units in mm unless otherwise shown





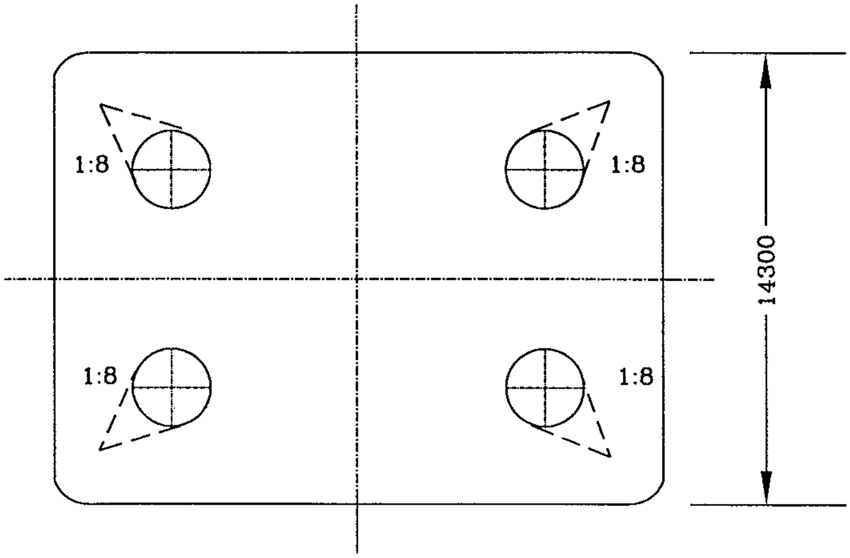
LAYOUT OF PIER E2

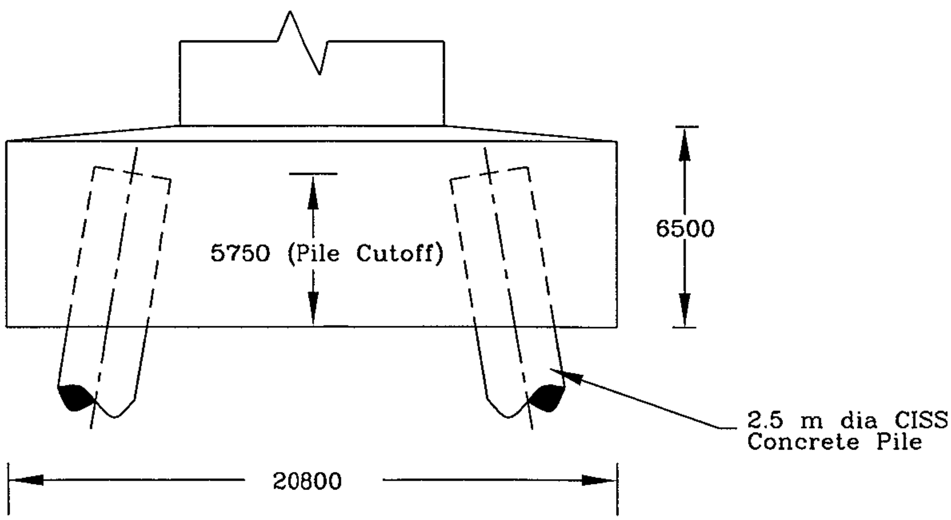
LAYOUT OF PIER E3 THRU E14
(EASTBOUND OR WESTBOUND)

PILE LAYOUT FOR PIERS E02 THROUGH E14
SFOBB East Span Seismic Safety Project

Earth Mechanics
FUGRO

PLATE 3-1





Note: Units in mm unless otherwise shown

PILE LAYOUT FOR PIERS E15 AND E16

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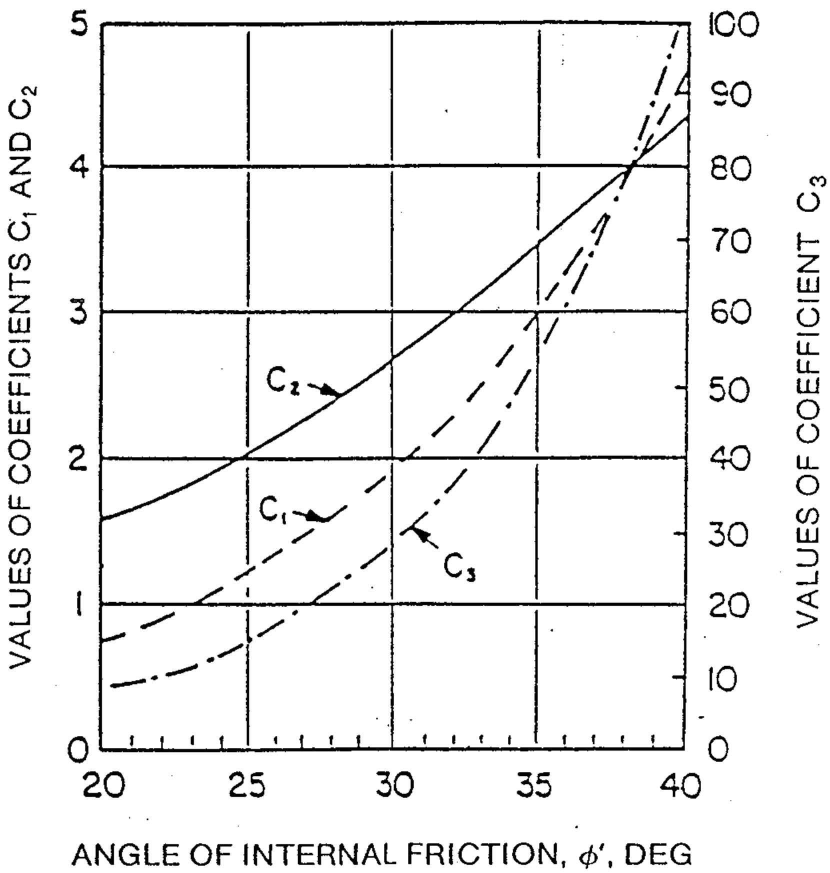

VARIATION OF FACTORS C1, C2 AND C3 WITH ϕ

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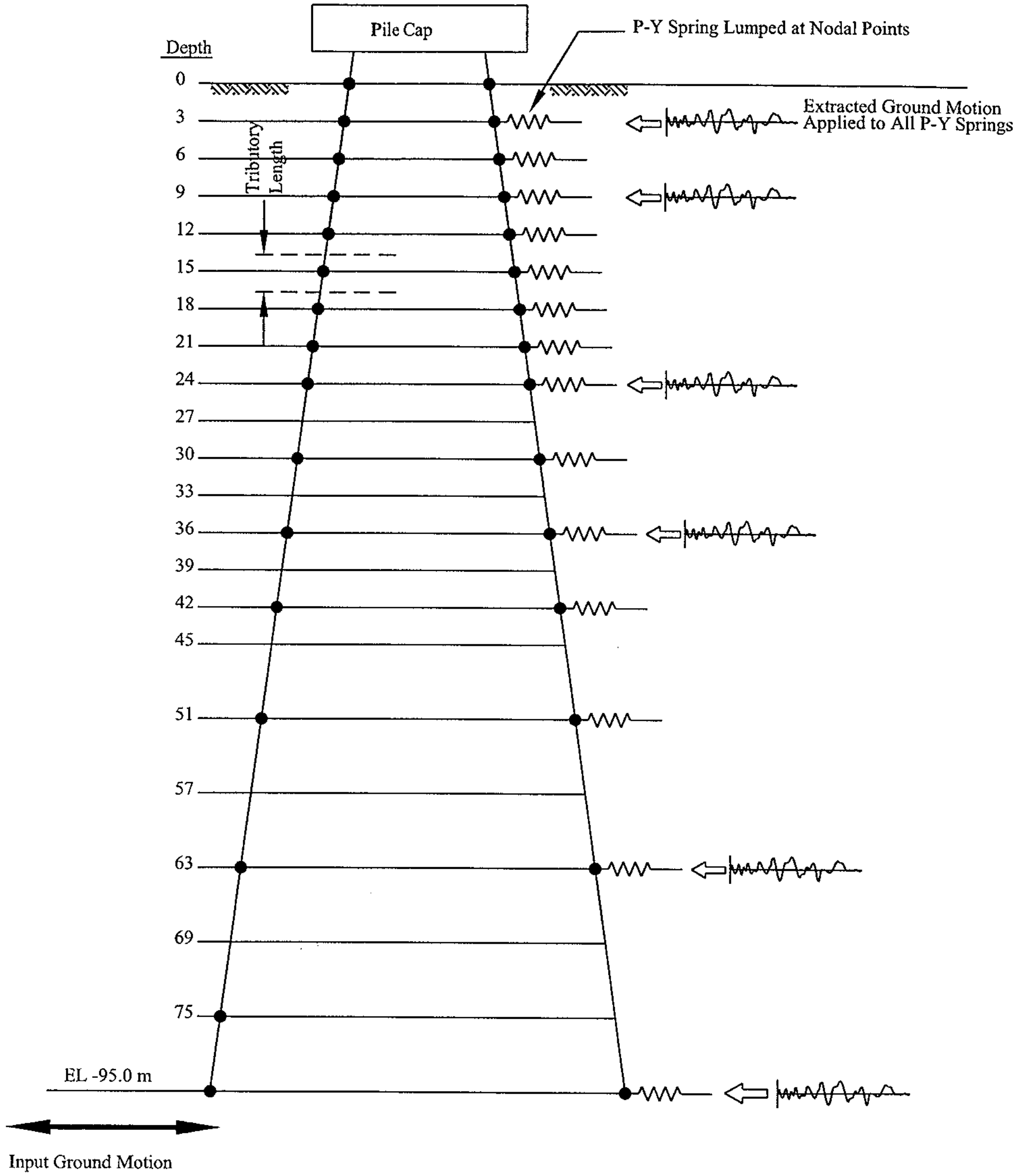
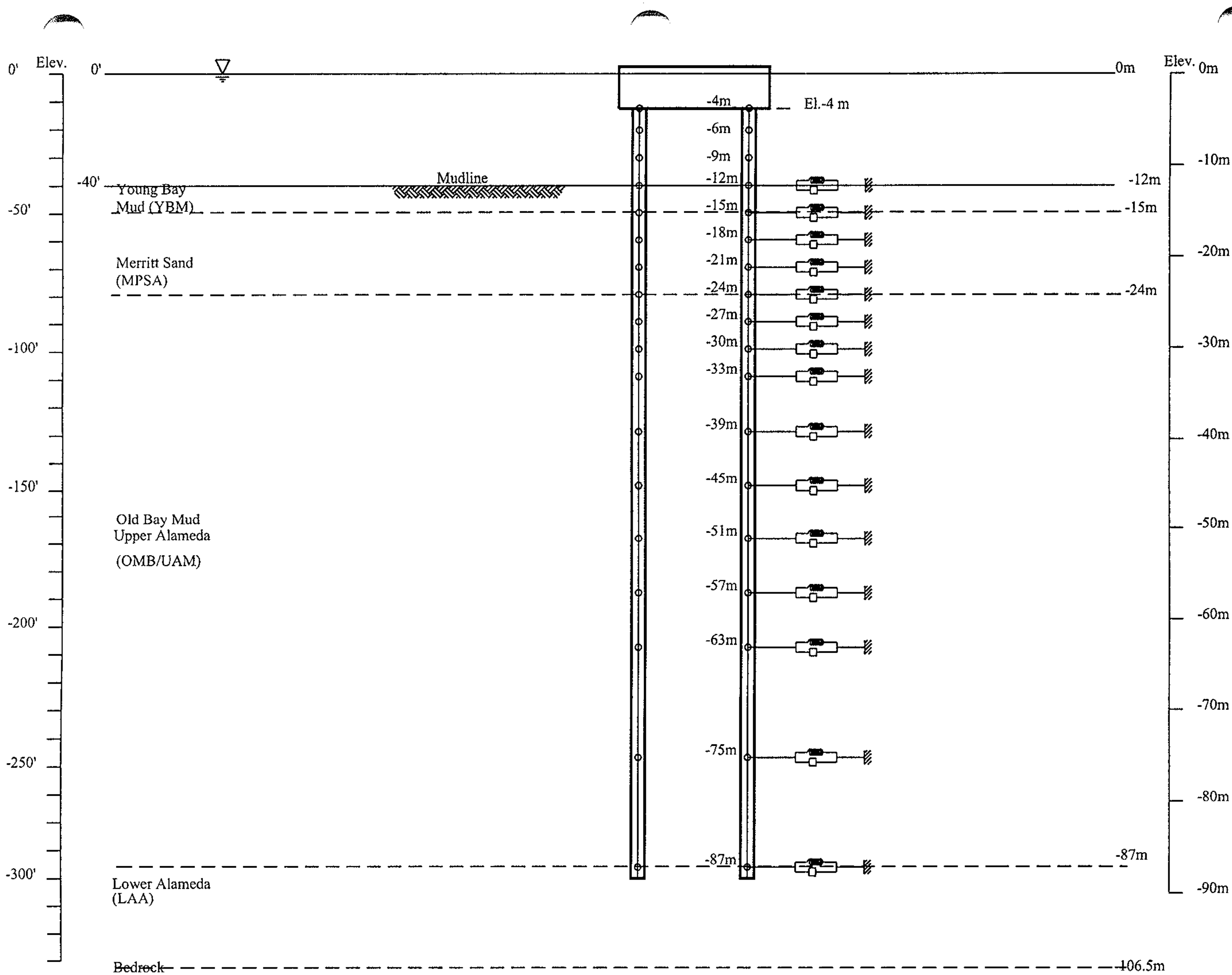


DISCRETIZATION SCHEME
SFOBB East Span Seismic Safety Project



DAMPING ARRANGEMENT WITH DASHPOT IN PARALLEL WITH p-y SPRINGS

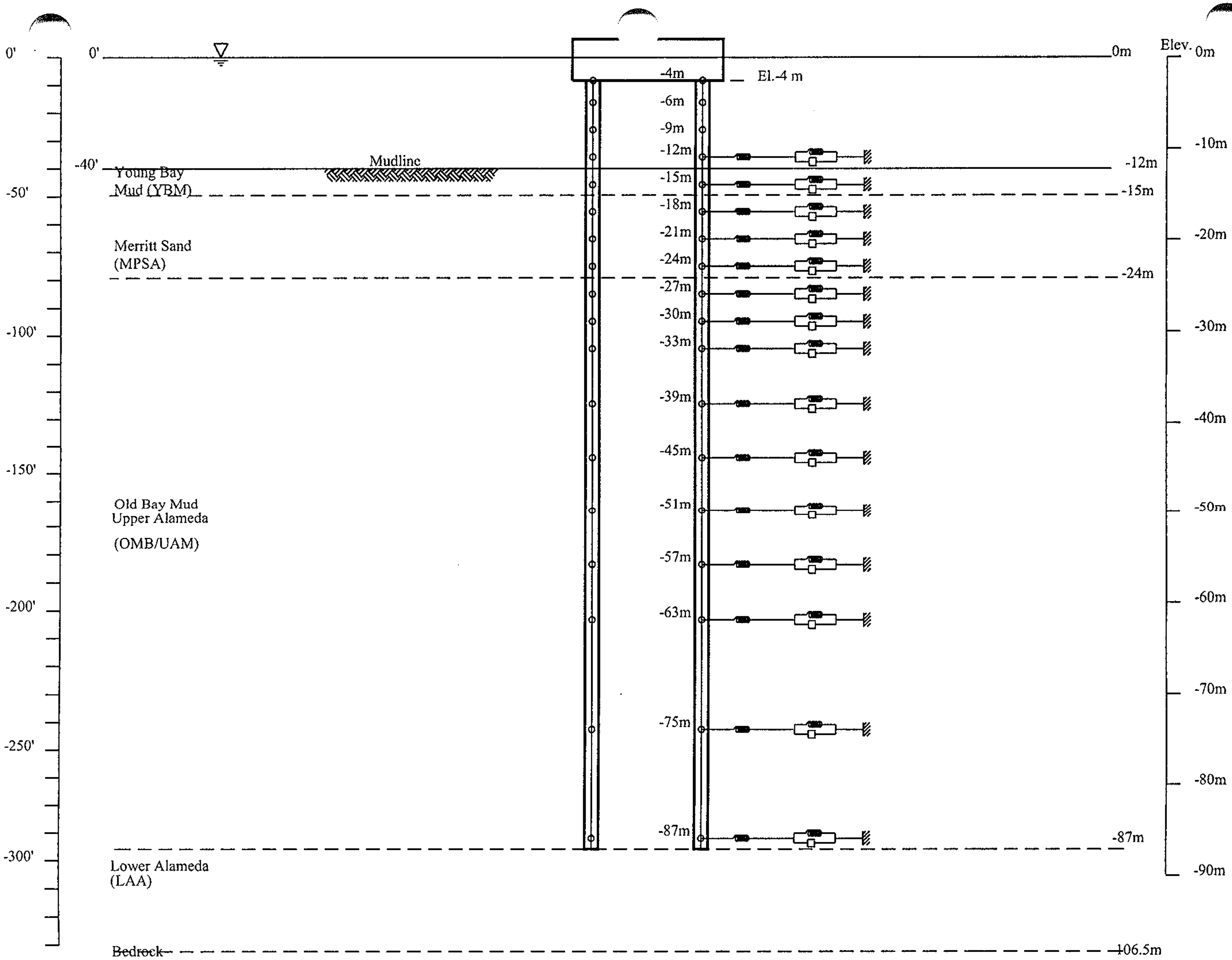
SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5
EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE 3-5



DAMPING ARRANGEMENT WITH DASHPOT IN SERIES WITH p-y SPRINGS

SFOBB East Span Seismic Safety Project

PLATE 3-6

SFOBB Task Order No. 5
EMI Project No. 98-145

Earth Mechanics

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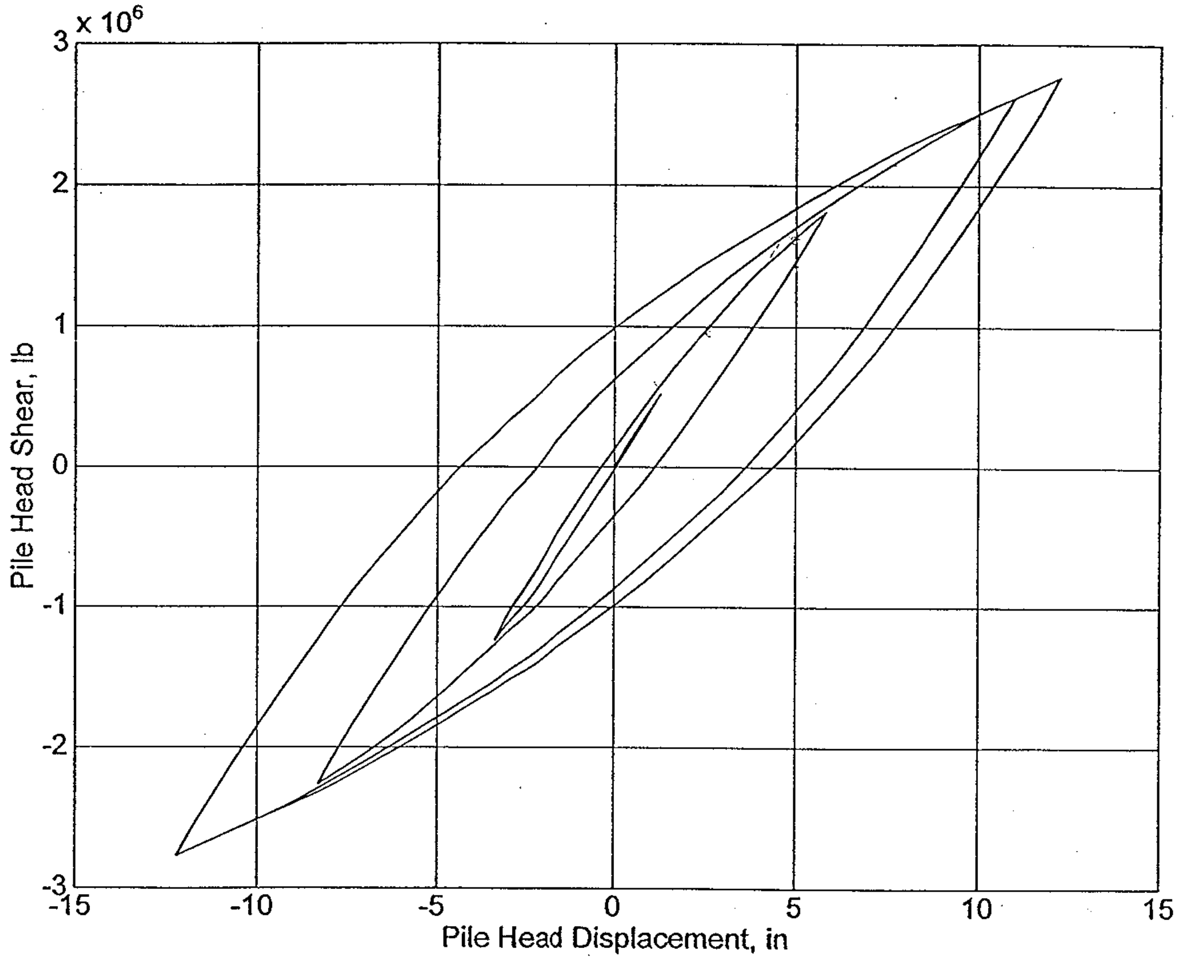
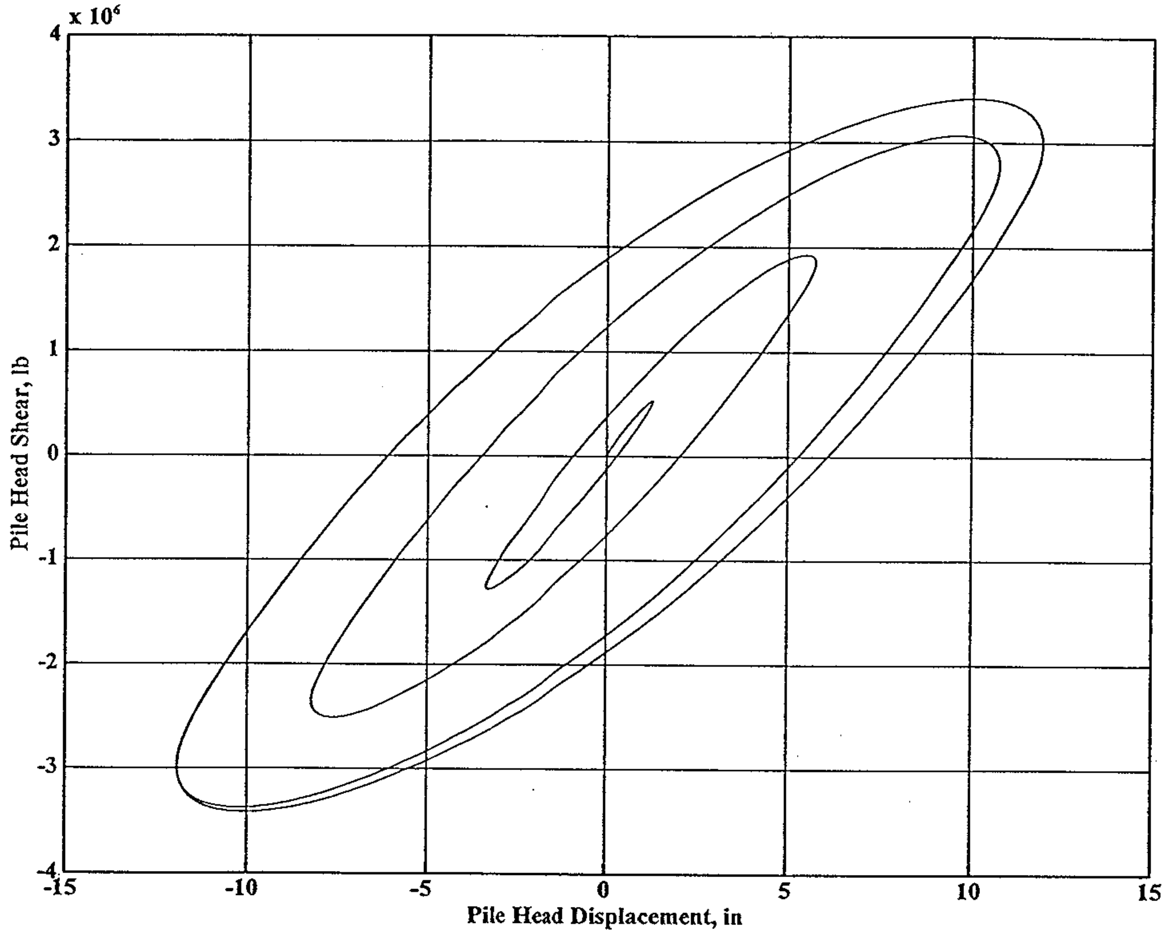
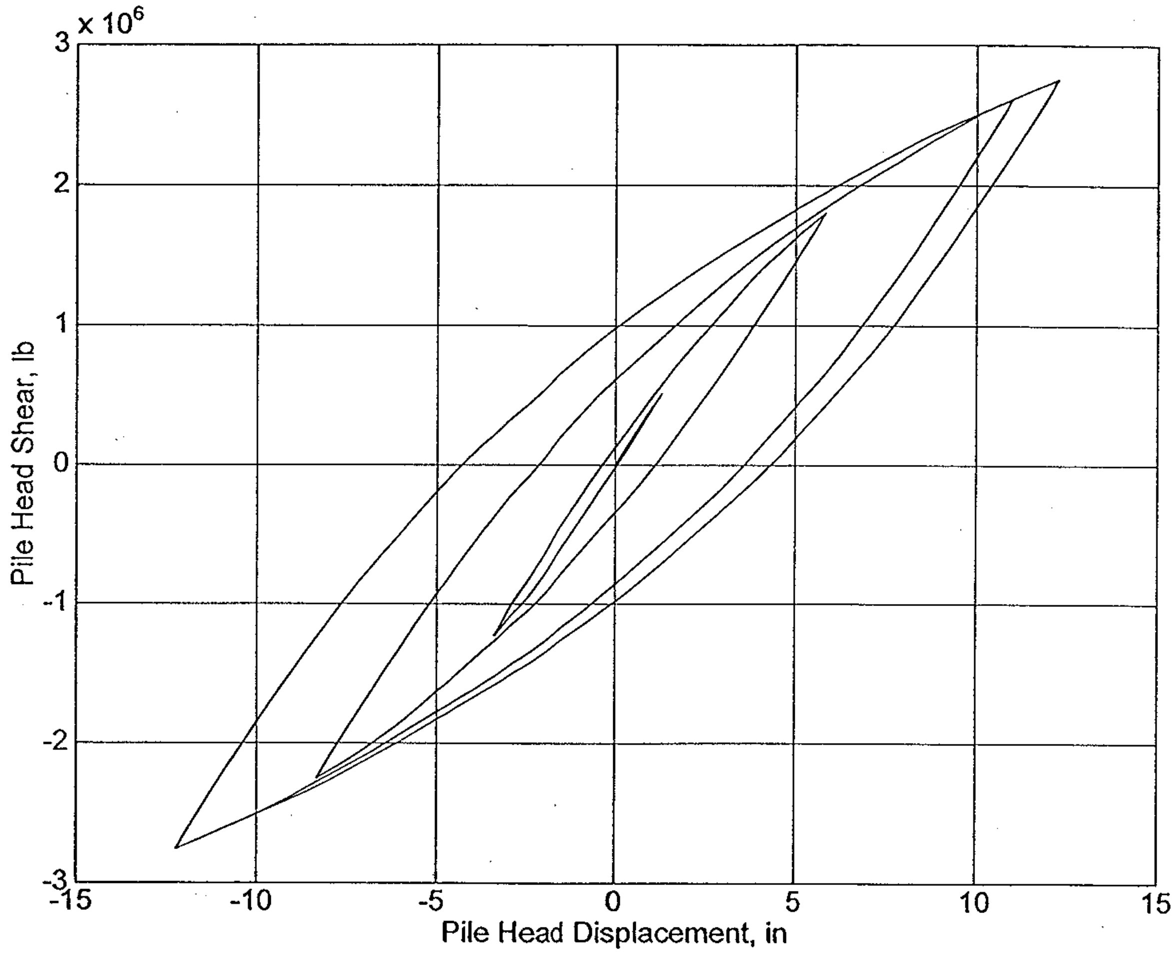


PILE RESPONSE WITH NO RADIATION DAMPING
(HYSTERETIC DAMPING ONLY)
SFOBB East Span Seismic Safety Project

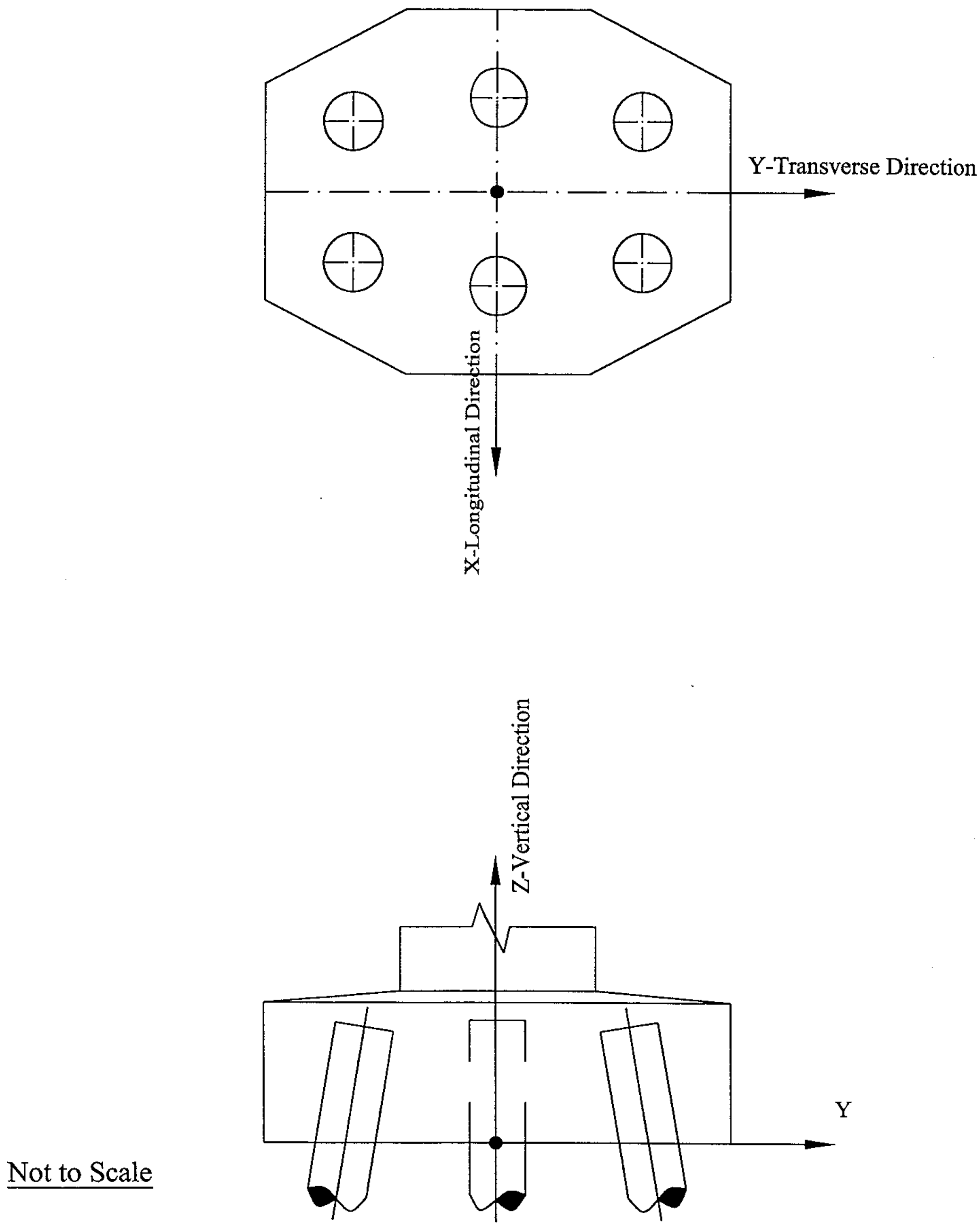


PILE RESPONSE WITH RADIATION DAMPING
(DASHPOT IN PARALLEL)
SFOBB East Span Seismic Safety Project



PILE RESPONSE WITH RADIATION DAMPING (DASHPOT IN SERIES)

SFOBB East Span Seismic Safety Project



COORDINATE SYSTEM USED FOR SUBSTRUCTURING
SFOBB East Span Seismic Safety Project

SECTION 4.0
PIER SPECIFIC ANALYSES

SECTION 4.0

4.0 PIER SPECIFIC ANALYSIS

4.1 DESIGN BASIS

A total of 44 borings were drilled during the Phase I and Phase II marine investigation, and extensive in-situ and laboratory tests were conducted. Based on the information obtained from these tests pier-specific subsoil stratigraphy have been developed. Detailed discussion on investigation methodology and interpretation procedure is presented in various Fugro-EMI reports (1998, 2001a, 2001b, 2001c, 2001f). Lateral pile design data were estimated at each pier location on the basis of pier-specific subsoil information given in the above mentioned reports. p-y curves at different depths were formulated and lateral pushover analyses of a single pile were performed using the computer program BMCOL76 (Matlock et al., 1981). The design parameters and the results of pushover analyses are presented in this section.

As explained in Section 3, the p-y curves are non-linear. The coordinates of p-y curves presented in this report include a p-multiplier of 0.5 to collectively account of group effect and cyclic loading. For service loading condition (p-multiplier of 1.0), the presented p-values (soil resistance) should be multiplied by a factor of 2 (p-multiplier 1.0/ p-multiplier 0.5) in order to obtain the p-y curves for a single isolated pile with undegraded soil properties.

The single pile lateral pushover analyses were conducted with the presented p-y curve (i.e. p-multiplier of 0.5 included) and using effective sectional pile properties. The results of these lateral pile solutions therefore represent the soil-pile behavior under seismic loading. For the service load case, the presented lateral pile solutions are not appropriate. It would be more appropriate to use gross sectional pile properties and the p-y curves with the p-multiplier of 1.0. The pile group stiffness matrices were developed for two load cases, seismic and service loading conditions. The stiffness matrix formulation is based on substructuring, as discussed in the previous section. The substructuring approach can be implemented if the system is linear. It is therefore necessary to linearize the p-y curves to generate pile group stiffness matrix.

For the seismic load case, the p-y curves are linearized at the displacement level (y) associated with pile top displacement of 125 mm. The pile top displacement of 125 mm is a representative displacement expected during a seismic event, based on preliminary analyses conducted using the response spectrum approach. The linear spring stiffness at each elevation is estimated as the secant stiffness resulting from pile displacement at that particular elevation. For the service load case, the p-y curves are linearized using the first branch of the curve. In addition, effective sectional properties and gross sectional properties are used for the seismic and service load cases, respectively. The following provides a summary of foundation parameters for the two different load cases:

1) Seismic load case: p-y curves with a p-multiplier of 0.5, effective pile sectional properties, spring from curves linearized at pile head deflection of 125 mm.

2) Service load case: p-y curves with a p-multiplier of 1.0, gross pile sectional properties, spring linearized using the first branch of p-y curve.

Other than pile group stiffness, soil resistances developed on the vertical face of the pile cap and on the wall of the column isolation casing are considered for the sunken pile cap.

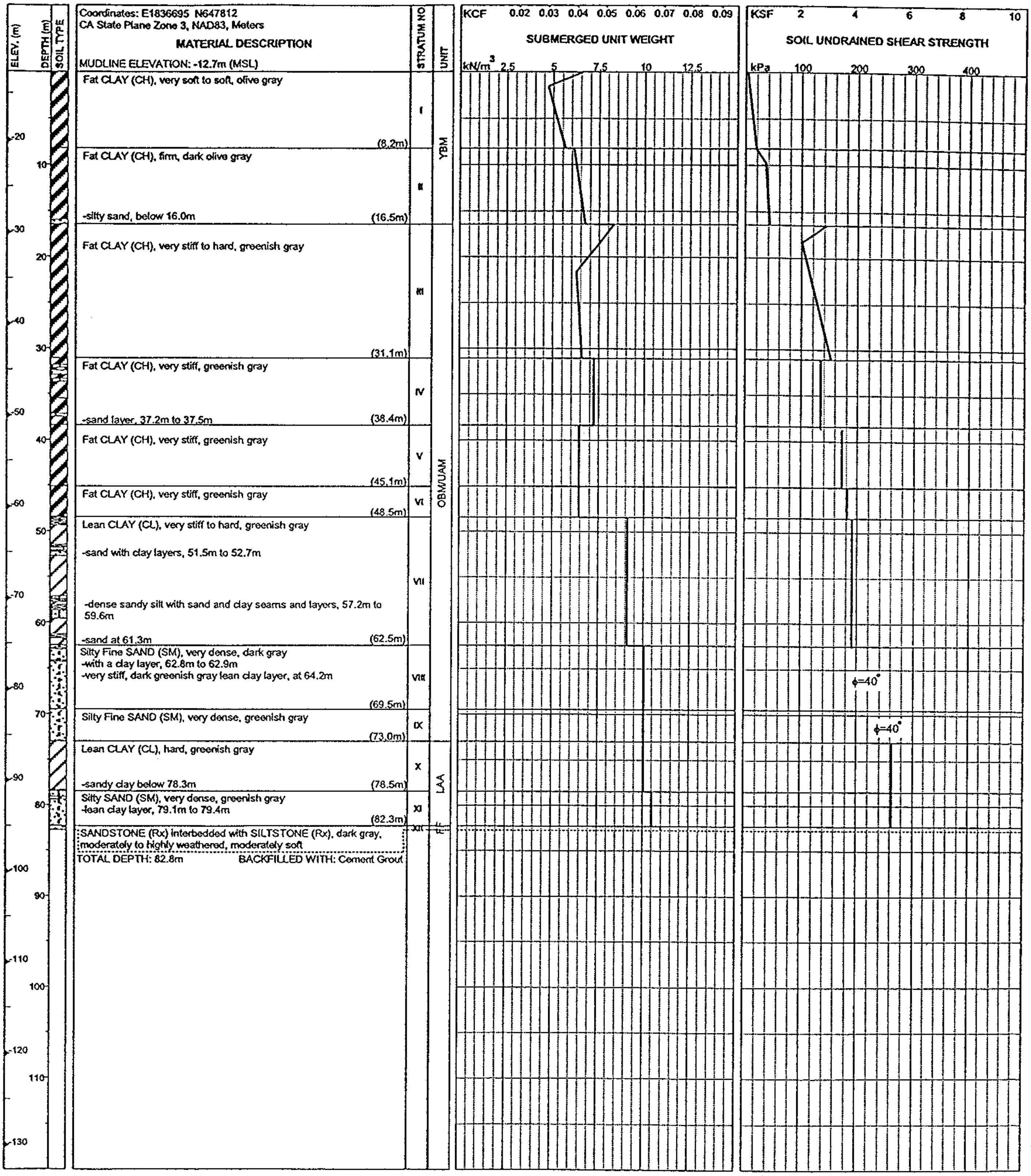
4.2 PRESENTATION OF PIER-SPECIFIC DATA

The pier-specific data are included at the end of this section. For each pier, six sheets are presented. The first contains the subsoil information pertaining to the pier, the second sheet presents the soil parameters used to determine the p-y curves, the third sheet presents detailed coordinates of p-y curves at different depths. The fourth and the fifth sheets contain the results of the pushover analyses. The fourth sheet presents the variations of pile head moment and shear with deflection, while the fifth sheet presents the variations of pile deflection, bending moment, and shear with depth. The sixth sheet presents the condensed stiffness and mass matrices of the foundation system. Two sets of stiffness matrices are provided. One for seismic load case and the other for the service load case including temperature and shrinkage loading effects. The former is for large displacement condition while the latter is essentially for small displacement condition as explained in Section 3.4.

The following system has been adopted for numbering the plates pertaining to each pier. For example, six plates corresponding to eastbound Pier 3 are numbered as Plate E03-EB.1, E03-EB.2, etc. Similarly the plates for the westbound pier are numbered as Plate E03-WB.1, E03-WB.2, etc. For some piers, same soil profile was used for both eastbound and westbound piers. In such cases, the suffix EB or WB was dropped.

It can be noted that the stiffness matrices for the EB and WB are identical for the seismic load case. This is due to substantial uncertainties in cyclic degradation, assumption on pile displacement level required in linearization of soil spring and estimation of effective pile sectional properties. It was decided that development of separate stiffness matrix for WB and EB is not warranted and therefore the soil properties were combined for the seismic load case. On the other hand, soil behavior and pile properties under service loading condition are more predictable. Uncertainties in development of foundation stiffness matrix under the service load case are not as severe as compared to the seismic case. For this reason, two separate stiffness matrices were developed for EB and WB by using pier specific data.

Earth Mechanics FUGRO

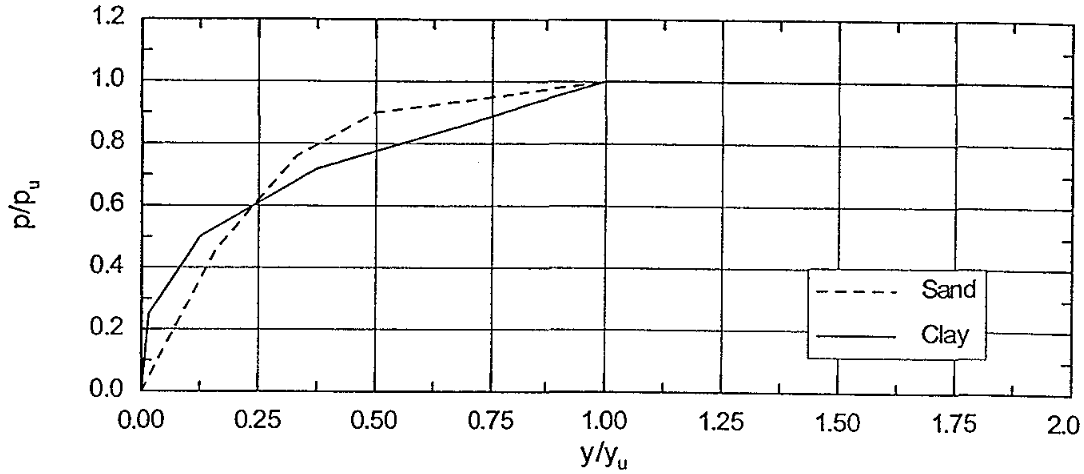


SUBSOIL CONDITION AND SOIL PROPERTIES

PIER E02 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

PLATE E02.1



NORMALIZED p-y CURVES

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	clay	0.02	10		
3-6	clay	0.02	15		
6-9	clay	0.02	15		
9-12	clay	0.01	30		
12-15	clay	0.01	40		
15-18	clay	0.005	100		
18-21	clay	0.005	110		
21-24	clay	0.005	120		
24-27	clay	0.005	130		
27 -30	clay	0.005	140		
30-33	clay	0.005	140		
33-36	clay	0.005	140		
36-39	clay	0.005	150		
39-42	clay	0.005	170		
42-45	clay	0.005	170		
45-51	clay	0.005	180		
51-57	clay	0.005	180		
57-63	clay	0.005	180		
63-69	sand			40	5400
69-75	sand			40	5400
75-81	clay	0.001	5200		

p-y DATA

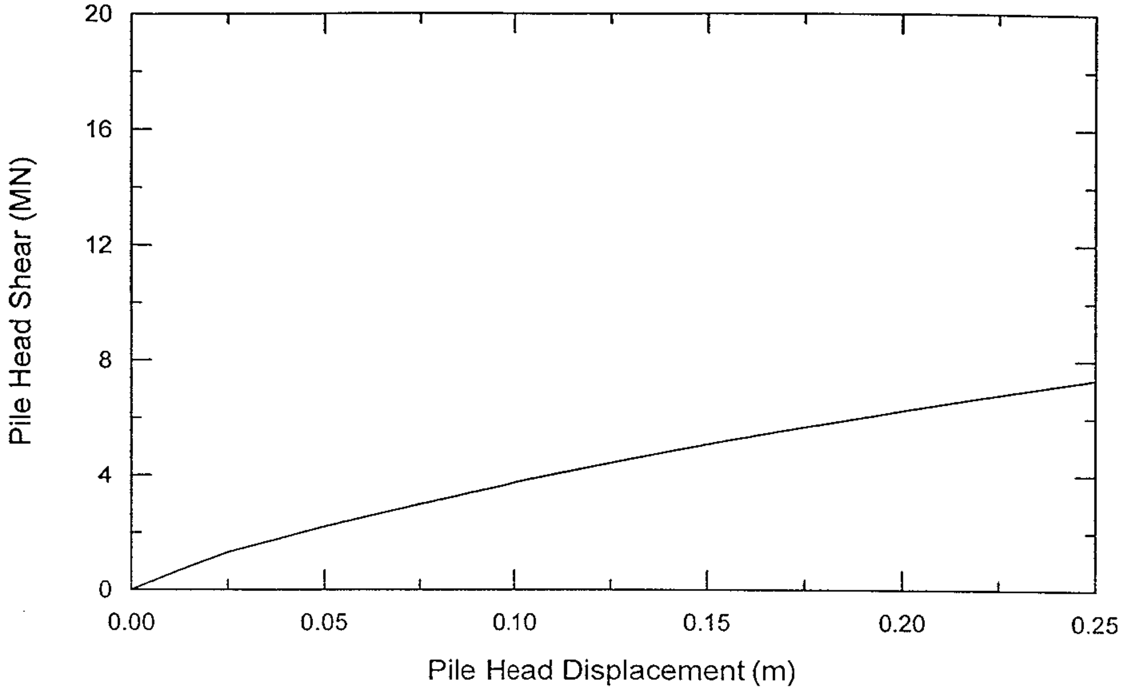
Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	36	100.0	clay
3.0	81	100.0	clay
6.0	115	100.0	clay
9.0	149	100.0	clay
9.0	236	50.0	clay
12.0	281	50.0	clay
15.0	844	25.0	clay
18.0	940	25.0	clay
21.0	1126	25.0	clay
24.0	1292	25.0	clay
30.0	1561	25.0	clay
36.0	1507	25.0	clay
42.0	1615	25.0	clay
51.0	2045	25.0	clay
63.0	2045	25.0	clay
63.0	60874	106.8	Sand
81.0	2799	25.0	clay

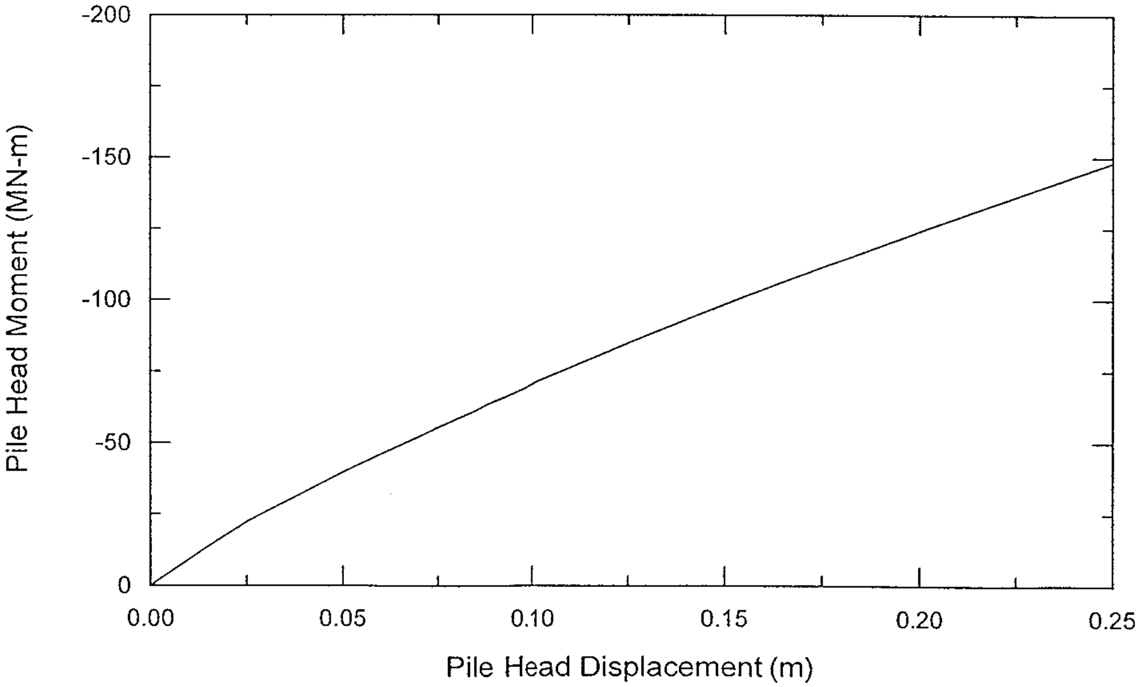
LATERAL PILE DESIGN PARAMETERS
PIER E02 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0.0	9	1.6	18	12.5	25.841	37.5	36	100.0	36	249.9		
3.0	2	0	0.0	20	1.6	41	12.5	58.551	37.5	81	100.0	81	249.9		
6.0	3	0	0.0	28	1.6	57	12.5	83	37.5	115	100.0	115	249.9		
9.0	4	0	0.0	37	1.6	74	12.5	107	37.5	149	100.0	149	249.9		
9.0	5	0	0.0	59	0.8	118	6.2	170	18.7	236	50.0	236	125.0		
12.0	6	0	0.0	70	0.8	140	6.2	202	18.7	281	50.0	281	125.0		
15.0	7	0	0.0	211	0.4	422	3.1	608	9.4	844	25.0	844	62.5		
18.0	8	0	0.0	235	0.4	470	3.1	677	9.4	940	25.0	940	62.5		
21.0	9	0	0.0	281	0.4	563	3.1	811	9.4	1126	25.0	1126	62.5		
24.0	10	0	0.0	323	0.4	646	3.1	930	9.4	1292	25.0	1292	62.5		
30.0	11	0	0.0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
36.0	12	0	0.0	376	0.4	753	3.1	1085	9.4	1507	25.0	1507	62.5		
42.0	13	0	0.0	403	0.4	807	3.1	1162	9.4	1615	25.0	1615	62.5		
51.0	14	0	0.0	511	0.4	1022	3.1	1472	9.4	2045	25.0	2045	62.5		
63.0	15	0	0.0	511	0.4	1022	3.1	1472	9.4	2045	25.0	2045	62.5		
63.0	16	0	0.0	6087	3.6	28002	17.8	46264	35.6	55396	53.4	60874	106.8	60874	178.0
81.0	17	0	0.0	699	0.4	1399	3.1	2015	9.4	2799	25.0	2799	62.5		

COORDINATES OF p-y CURVES
PIER E02 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

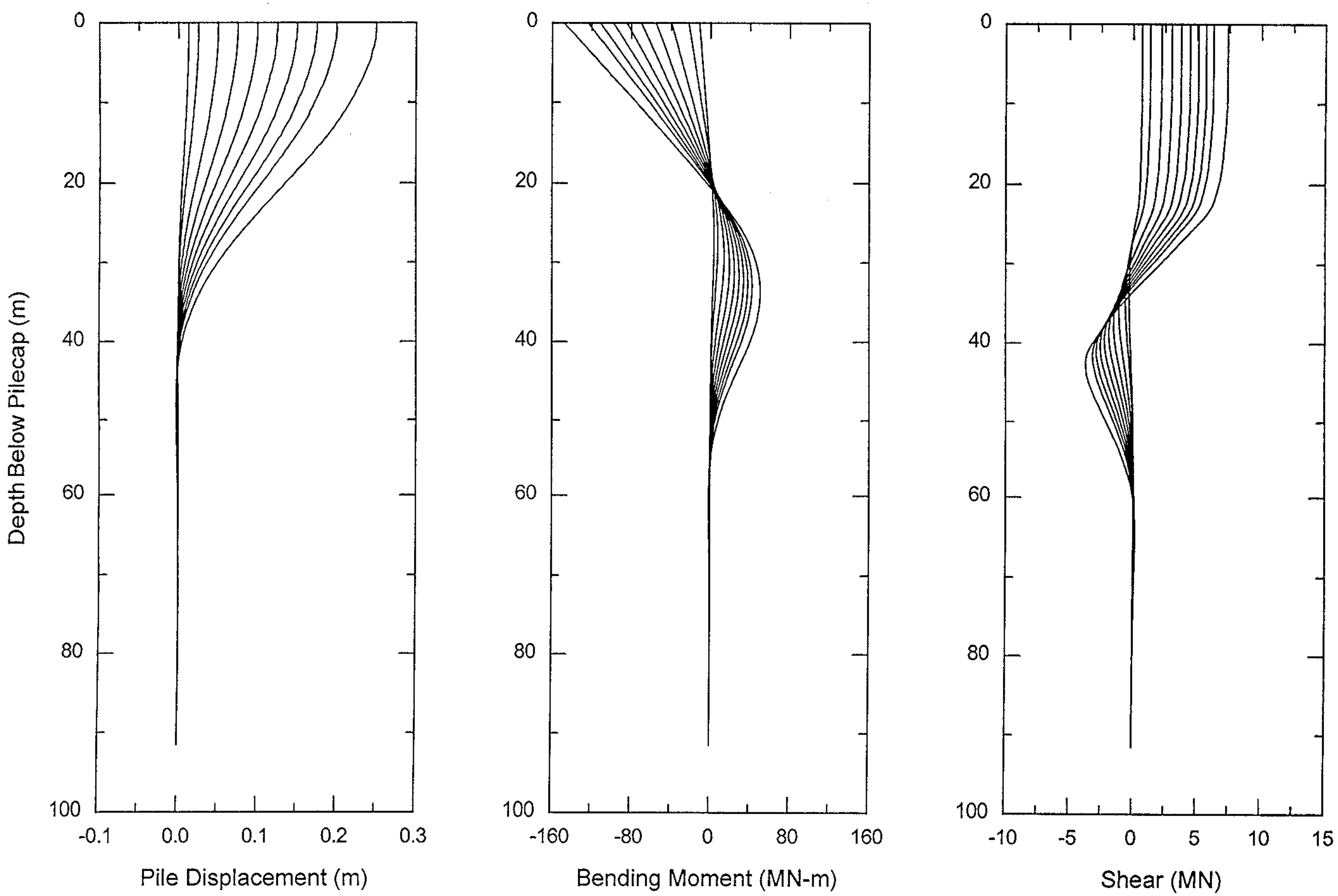
Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E02 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E02.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR
WITH DEPTH

PIER E02 EASTBOUND & WESTBOUND

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EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E02.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

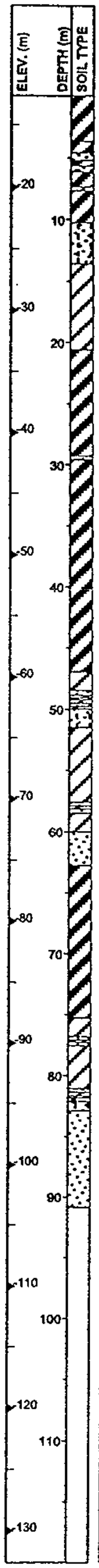
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.112E+005	0.000E+000	0.000E+000	0.000E+000	-1.004E+007	0.000E+000
0.000E+000	5.112E+005	0.000E+000	1.004E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	3.466E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.004E+007	0.000E+000	1.778E+010	0.000E+000	0.000E+000
-1.004E+007	0.000E+000	0.000E+000	0.000E+000	2.145E+009	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.864E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -4.5 m

CONDENSED STIFFNESS MATRICES
PIER E02 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

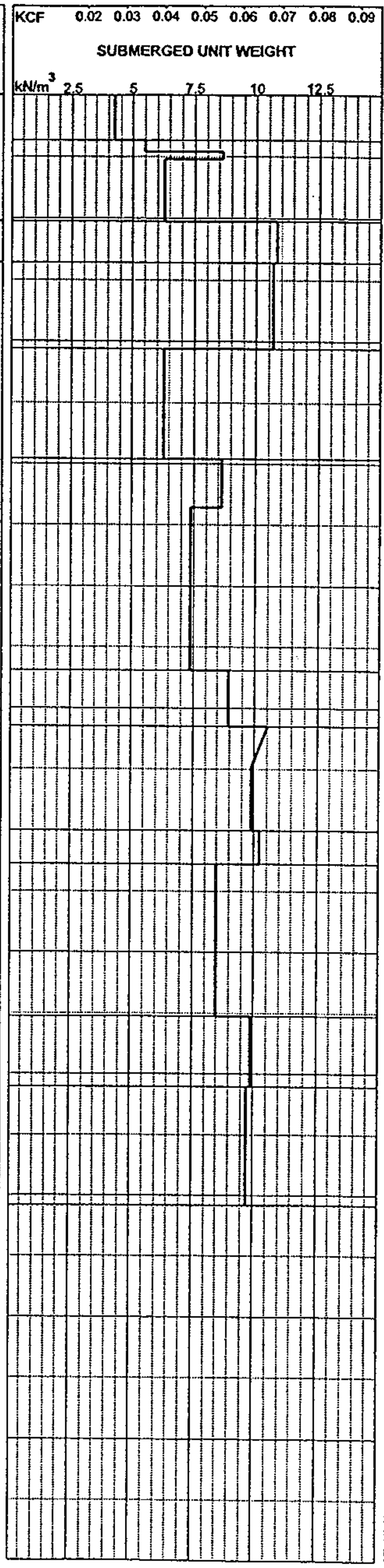
Coordinates: E1836840 N647873
CA State Plane Zone 3, NAD83, Meters

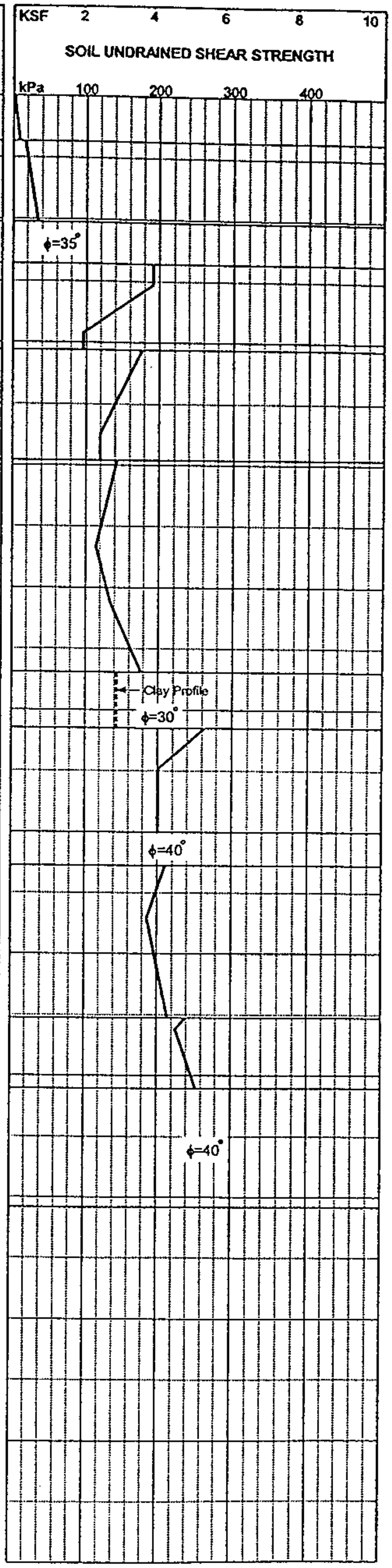
MUDLINE ELEVATION: -12.6m (MSL)



MATERIAL DESCRIPTION	STRATUM NO	UNIT
Fat CLAY (CH), very soft, gray to dark gray (3.7m)	I	YBM
Fat CLAY (CH), soft to firm, gray -silty fine to medium sand, with clay pockets and seams, and shells, 4.6m to 5.2m -silty sand layer with clay seams, 5.6m to 6.1m -sand, 7.3m to 7.6m (10.2m)	II	YBM
Silty Fine Sand (SM), dense to very dense, greenish gray (13.6m)	III	MPSA
Lean CLAY (CL), very stiff to hard, greenish gray (20.6m)	IV	OBM/UAM
Fat CLAY (CH), very stiff, olive gray -sand below 29.3m (29.6m)	V	OBM/UAM
Fat CLAY (CH), very stiff, gray (46.9m)	VI	OBM/UAM
Interlayered CLAY (CL), very stiff, and SAND (SP), dense, gray (51.5m)	VII	OBM/UAM
Lean CLAY (CH), hard, gray -sand with clay layers, 57.6m to 58.5m (60.0m)	VIII	OBM/UAM
Fine SAND (SP) with gravel, dense to very dense, gray (62.8m)	IX	OBM/UAM
Fat CLAY (CH), very stiff to hard, gray (75.3m)	X	OBM/UAM
Lean CLAY (CL), hard, dark greenish gray -silt, 76.8m to 77.1m -silt, 77.3m to 77.6m (81.1m)	XI	LAA
SAND (SP), dense to very dense, gray -clay layer, 81.4m to 81.7m -clay layer, 81.8m to 82.1m (90.8m)	XII	LAA
CLAYSTONE (RX), dark gray, intensely weathered	XIII	FF

TOTAL DEPTH: 90.9m BACKFILLED WITH: Cement Grout

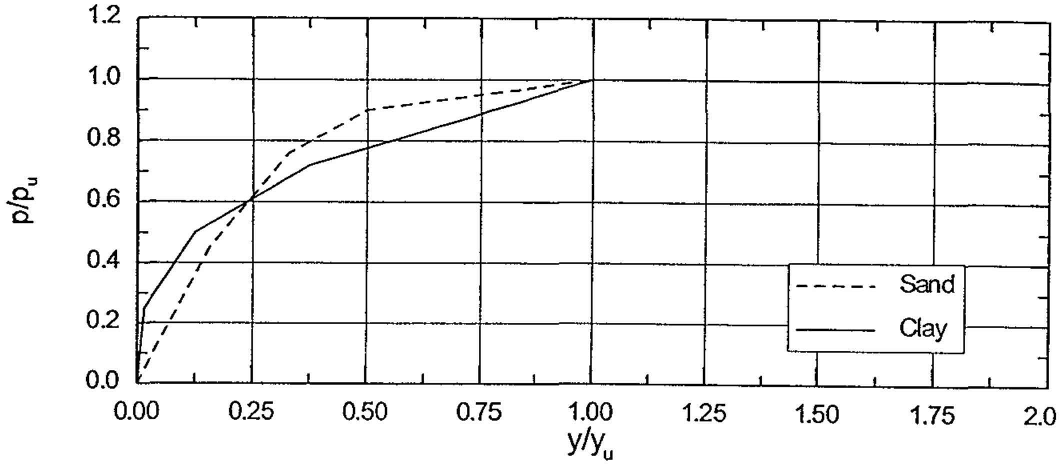




SUBSOIL CONDITION AND SOIL PROPERTIES

PIER E03 EASTBOUND

SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVES

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	8.5		
3-6	Clay	0.01	25		
6-9	Clay	0.01	35		
9-12	Sand			35	5440
12-15	Sand			35	5440
15-18	Clay	0.005	150		
18-21	Clay	0.005	120		
21-24	Clay	0.005	160		
24-27	Clay	0.005	135		
27 -30	Clay	0.005	120		
30-33	Clay	0.005	135		
33-36	Clay	0.005	125		
36-39	Clay	0.005	125		
39-42	Clay	0.005	135		
42-45	Clay	0.005	150		
45-51	Sand			30	5440
51-57	Clay	0.005	230		
57-63	Clay	0.005	200		
63-69	Clay	0.005	200		
69-75	Clay	0.005	200		
75-81	Clay	0.005	230		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	31	100.0	Clay
3.0	128	50.0	Clay
6.0	224	50.0	Clay
8.9	272	50.0	Clay
9.1	813	10.0	Sand
12.0	1634	15.0	Sand
14.9	2689	19.9	Sand
15.1	1255	25.0	Clay
18.0	1389	25.0	Clay
21.0	1271	25.0	Clay
24.0	1760	25.0	Clay
30.0	1345	25.0	Clay
36.0	1399	25.0	Clay
42.0	1507	25.0	Clay
50.9	26006	56.4	Sand
51.1	2584	25.0	Clay
63.0	2207	25.0	Clay
81.0	2476	25.0	Clay

LATERAL PILE DESIGN PARAMETERS
PIER E03 EASTBOUND
SFOBB East Span Seismic Safety Project

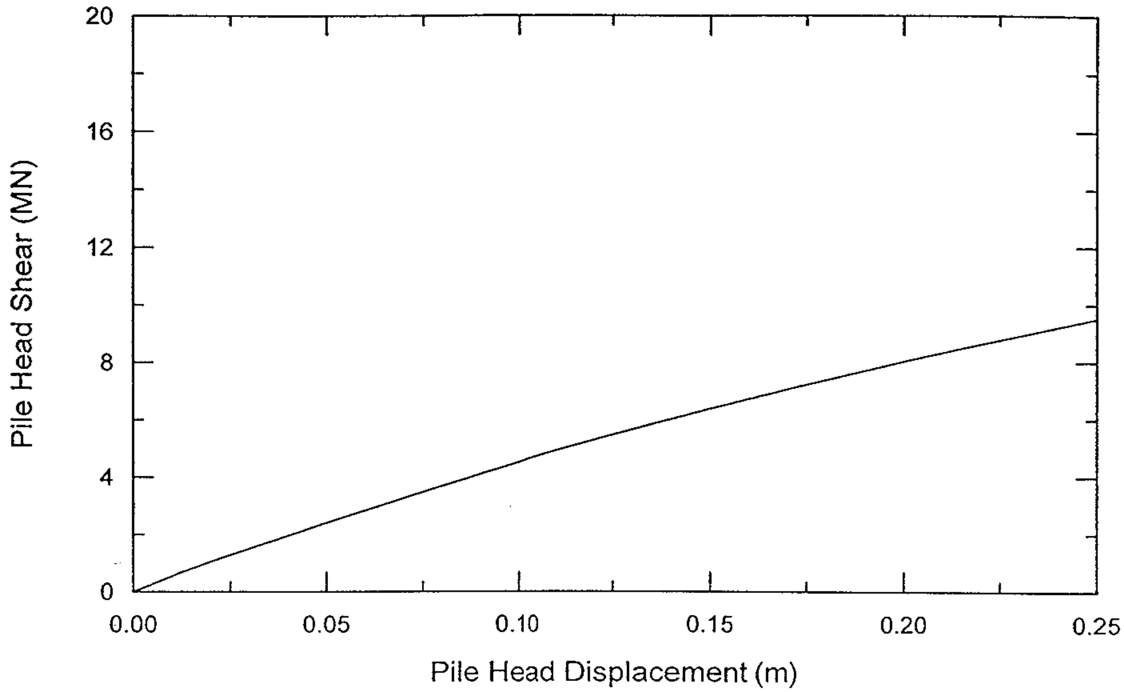
Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0.0	8	1.6	16	12.5	22.611	37.5	31	100.0	31	249.9		
3.0	2	0	0.0	32	0.8	64	6.2	92	18.7	128	50.0	128	125.0		
6.0	3	0	0.0	56	0.8	112	6.2	161	18.7	224	50.0	224	125.0		
8.9	4	0	0.0	68	0.8	136	6.2	196	18.7	272	50.0	272	125.0		
9.1	5	0	0.0	81	0.3	374	1.7	618	3.3	740	5.0	813	10.0	813	16.6
12.0	6	0	0.0	163	0.5	751	2.5	1241	5.0	1487	7.5	1634	15.0	1634	25.1
14.9	7	0	0.0	268	0.7	1237	3.3	2044	6.6	2447	9.9	2689	19.9	2689	33.1
15.1	8	0	0.0	313	0.4	627	3.1	903	9.4	1255	25.0	1255	62.5		
18.0	9	0	0.0	347	0.4	694	3.1	1000	9.4	1389	25.0	1389	62.5		
21.0	10	0	0.0	317	0.4	635	3.1	915	9.4	1271	25.0	1271	62.5		
24.0	11	0	0.0	440	0.4	880	3.1	1267	9.4	1760	25.0	1760	62.5		
30.0	12	0	0.0	336	0.4	672	3.1	969	9.4	1345	25.0	1345	62.5		
36.0	13	0	0.0	349	0.4	699	3.1	1007	9.4	1399	25.0	1399	62.5		
42.0	14	0	0.0	376	0.4	753	3.1	1085	9.4	1507	25.0	1507	62.5		
50.9	15	0	0.0	2600	1.9	11963	9.4	19765	18.8	23666	28.2	26006	56.4	26006	94.0
51.1	16	0	0.0	646	0.4	1292	3.1	1860	9.4	2584	25.0	2584	62.5		
63.0	17	0	0.0	551	0.4	1103	3.1	1589	9.4	2207	25.0	2207	62.5		
81.0	18	0	0.0	619	0.4	1238	3.1	1783	9.4	2476	25.0	2476	62.5		

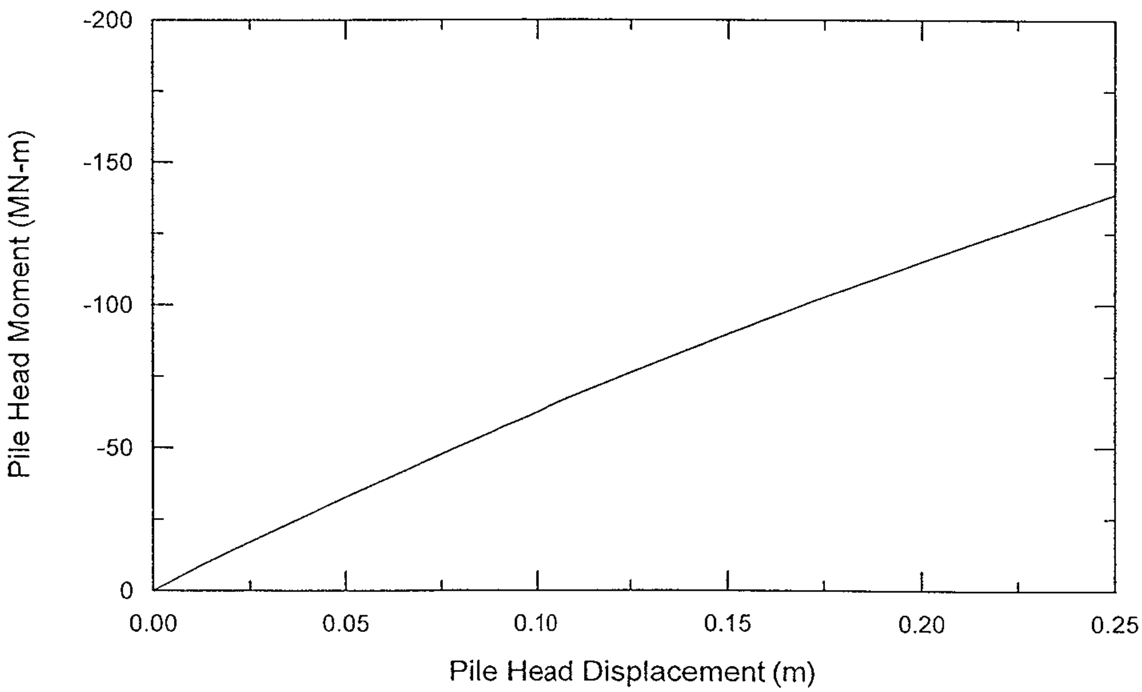
COORDINATES of p-y CURVES
PIER E03 EASTBOUND
SFOBB East Span Seismic Safety Project

PLATE E03-EB.3

Earth Mechanics

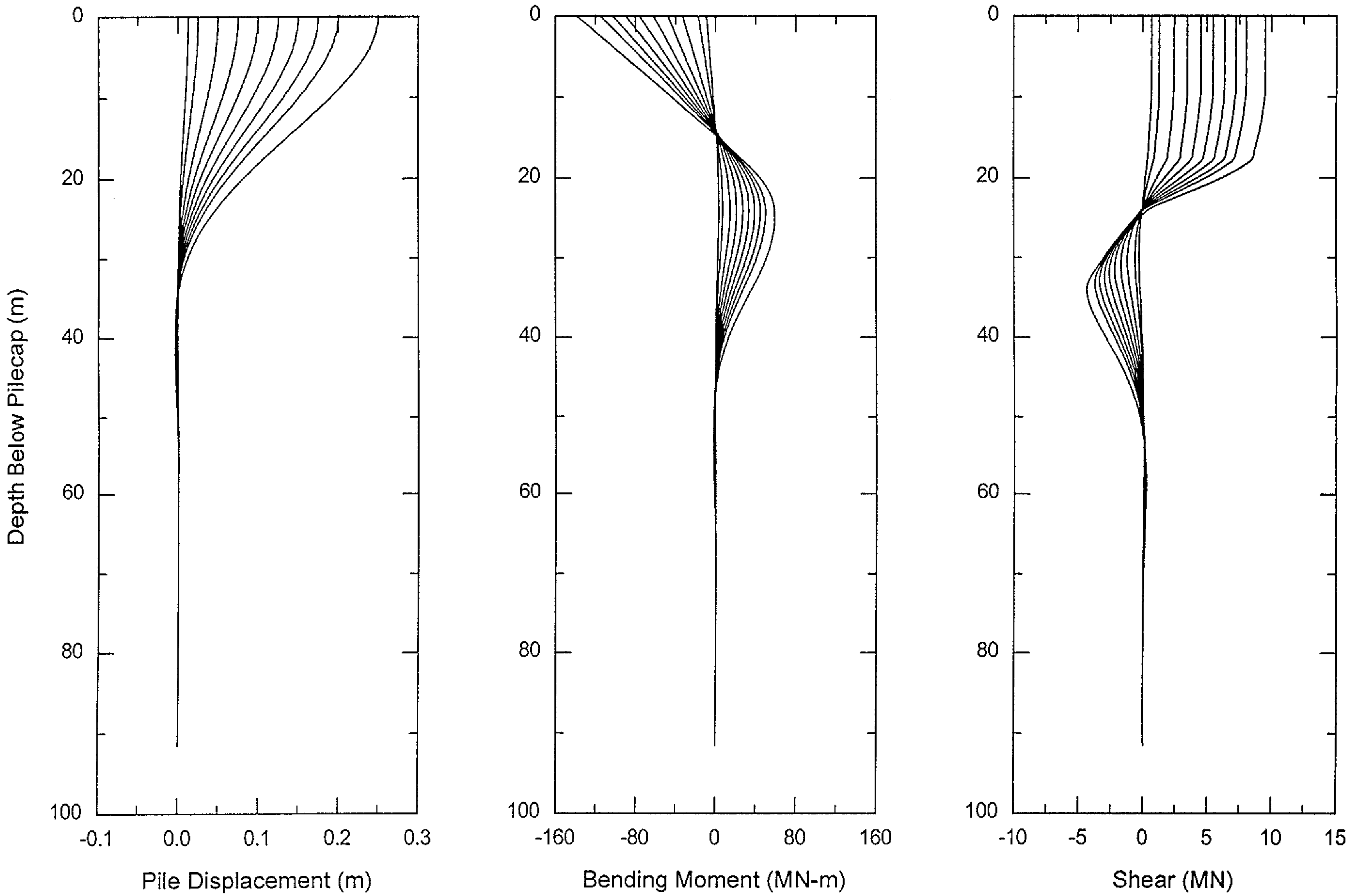
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E03 EASTBOUND
SFOBB East Span Seismic Safety Project

PLATE E03-EB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E03 EASTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5

EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E03-EB.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

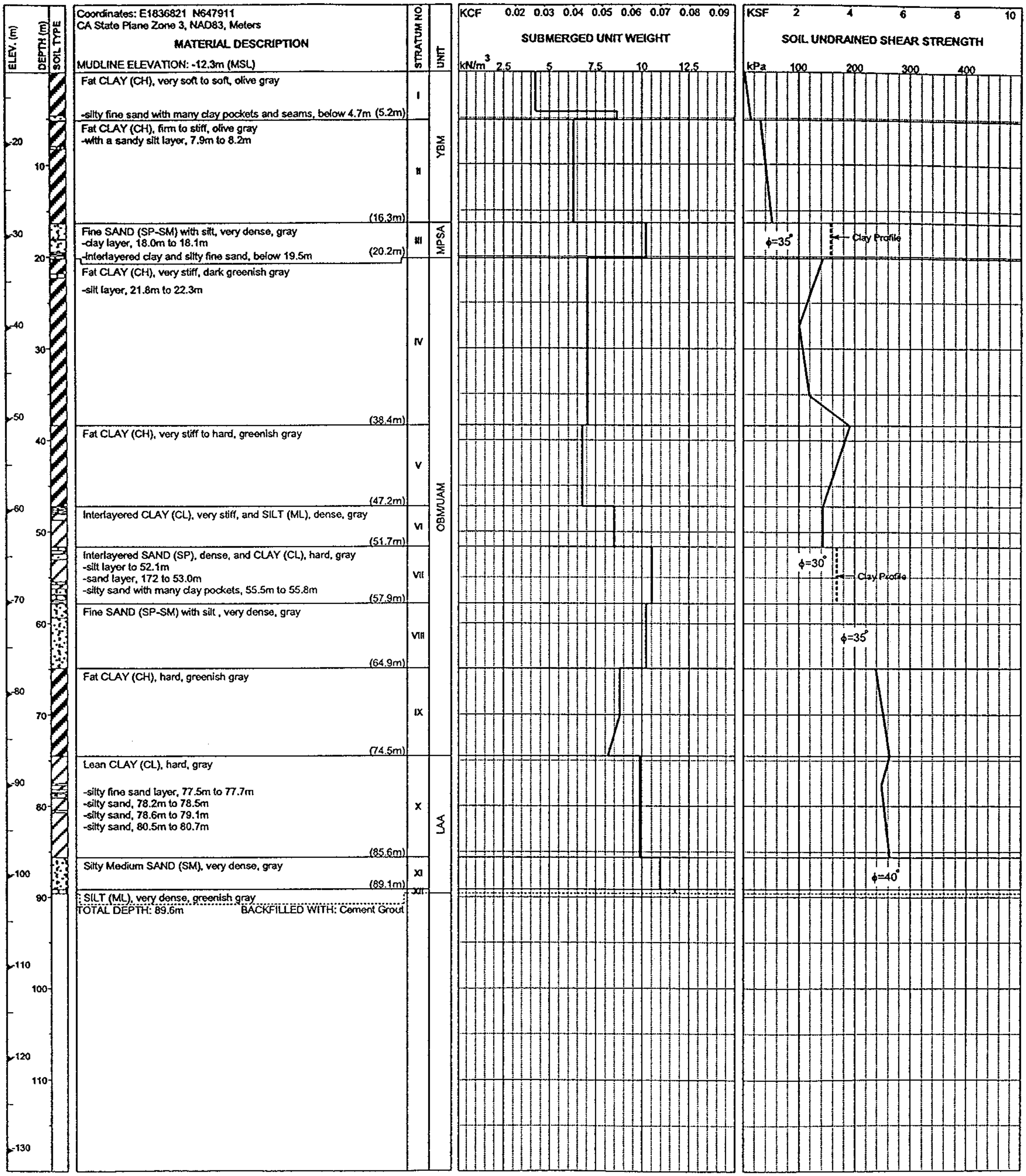
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.848E+005	0.000E+000	0.000E+000	0.000E+000	4.958E+005	0.000E+000
0.000E+000	2.540E+005	0.000E+000	-7.583E+005	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.338E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-7.583E+005	0.000E+000	4.545E+008	0.000E+000	0.000E+000
4.958E+005	0.000E+000	0.000E+000	0.000E+000	3.324E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.552E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.945E+005	0.000E+000	0.000E+000	0.000E+000	-9.267E+005	0.000E+000
0.000E+000	5.445E+005	0.000E+000	4.930E+005	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.186E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	4.930E+005	0.000E+000	7.572E+008	0.000E+000	0.000E+000
-9.267E+005	0.000E+000	0.000E+000	0.000E+000	5.571E+008	0.000E+000
0.000E+000	1.746E-010	0.000E+000	0.000E+000	0.000E+000	3.343E+007

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. +3.0 m

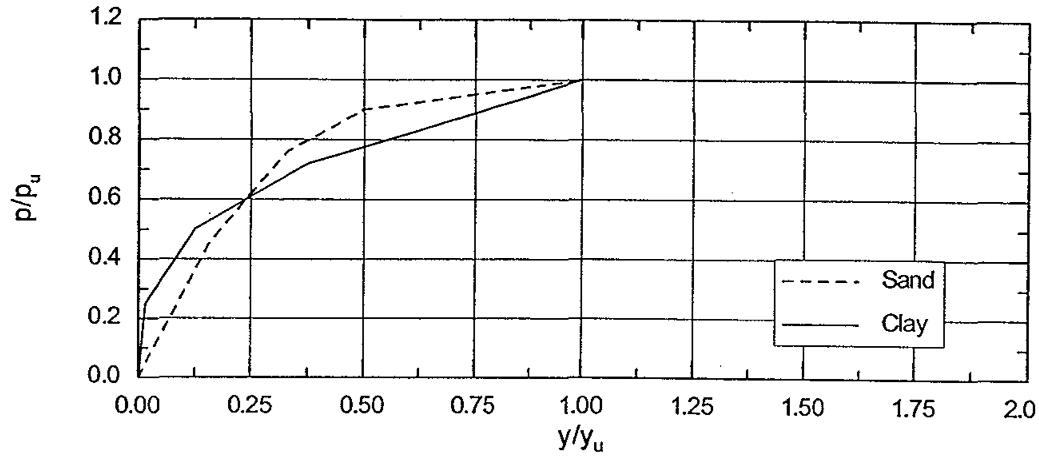
CONDENSED STIFFNESS MATRICES
PIER E03 EASTBOUND
SFOBB East Span Seismic Safety Project



SUBSOIL CONDITION AND SOIL PROPERTIES

PIER E03 WESTBOUND

SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVES

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.01	35		
9-12	Clay	0.01	40		
12-15	Clay	0.01	50		
15-18	Sand			35	5440
18-21	Clay	0.005	140		
21-24	Clay	0.005	130		
24-27	Clay	0.005	110		
27 -30	Clay	0.005	110		
30-33	Clay	0.005	110		
33-36	Clay	0.005	125		
36-39	Clay	0.005	175		
39-42	Clay	0.005	175		
42-45	Clay	0.005	160		
45-51	Clay	0.005	140		
51-57	Sand			30	5440
57-63	Sand			35	5440
63-69	Clay	0.005	250		
69-75	Clay	0.005	275		
75-81	Clay	0.005	250		

p-y DATA

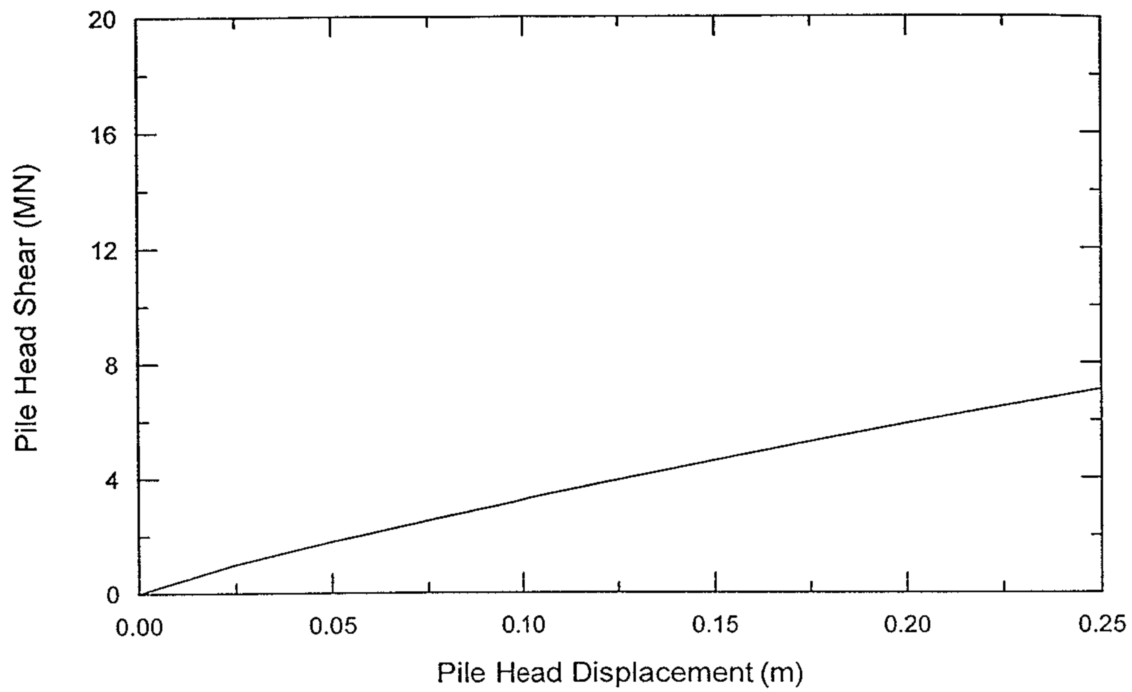
Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	36	100.0	Clay
3.0	101	100.0	Clay
6.0	131	100.0	Clay
9.0	255	50.0	Clay
12.0	336	50.0	Clay
14.9	459	50.0	Clay
15.1	1945	14.3	Sand
17.9	3069	18.9	Sand
18.1	1283	25.0	Clay
21.0	1413	25.0	Clay
24.0	1450	25.0	Clay
30.0	1238	25.0	Clay
36.0	1399	25.0	Clay
42.0	1938	25.0	Clay
50.9	1561	25.0	Clay
51.1	11400	24.7	Sand
62.9	28809	50.6	Sand
63.1	2799	25.0	Clay
81.0	2799	25.0	Clay

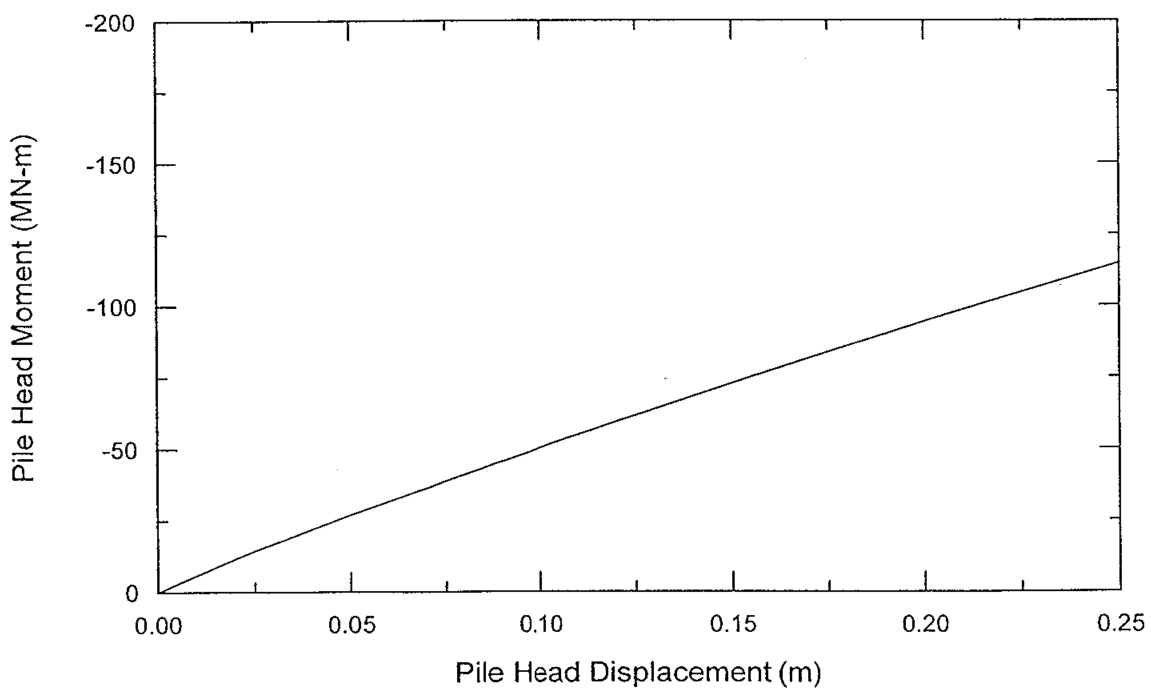
LATERAL PILE DESIGN PARAMETERS
PIER E03 WESTBOUND
SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0.0	9	1.6	18	12.5	25.841	37.5	36	100.0	36	249.9		
3.0	2	0	0.0	25	1.6	50	12.5	73	37.5	101	100.0	101	249.9		
6.0	3	0	0.0	32	1.6	65	12.5	94	37.5	131	100.0	131	249.9		
9.0	4	0	0.0	63	0.8	127	6.2	183	18.7	255	50.0	255	125.0		
12.0	5	0	0.0	84	0.8	168	6.2	242	18.7	336	50.0	336	125.0		
14.9	6	0	0.0	114	0.8	229	6.2	330	18.7	459	50.0	459	125.0		
15.1	7	0	0.0	194	0.5	895	2.4	1478	4.8	1770	7.2	1945	14.3	1945	23.9
17.9	8	0	0.0	306	0.6	1412	3.2	2332	6.3	2793	9.5	3069	18.9	3069	31.5
18.1	9	0	0.0	320	0.4	641	3.1	924	9.4	1283	25.0	1283	62.5		
21.0	10	0	0.0	353	0.4	706	3.1	1018	9.4	1413	25.0	1413	62.5		
24.0	11	0	0.0	362	0.4	725	3.1	1044	9.4	1450	25.0	1450	62.5		
30.0	12	0	0.0	309	0.4	619	3.1	891	9.4	1238	25.0	1238	62.5		
36.0	13	0	0.0	349	0.4	699	3.1	1007	9.4	1399	25.0	1399	62.5		
42.0	14	0	0.0	484	0.4	969	3.1	1395	9.4	1938	25.0	1938	62.5		
50.9	15	0	0.0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
51.1	16	0	0.0	1140	0.8	5244	4.1	8664	8.2	10374	12.4	11400	24.7	11400	41.2
62.9	17	0	0.0	2880	1.7	13252	8.4	21895	16.9	26216	25.3	28809	50.6	28809	84.3
63.1	18	0	0.0	699	0.4	1399	3.1	2015	9.4	2799	25.0	2799	62.5		
81.0	19	0	0.0	699	0.4	1399	3.1	2015	9.4	2799	25.0	2799	62.5		

COORDINATES of p-y CURVES
PIER E03 WESTBOUND
SFOBB East Span Seismic Safety Project

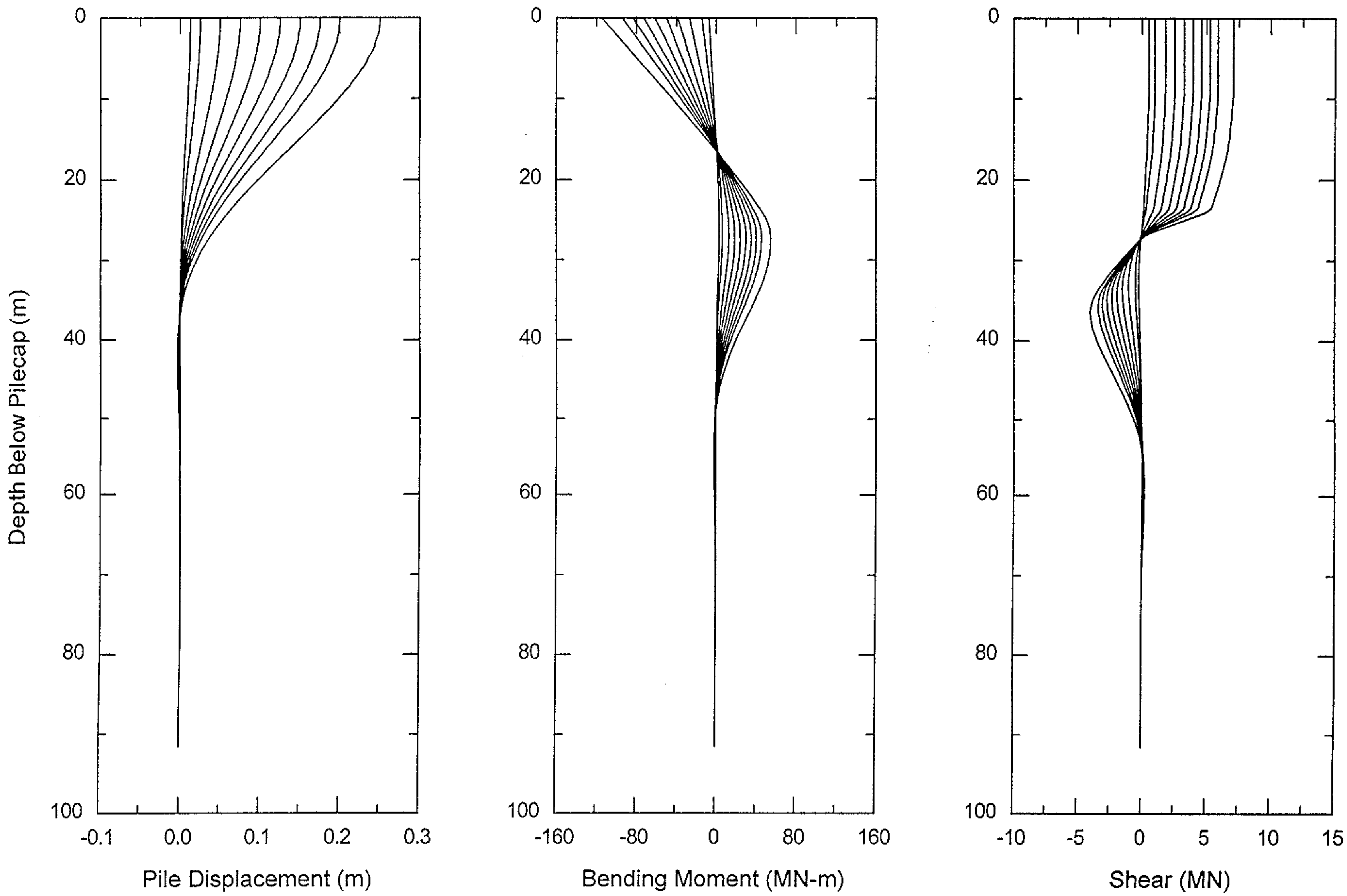
Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E03 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E03-WB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E03 WESTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5

EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E03-WB.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.848E+005	0.000E+000	0.000E+000	0.000E+000	4.958E+005	0.000E+000
0.000E+000	2.540E+005	0.000E+000	-7.583E+005	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.338E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-7.583E+005	0.000E+000	4.545E+008	0.000E+000	0.000E+000
4.958E+005	0.000E+000	0.000E+000	0.000E+000	3.324E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.552E+007

PILE-GROUP STIFFNESS MATRIX (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.056E+005	0.000E+000	0.000E+000	0.000E+000	5.397E+005	0.000E+000
0.000E+000	4.554E+005	0.000E+000	-9.751E+005	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.186E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-9.751E+005	0.000E+000	7.329E+008	0.000E+000	0.000E+000
5.397E+005	0.000E+000	0.000E+000	0.000E+000	5.328E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.730E+007

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. +3.0 m

CONDENSED STIFFNESS MATRICES
PIER E03 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E03-WB.6

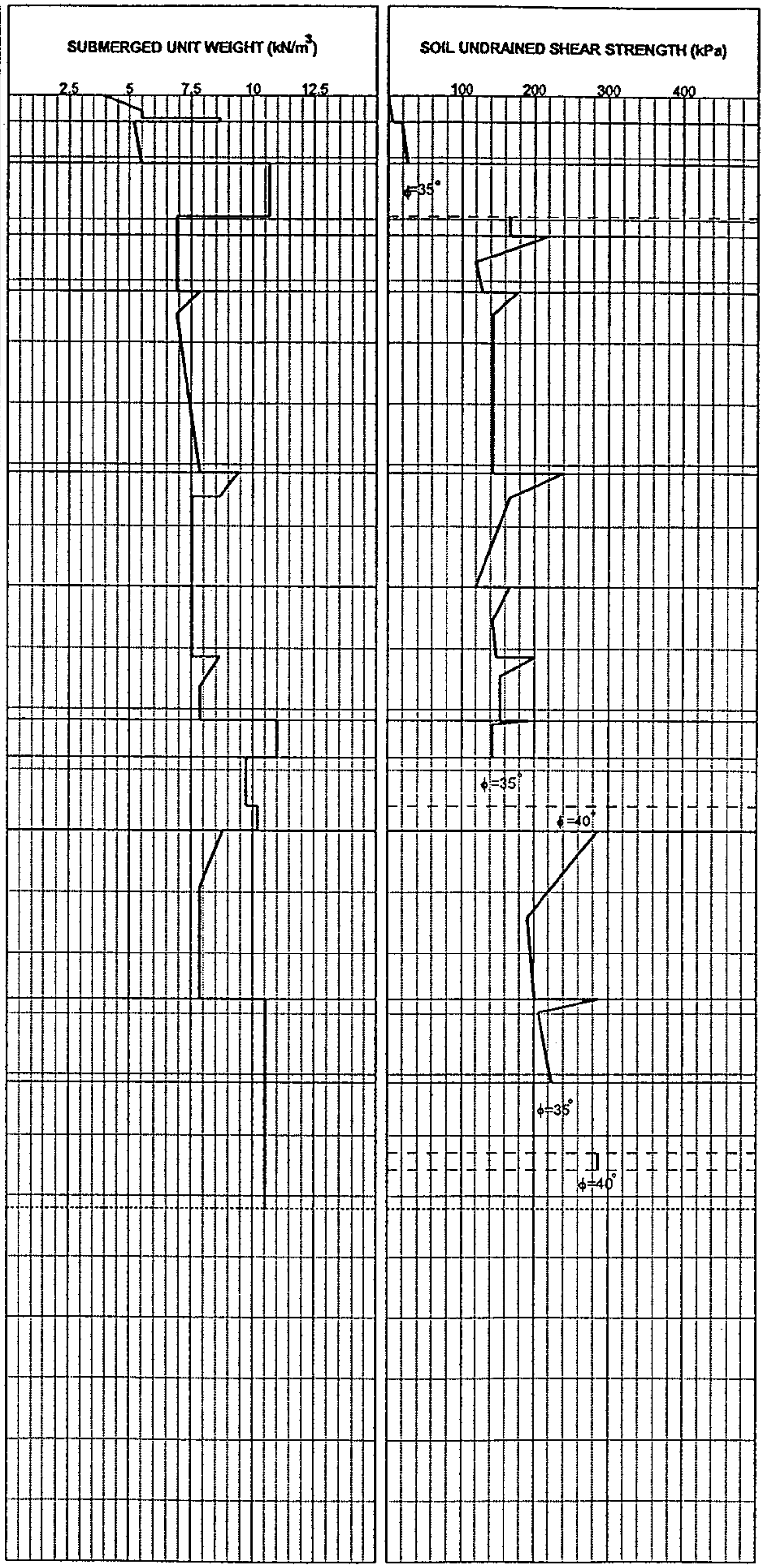
Coordinates: E1836982 N647931
CA State Plane Zone 3, NAD83, Meters

MUDLINE ELEVATION: -12.0m (MSL)

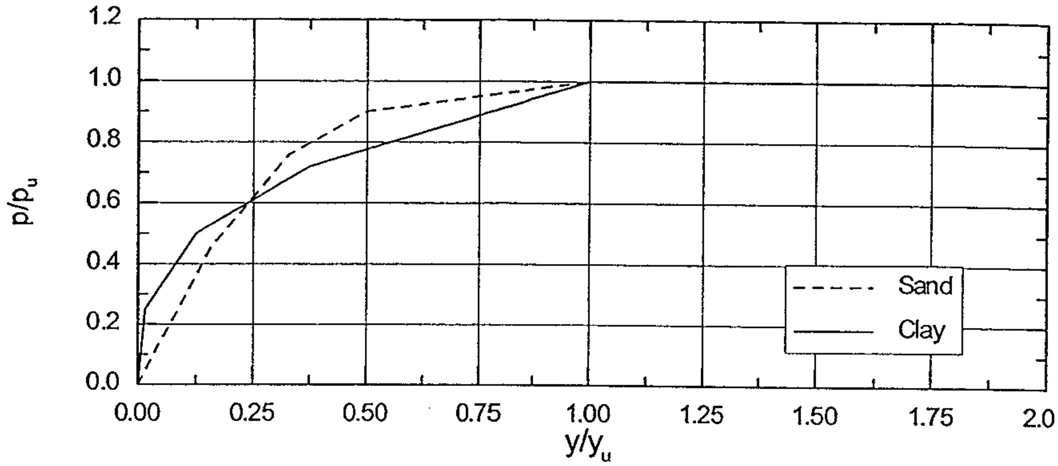
MATERIAL DESCRIPTION	Bottom depth	STRATUM NO.	UNIT
Fat CLAY (CH), very soft, olive gray -silty fine sand with many clay pockets, 1.8m to 2.1m	(2.1m)	I	YBM
Fat CLAY (CH), soft to firm, olive gray	(5.5m)	II	YBM
Silty Fine SAND (SM), very dense, olive gray -with clay layers, at 7.8m and 8.4m -fine sand, 8.8m to 10.5m -silty fine sand with clay seams and layers, below 10.5m	(11.3m)	III	MPSA
Fat CLAY (CH), very stiff, olive gray -lean clay to 12.2m -fine sand layer, 15.2m to 15.5m	(15.8m)	IV	OBM/UAM
Fat CLAY (CH), very stiff, greenish gray -silt layer, 29.3m to 29.6m	(30.6m)	V	OBM/UAM
Fat CLAY (CH), very stiff to hard, greenish gray -silt with fat clay pockets, 31.1m to 32.6m	(39.9m)	VI	OBM/UAM
Fat CLAY (CH), very stiff, greenish gray -interlayered silt, sand, and clay, 44.5m to 46.0m	(50.9m)	VII	OBM/UAM
Sandy Lean CLAY (CL), very stiff to hard, greenish gray	(53.9m)	VIII	OBM/UAM
Silty Fine SAND (SM), dense, dark gray -very dense dark gray fine gravel below 57.9m	(59.9m)	IX	OBM/UAM
Fat CLAY (CH), very stiff to hard, olive gray -silt layer, 67.7m to 68.0m	(73.8m)	X	OBM/UAM
Lean CLAY (CL), hard, greenish gray to gray -dense sand with clay layers, 75.3m to 76.2m -dense fine sand layer, 76.7m to 77.4m -very dense, fine sand layer, 79.4m to 79.9m	(80.6m)	XI	LAA
Fine SAND with silt (SP-SM), very dense, gray -hard, olive gray, lean clay layer, 86.4m to 87.8m -very dense, greenish gray, sandy silt with gravel fragments, below 90.8m		XII	LAA

TOTAL DEPTH: 91.0m BACKFILLED WITH: Cement Grout

ELEV. (m): -20, -30, -40, -50, -60, -70, -80, -90, -100, -110, -120, -130
DEPTH (m): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110



SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E04 EASTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	8		
3-6	Clay	0.02	20		
6-9	Sand			35	16300
9-12	Sand			35	5440
12-15	Clay	0.005	140		
15-18	Clay	0.005	160		
18-21	Clay	0.005	140		
21-24	Clay	0.005	140		
24-27	Clay	0.005	140		
27 -30	Clay	0.005	140		
30-33	Clay	0.005	200		
33-36	Clay	0.005	150		
36-39	Clay	0.005	130		
39-42	Clay	0.005	150		
42-45	Clay	0.005	150		
45-51	Clay	0.005	150		
51-57	Sand			37	5440
57-63	Clay	0.005	240		
63-69	Clay	0.005	200		
69-75	Clay	0.005	200		
75-81	Clay	0.005	200		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	31	100.0	Clay
3.0	107	100.0	Clay
5.9	144	100.0	Clay
6.1	456	2.8	Sand
9.0	806	3.3	Sand
11.9	1598	14.9	Sand
12.1	1042	25.0	Clay
15.0	1169	25.0	Clay
18.0	1457	25.0	Clay
21.0	1431	25.0	Clay
24.0	1561	25.0	Clay
30.0	1561	25.0	Clay
36.0	1679	25.0	Clay
42.0	1679	25.0	Clay
50.9	1679	25.0	Clay
51.1	31484	68.1	Sand
63.0	2686	25.0	Clay
81.0	2234	25.0	Clay

LATERAL PILE DESIGN PARAMETERS

PIER E04 EASTBOUND

SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	8	1.6	15	12.5	21.965	37.5	31	100.0	31	249.9		
3.0	2	0	0	26	1.6	53	12.5	77	37.5	107	100.0	107	249.9		
5.9	3	0	0	36	1.6	72	12.5	104	37.5	144	100.0	144	249.9		
6.1	4	0	0	45	0.1	210	0.5	346	0.9	415	1.4	456	2.8	456	4.6
9.0	5	0	0	80	0.1	371	0.6	613	1.1	734	1.7	806	3.3	806	5.5
11.9	6	0	0	159	0.5	735	2.5	1215	5.0	1454	7.4	1598	14.9	1598	24.8
12.1	7	0	0	260	0.4	521	3.1	750	9.4	1042	25.0	1042	62.5		
15.0	8	0	0	292	0.4	584	3.1	842	9.4	1169	25.0	1169	62.5		
18.0	9	0	0	364	0.4	728	3.1	1049	9.4	1457	25.0	1457	62.5		
21.0	10	0	0	357	0.4	715	3.1	1030	9.4	1431	25.0	1431	62.5		
24.0	11	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
30.0	12	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
36.0	13	0	0	419	0.4	839	3.1	1209	9.4	1679	25.0	1679	62.5		
42.0	14	0	0	419	0.4	839	3.1	1209	9.4	1679	25.0	1679	62.5		
50.9	15	0	0	419	0.4	839	3.1	1209	9.4	1679	25.0	1679	62.5		
51.1	16	0	0	3148	2.3	14483	11.4	23928	22.7	28651	34.1	31484	68.1	31484	113.6
63.0	17	0	0	671	0.4	1343	3.1	1934	9.4	2686	25.0	2686	62.5		
81.0	18	0	0	558	0.4	1117	3.1	1608	9.4	2234	25.0	2234	62.5		

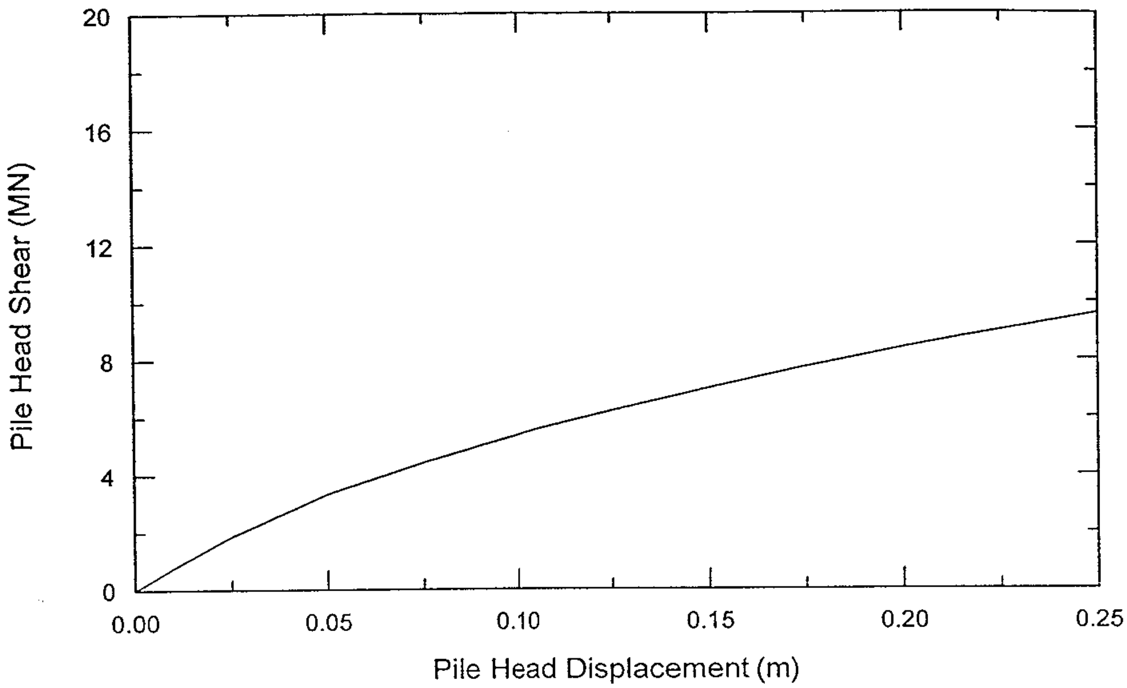
COORDINATES of p-y CURVES

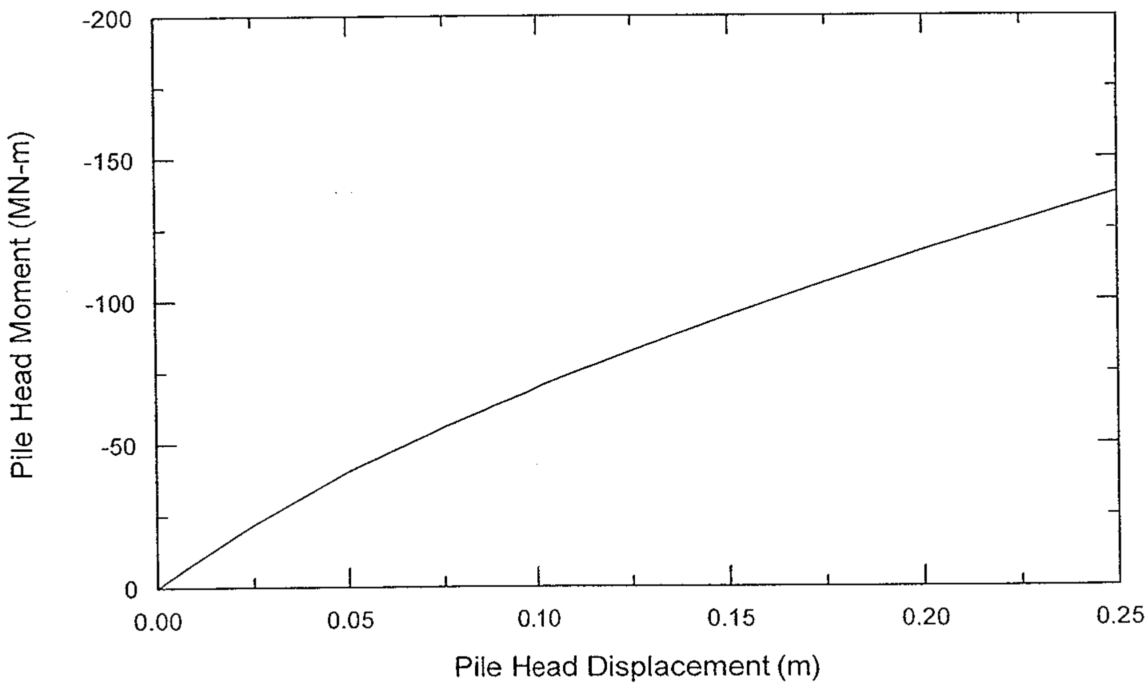
PIER E04 EASTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

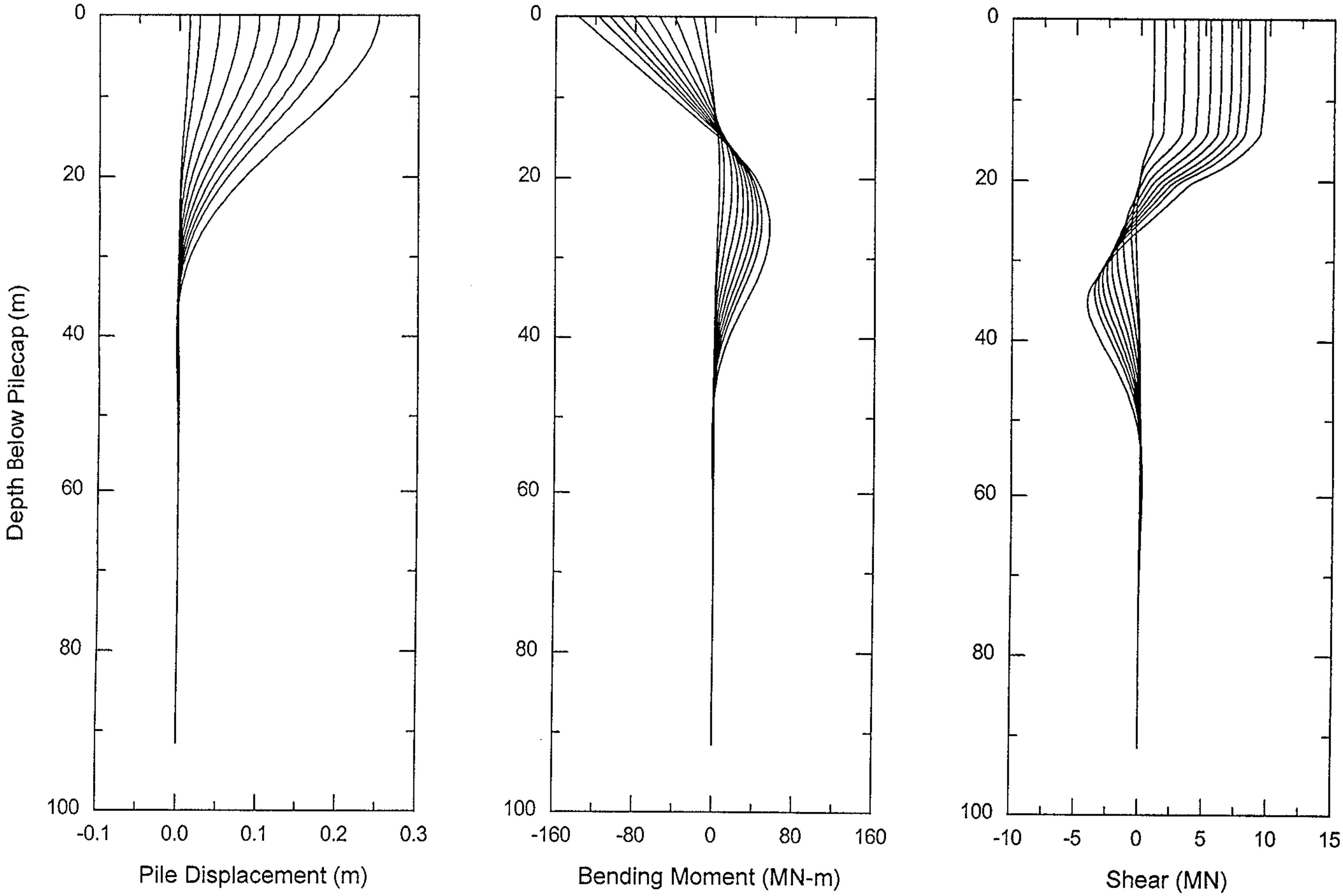
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E04 EASTBOUND
SFOBB East Span Seismic Safety Project

PLATE E04-EB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E04 EASTBOUND

SFOBB East Span Seismic Safety Project

PLATE E04-EB.5

SFOBB Task Order No. 5

EMI Project No. 98-145

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.596E+005	0.000E+000	0.000E+000	0.000E+000	-2.746E+005	0.000E+000
0.000E+000	3.266E+005	0.000E+000	-5.870E+003	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.435E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-5.870E+003	0.000E+000	4.977E+008	0.000E+000	0.000E+000
-2.746E+005	0.000E+000	0.000E+000	0.000E+000	3.667E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.019E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.240E+005	0.000E+000	0.000E+000	0.000E+000	-4.336E+006	0.000E+000
0.000E+000	7.746E+005	0.000E+000	3.907E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.186E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	3.907E+006	0.000E+000	8.081E+008	0.000E+000	0.000E+000
-4.336E+006	0.000E+000	0.000E+000	0.000E+000	6.079E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	4.857E+007

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. +3.0 m

CONDENSED STIFFNESS MATRICES
PIER E04 EASTBOUND
SFOBB East Span Seismic Safety Project

Earth Mechanics FUGRO

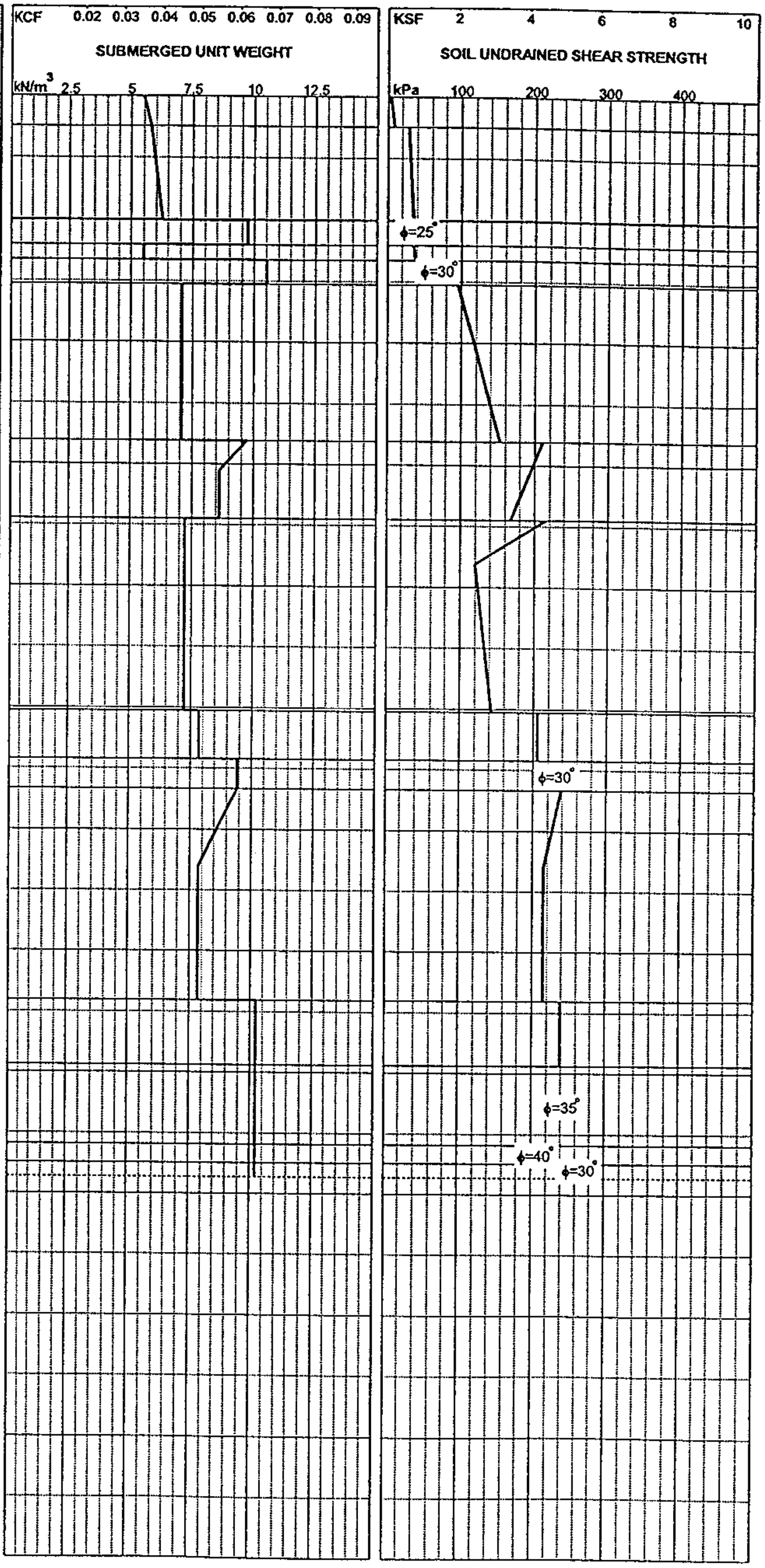
Coordinates: E1836969 N647970
CA State Plane Zone 3, NAD83, Meters

MUDLINE ELEVATION: -11.4m (MSL)

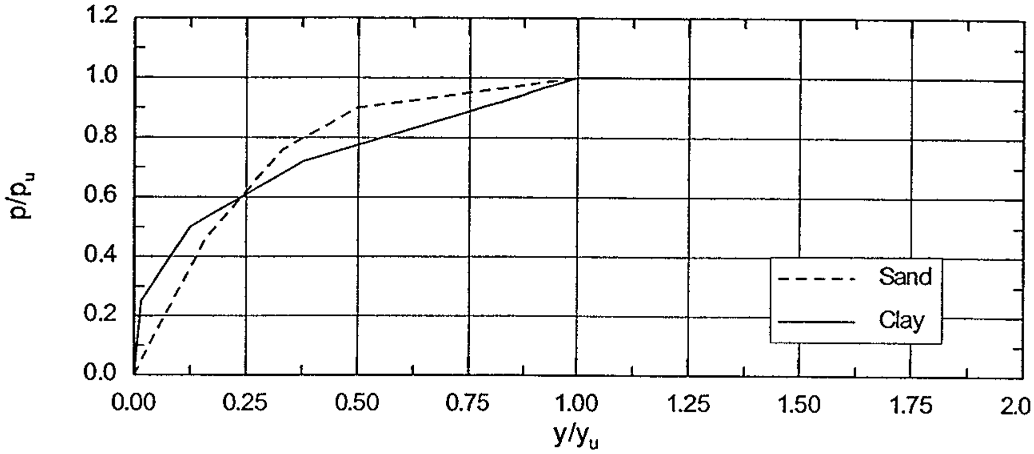
MATERIAL DESCRIPTION	Bottom depth	STRATUM NO	UNIT
Fat CLAY (CH), very soft, olive gray	(2.4m)	I	YBM
Fat CLAY (CH), firm, olive gray	(10.1m)	II	YBM
Silty Fine SAND (SM), dense, gray -intermixed clay and sand, at 11.3m	(12.0m)	III	YBM
Fat CLAY (CH), firm, olive gray	(13.3m)	IV	YBM
-with a silty sand layer, below 13.1m		V	YBM
Silty Fine SAND (SP), dense, greenish gray	(15.2m)		YBM
Fat CLAY (CH), very stiff, gray	(28.0m)	VI	OBM/UAM
Fat CLAY (CH), very stiff to hard, greenish gray	(34.4m)	VII	OBM/UAM
Fat CLAY (CH), very stiff to hard, gray -lean clay, 36.6m to 37.8m -intermixed fine sand and clay, 43.6m to 46.6m -silty sand, below 49.8m	(50.3m)	VIII	OBM/UAM
Fat CLAY (CH), hard, gray -silt with clay seams, 52.7m to 53.6m	(54.3m)	IX	OBM/UAM
Silty Fine SAND (SM), very dense, gray	(56.7m)	X	OBM/UAM
Fat CLAY (CH), hard, gray -with a sand layer, 65.1m to 65.4m	(74.1m)	XI	OBM/UAM
Lean CLAY (CL), hard, greenish gray to gray -sand layer, 76.2m to 77.4m -intermixed silt and clay layer, 78.6m to 78.9m -sand layer, 78.9m to 79.2m	(79.4m)	XII	LAA
Silty Fine SAND (SM), very dense, greenish gray to gray	(86.0m)	XIII	LAA
Fine GRAVEL with sand (GP), very dense, black to gray	(87.5m)	XIV	LAA
Sandy SILT (ML), very dense, greenish gray to gray		XV	LAA

TOTAL DEPTH: 88.6m BACKFILLED WITH: Cement Grout

ELEV. (m): -20, -30, -40, -50, -60, -70, -80, -90, -100, -110, -120, -130
DEPTH (m): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110
SOIL TYPE



SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E04 WESTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.01	30		
6-9	Sand	-		30	16300
9-12	Clay	0.075	40		
12-15	Clay	0.075	50		
15-18	Clay	0.005	100		
18-21	Clay	0.005	110		
21-24	Clay	0.005	130		
24-27	Clay	0.005	145		
27 -30	Clay	0.005	190		
30-33	Clay	0.005	180		
33-36	Clay	0.005	180		
36-39	Clay	0.005	140		
39-42	Clay	0.005	130		
42-45	Clay	0.005	130		
45-51	Clay	0.005	140		
51-57	Clay	0.005	200		
57-63	Clay	0.005	230		
63-69	Clay	0.005	220		
69-75	Clay	0.005	220		
75-81	Sand			35	5440

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	36	100.0	Clay
3.0	155	50.0	Clay
5.9	199	50.0	Clay
6.1	337	3.4	Sand
8.9	681	4.7	Sand
9.1	259	37.5	Clay
12.0	286	37.5	Clay
15.1	889	25.0	Clay
18.0	988	25.0	Clay
21.0	1176	25.0	Clay
24.0	1453	25.0	Clay
30.0	2126	25.0	Clay
36.0	2018	25.0	Clay
42.0	1453	25.0	Clay
51.0	1561	25.0	Clay
63.0	2573	25.0	Clay
74.9	2460	25.0	Clay
75.1	34296	50.5	Sand
81.0	37854	51.7	Sand

LATERAL PILE DESIGN PARAMETERS

PIER E04 WESTBOUND

SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	18	12.5	25.841	37.5	36	100.0	36	249.9		
3.0	3	0	0	38	0.8	77	6.2	111	18.7	155	50.0	155	125.0		
5.9	4	0	0	49	0.8	99	6.2	143	18.7	199	50.0	199	125.0		
6.1	5	0	0	33	0.1	155	0.3	256	0.7	307	1.0	337	2.1	337	3.4
8.9	6	0	0	68	0.1	313	0.5	518	0.9	620	1.4	681	2.8	681	4.7
9.1	7	0	0	64	0.6	129	4.7	186	14.1	259	37.5	259	93.7		
12.0	8	0	0	71	0.6	143	4.7	205	14.1	286	37.5	286	93.7		
15.1	10	0	0	222	0.4	444	3.1	640	9.4	889	25.0	889	62.5		
18.0	11	0	0	247	0.4	494	3.1	711	9.4	988	25.0	988	62.5		
21.0	12	0	0	294	0.4	588	3.1	847	9.4	1176	25.0	1176	62.5		
24.0	13	0	0	363	0.4	726	3.1	1046	9.4	1453	25.0	1453	62.5		
30.0	14	0	0	531	0.4	1063	3.1	1531	9.4	2126	25.0	2126	62.5		
36.0	15	0	0	504	0.4	1009	3.1	1453	9.4	2018	25.0	2018	62.5		
42.0	16	0	0	363	0.4	726	3.1	1046	9.4	1453	25.0	1453	62.5		
51.0	17	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
63.0	18	0	0	643	0.4	1286	3.1	1852	9.4	2573	25.0	2573	62.5		
74.9	19	0	0	615	0.4	1230	3.1	1771	9.4	2460	25.0	2460	62.5		
75.1	20	0	0	3429	1.7	15776	8.4	26065	16.8	31209	25.3	34296	50.5	34296	84.2
81.0	21	0	0	3785	1.7	17412	8.6	28769	17.2	34447	25.8	37854	51.7	37854	86.2

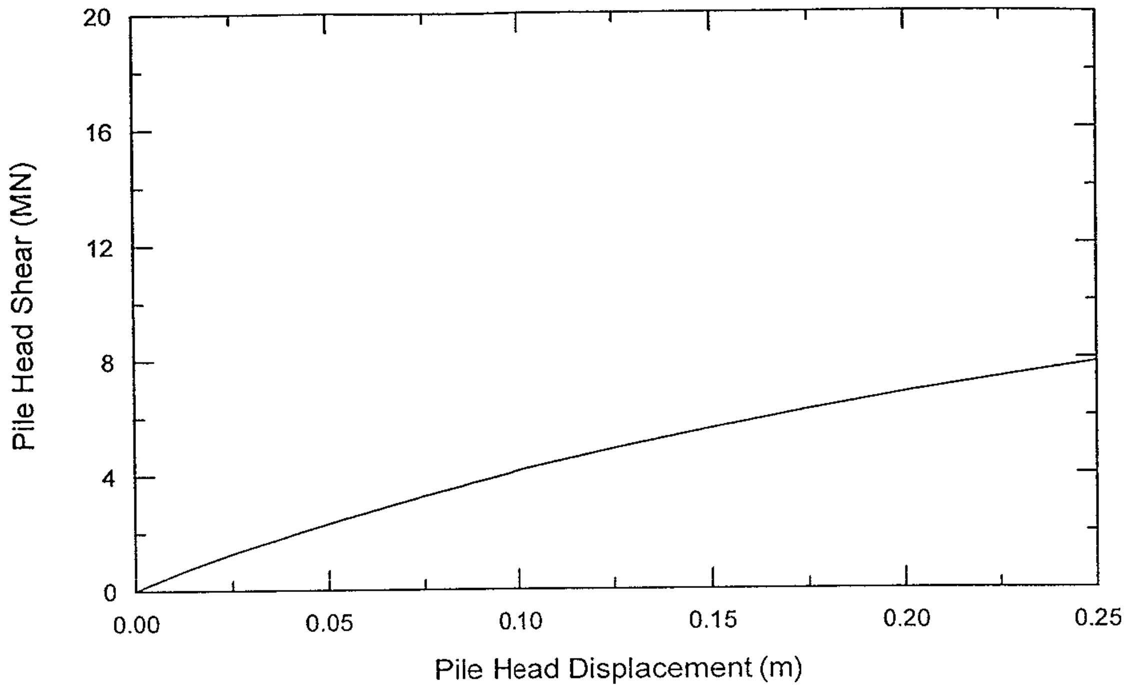
COORDINATES of p-y CURVES

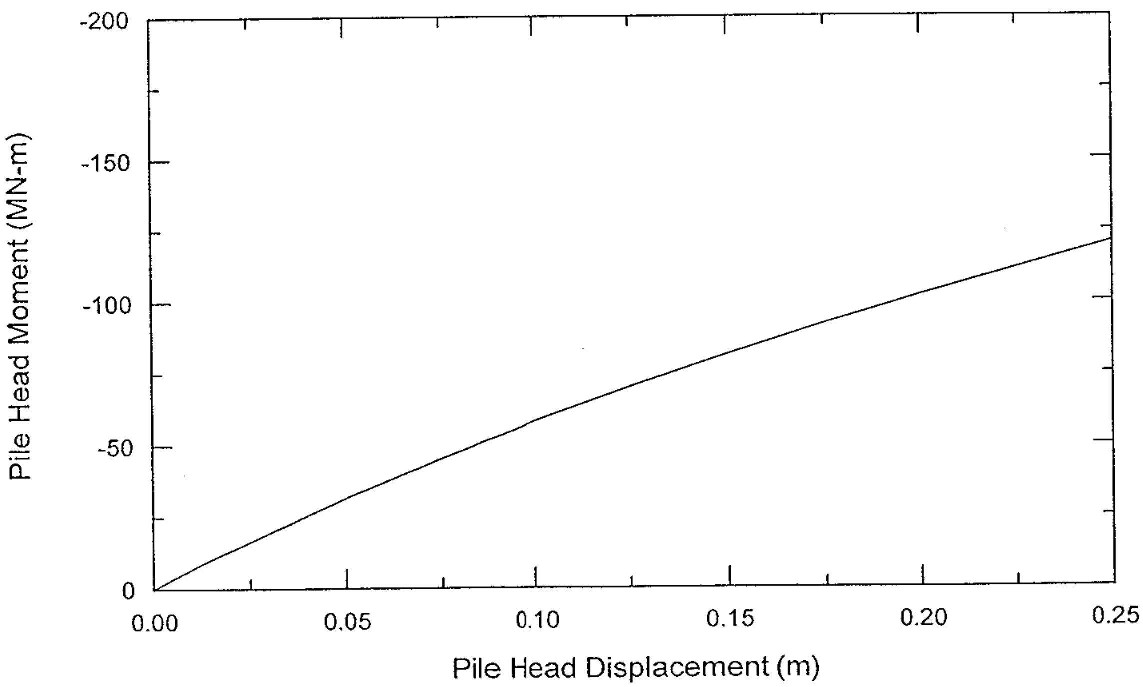
PIER E04 WESTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

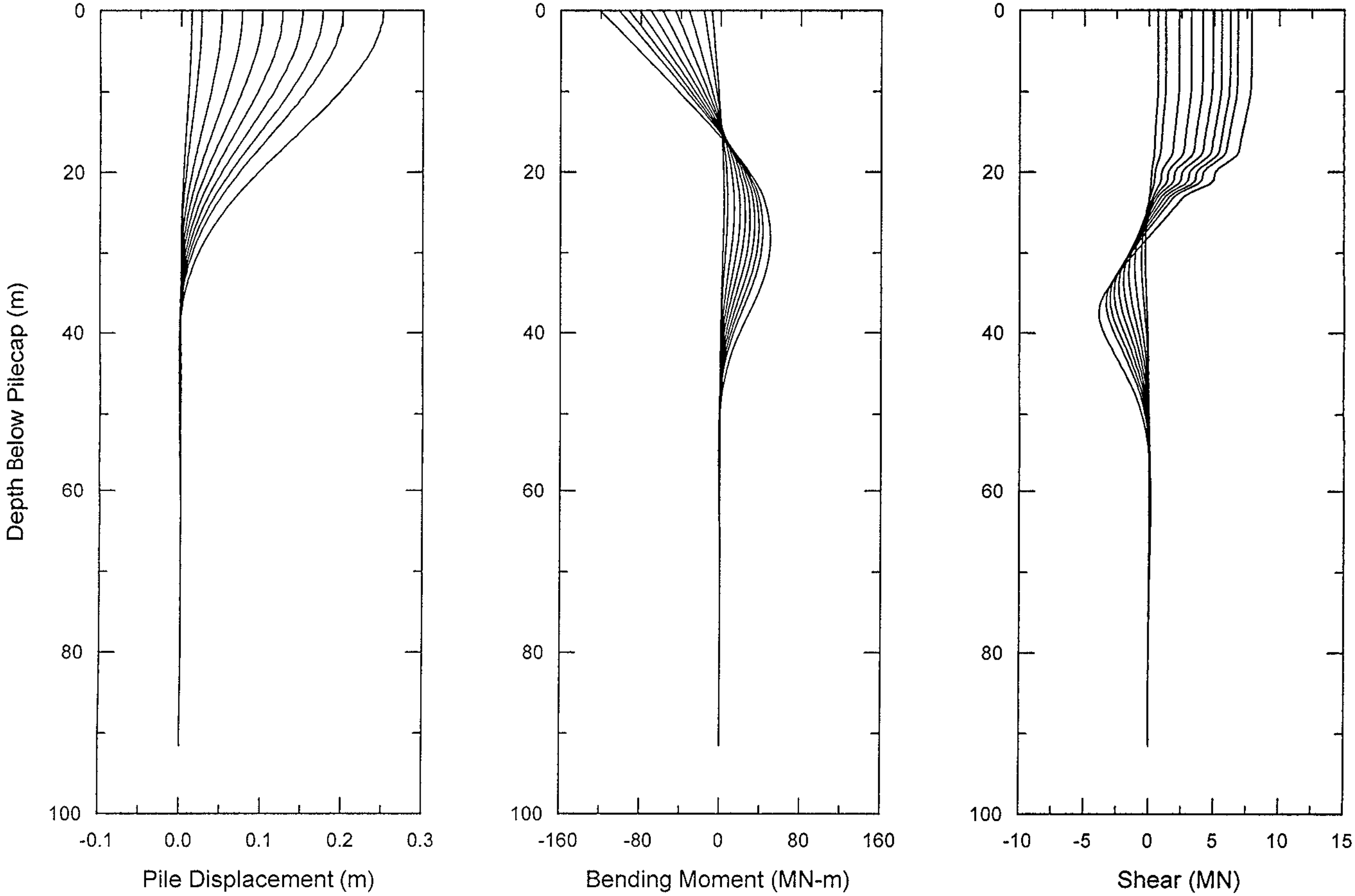
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E04 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E04-WB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E04 WESTBOUND

SFOBB East Span Seismic Safety Project

PLATE E04-WB.5

SFOBB Task Order No. 5
EMI Project No. 98-145

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

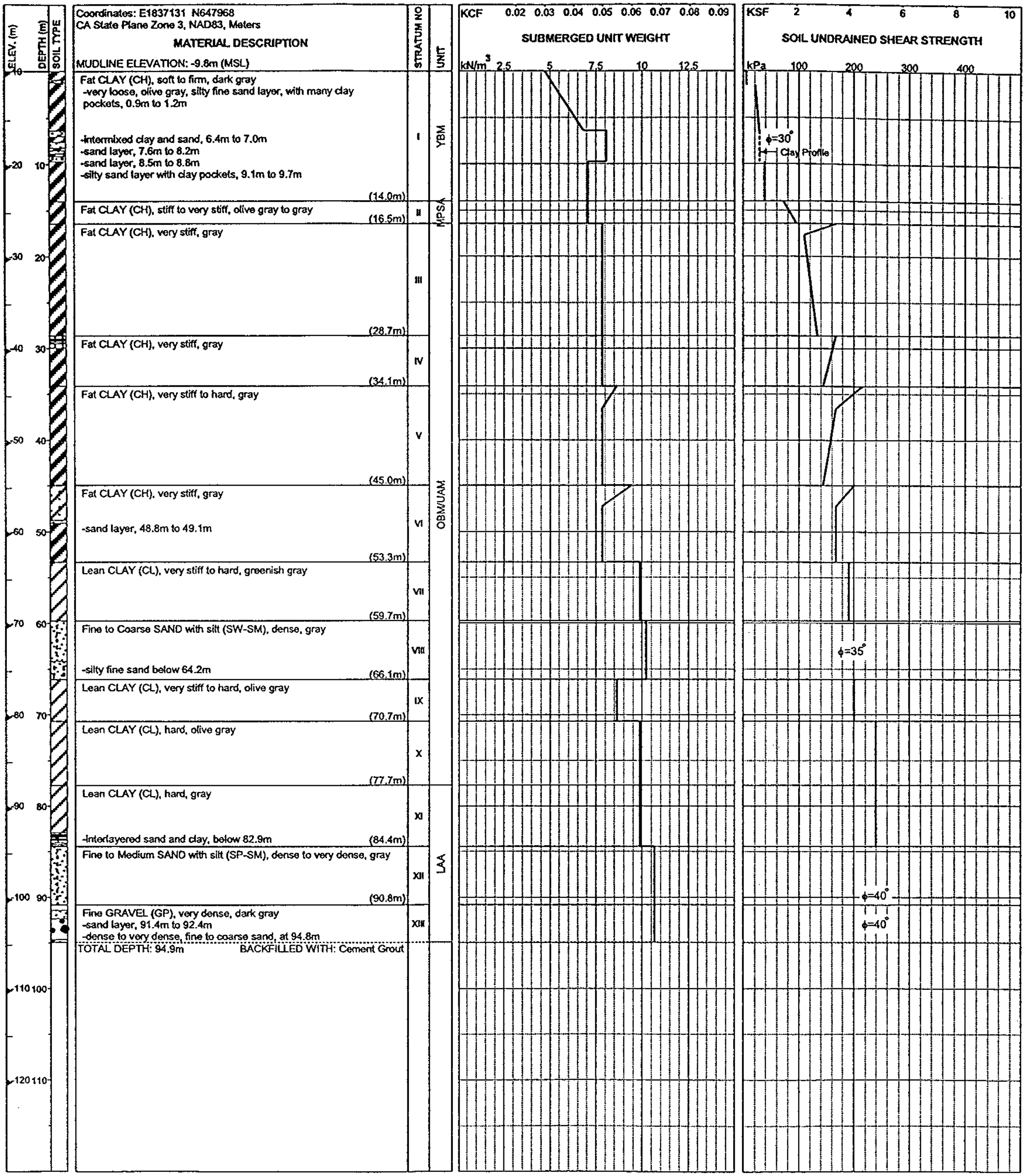
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.596E+005	0.000E+000	0.000E+000	0.000E+000	-2.746E+005	0.000E+000
0.000E+000	3.266E+005	0.000E+000	-5.870E+003	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.435E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-5.870E+003	0.000E+000	4.977E+008	0.000E+000	0.000E+000
-2.746E+005	0.000E+000	0.000E+000	0.000E+000	3.667E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.019E+007

PILE-GROUP STIFFNESS MATRIX (SERVICE CONDITION)

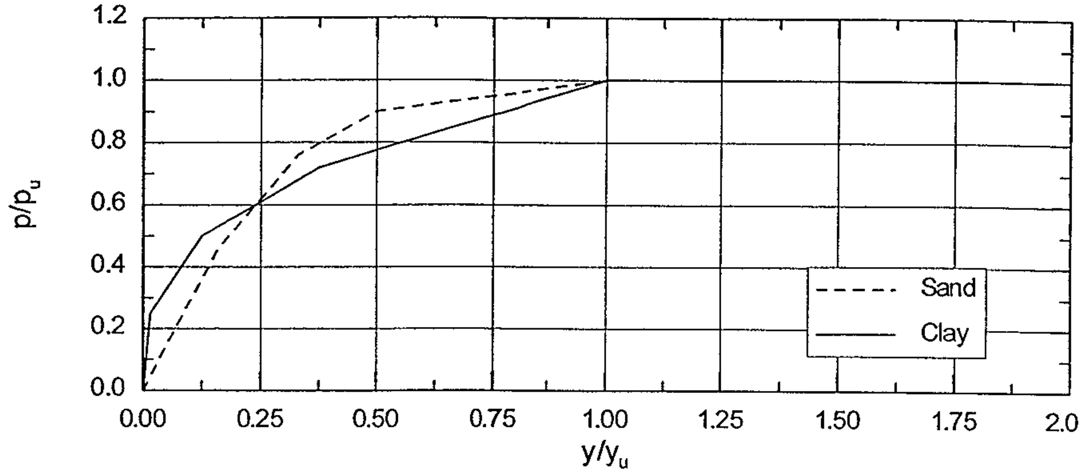
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.774E+005	0.000E+000	0.000E+000	0.000E+000	-4.974E+006	0.000E+000
0.000E+000	8.281E+005	0.000E+000	4.546E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.186E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	4.546E+006	0.000E+000	8.151E+008	0.000E+000	0.000E+000
-4.974E+006	0.000E+000	0.000E+000	0.000E+000	6.150E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	1.863E-009	0.000E+000	5.182E+007

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. +3.0 m

CONDENSED STIFFNESS MATRICES
PIER E04 WESTBOUND
SFOBB East Span Seismic Safety Project



SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E05 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.02	22		
6-9	Clay	0.01	30		
9-12	Clay	0.01	40		
12-15	Clay	0.007	60		
15-18	Clay	0.005	120		
18-21	Clay	0.005	118		
21-24	Clay	0.005	120		
24-27	Clay	0.005	125		
27 -30	Clay	0.005	150		
30-33	Clay	0.005	157		
33-36	Clay	0.005	165		
36-39	Clay	0.005	170		
39-42	Clay	0.005	158		
42-45	Clay	0.005	180		
45-51	Clay	0.005	180		
51-57	Clay	0.005	180		
57-63	Sand			35	5440
63-69	Clay	0.005	200		
69-75	Clay	0.005	240		
75-81	Clay	0.005	240		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	36	100.0	Clay
3.0	117	100.0	Clay
6.0	157	100.0	Clay
9.0	250	50.0	Clay
12.0	502	37.5	Clay
15.0	572	37.5	Clay
18.0	1140	25.0	Clay
21.0	1239	25.0	Clay
24.0	1345	25.0	Clay
30.0	1679	25.0	Clay
36.0	1846	25.0	Clay
42.0	1765	25.0	Clay
51.0	2018	25.0	Clay
62.9	31033	54.6	Sand
63.1	2239	25.0	Clay
81.0	2691	25.0	Clay

LATERAL PILE DESIGN PARAMETERS
PIER E05 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

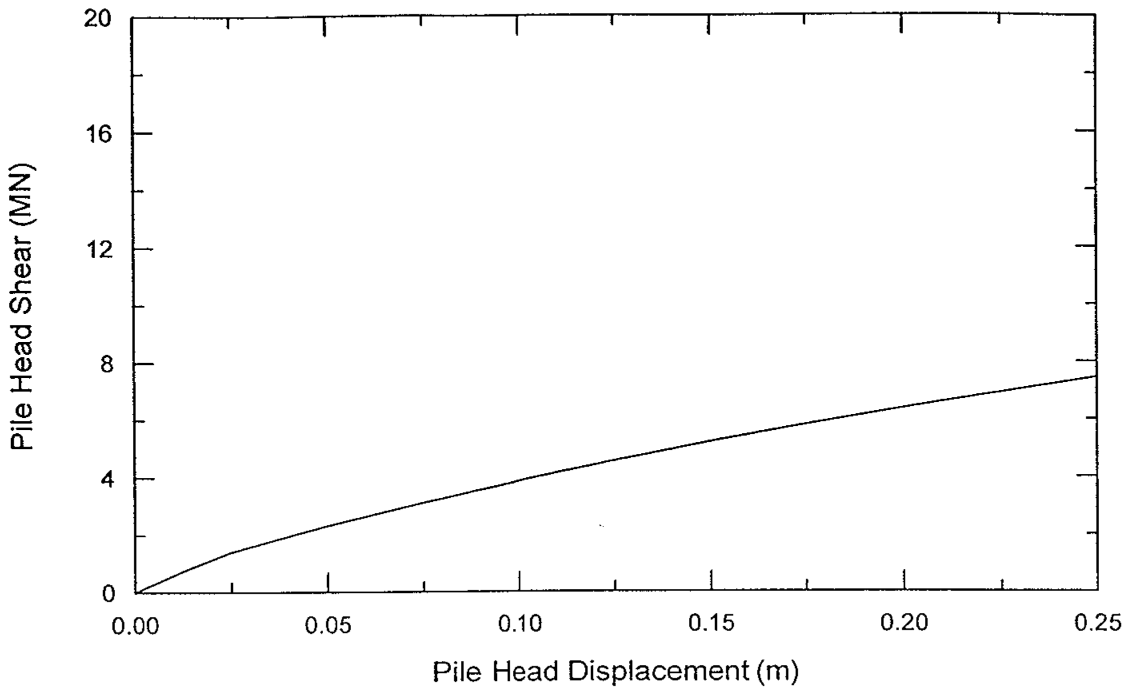
Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	18	12.5	25.841	37.5	36	100.0	36	249.9		
3.0	2	0	0	29	1.6	58	12.5	84	37.5	117	100.0	117	249.9		
6.0	3	0	0	39	1.6	78	12.5	113	37.5	157	100.0	157	249.9		
9.0	4	0	0	62	0.8	125	6.2	180	18.7	250	50.0	250	125.0		
12.0	5	0	0	125	0.6	251	4.7	361	14.1	502	37.5	502	93.7		
15.0	6	0	0	143	0.6	286	4.7	412	14.1	572	37.5	572	93.7		
18.0	7	0	0	285	0.4	570	3.1	821	9.4	1140	25.0	1140	62.5		
21.0	8	0	0	309	0.4	619	3.1	892	9.4	1239	25.0	1239	62.5		
24.0	9	0	0	336	0.4	672	3.1	969	9.4	1345	25.0	1345	62.5		
30.0	10	0	0	419	0.4	839	3.1	1209	9.4	1679	25.0	1679	62.5		
36.0	11	0	0	461	0.4	923	3.1	1329	9.4	1846	25.0	1846	62.5		
42.0	12	0	0	441	0.4	882	3.1	1271	9.4	1765	25.0	1765	62.5		
51.1	13	0	0	504	0.4	1009	3.1	1453	9.4	2018	25.0	2018	62.5		
62.9	14	0	0	3103	1.8	14275	9.1	23585	18.2	28240	27.3	31033	54.6	31033	90.9
63.1	15	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		
81.0	16	0	0	672	0.4	1345	3.1	1938	9.4	2691	25.0	2691	62.5		

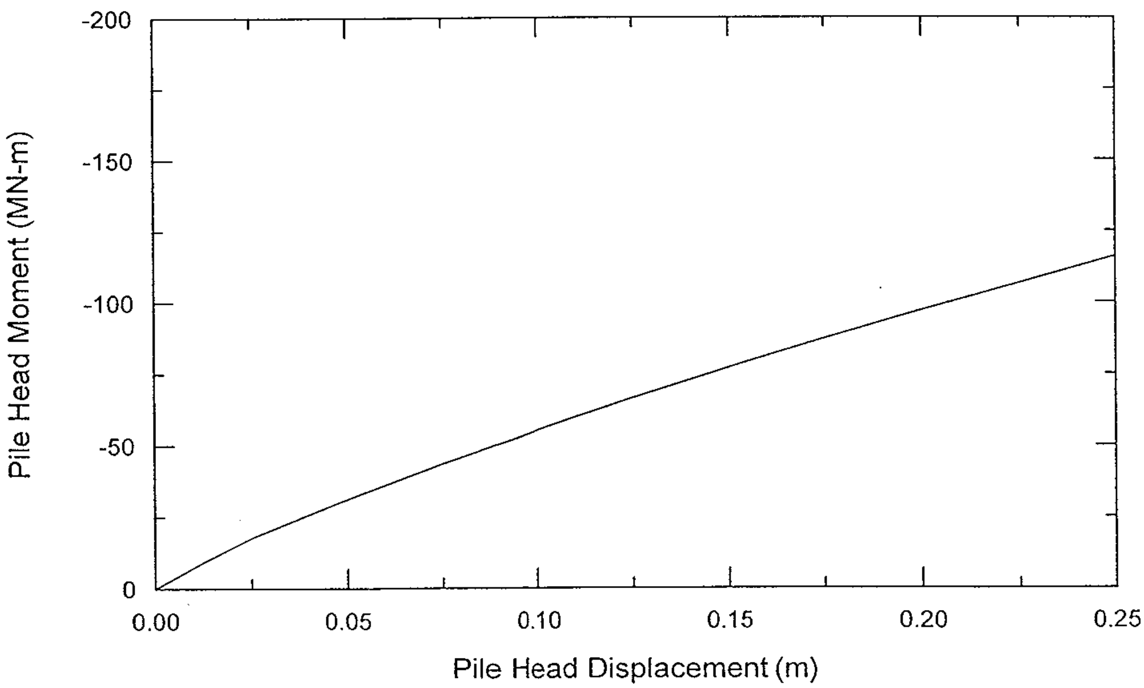
COORDINATES of p-y CURVES
PIER E05 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5
EMI Project No. 98-145

Earth Mechanics
FUGRO

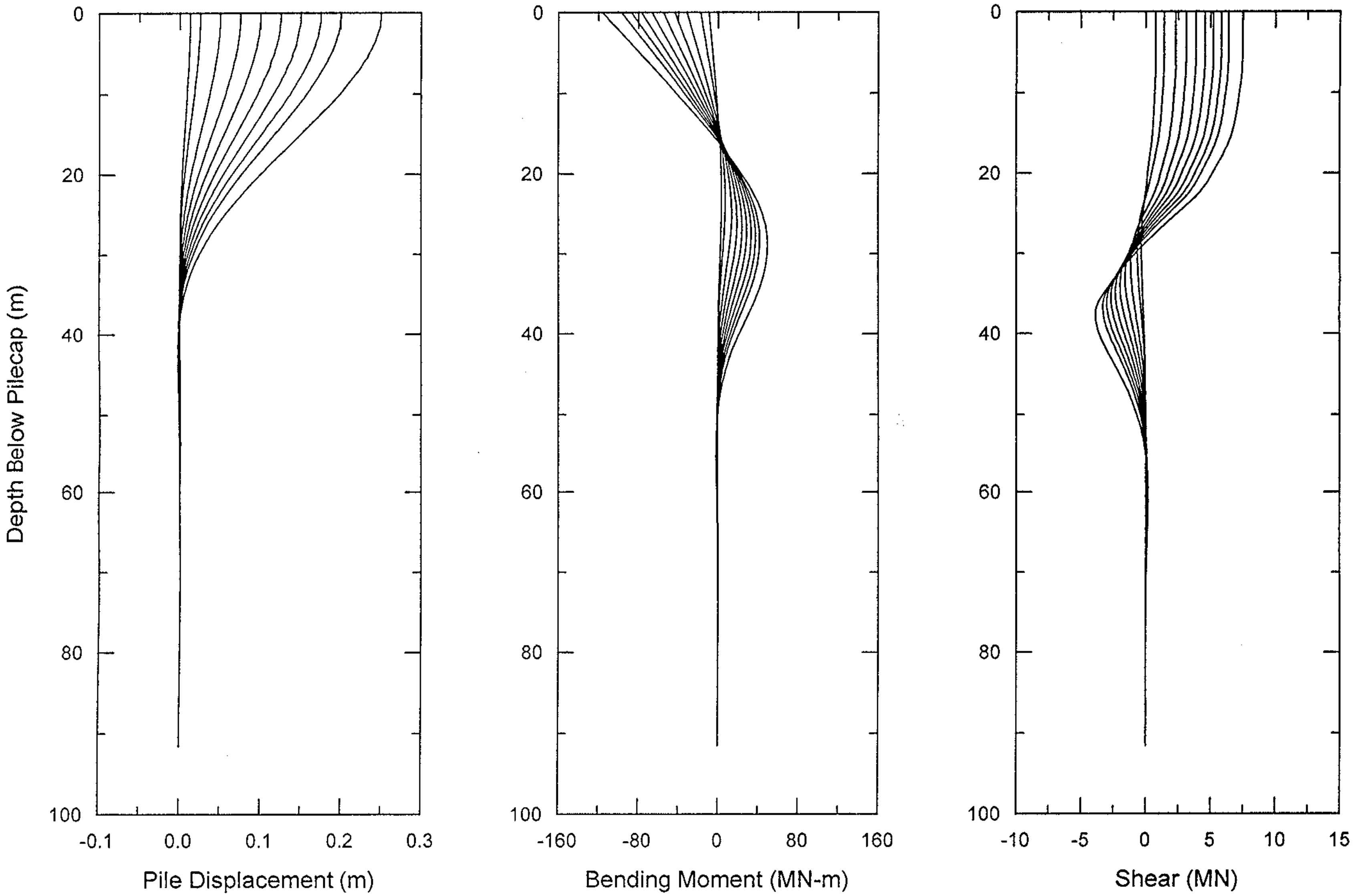
PLATE E05.3





PILE HEAD SHEAR AND BENDING MOMENT
PIER E05 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E05.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E05 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.980E+005	0.000E+000	0.000E+000	0.000E+000	1.117E+006	0.000E+000
0.000E+000	2.633E+005	0.000E+000	-1.412E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.506E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-1.412E+006	0.000E+000	4.962E+008	0.000E+000	0.000E+000
1.117E+006	0.000E+000	0.000E+000	0.000E+000	3.588E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.553E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.953E+005	0.000E+000	0.000E+000	0.000E+000	-2.326E+006	0.000E+000
0.000E+000	6.456E+005	0.000E+000	1.895E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.186E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.895E+006	0.000E+000	7.768E+008	0.000E+000	0.000E+000
-2.326E+006	0.000E+000	0.000E+000	0.000E+000	5.767E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	3.991E+007

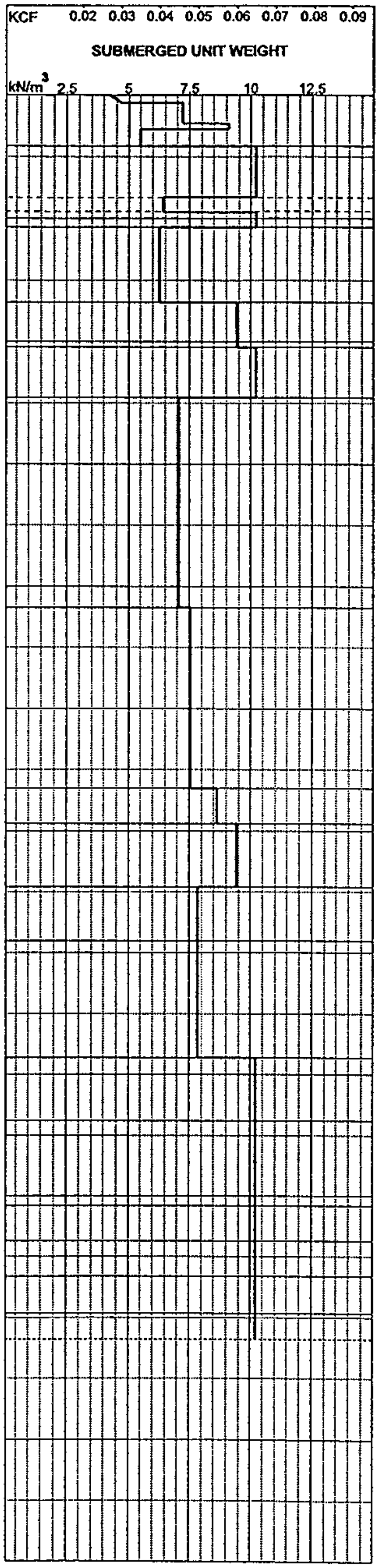
Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. +3.0 m

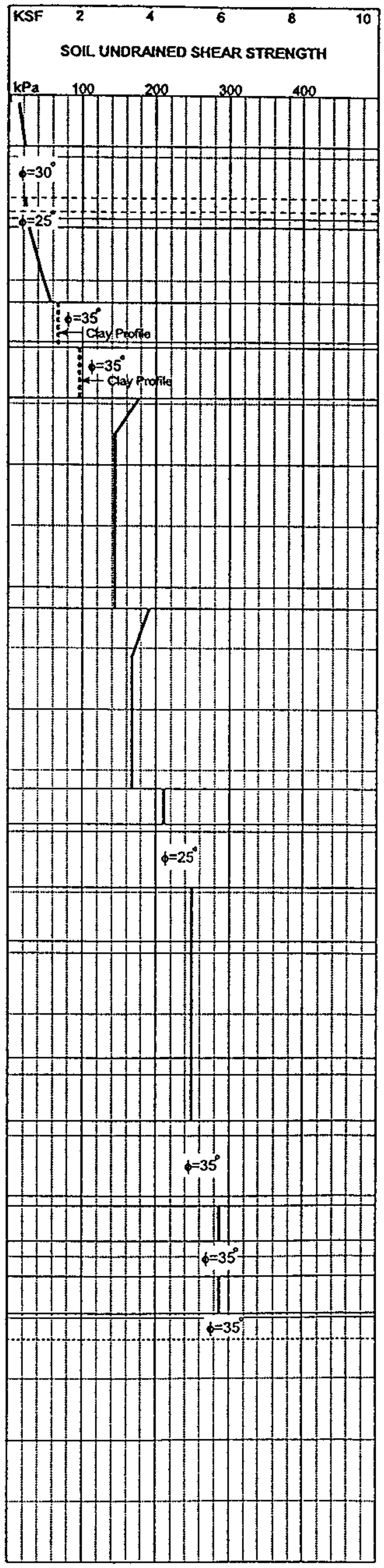
CONDENSED STIFFNESS MATRICES
PIER E05 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

Coordinates: E1837289 N647994
CA State Plane Zone 3, NAD83, Meters

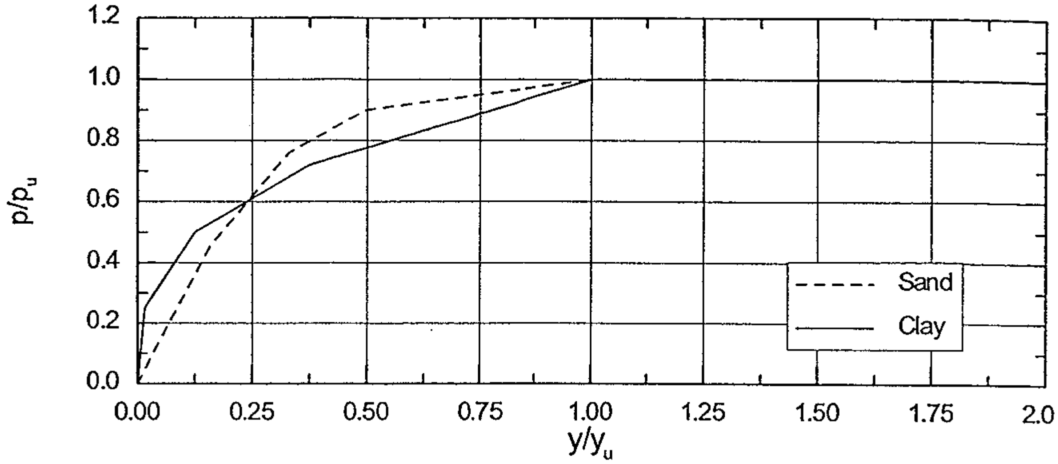
MUDLINE ELEVATION: -7.6m (MSL)

MATERIAL DESCRIPTION	STRATUM NO	UNIT
Fat CLAY (CH), soft to firm, dark olive gray -medium dense, silty fine sand layer, with clay pockets, 2.3m to 2.6m (4.1m)	I	YBM
Fine SAND with silt (SP-SM), dense, olive gray -firm, dark olive gray fat clay with many shells and shell fragments, 8.2m to 9.4m -medium dense, silty fine sand, 9.4m to 10.5m -with clay at 10.1m (10.7m)	II	YBM
Fat CLAY (CH), firm to stiff, olive gray (16.8m)	III	YBM
Silty Fine SAND (SM), very dense, brown -clay layer with sand seams, 17.4m to 17.7m -fat clay below 18.9m (20.4m)	IV	MPSA
Fine SAND (SP), dense to very dense, gray -fat clay, 22.3m to 22.6m -fat clay, 23.2m to 23.9m (24.5m)	V	MPSA
Fat CLAY (CH), very stiff, gray -silt, 36.0m to 36.6m (41.8m)	VI	OBM/UAM
Fat CLAY (CH), verty stiff to hard, greenish gray (56.5m)	VII	OBM/UAM
Lean CLAY (CL), hard, greenish gray -sand layer, 56.8m to 57.3m (59.4m)	VIII	OBM/UAM
Clayey SILT with sand (ML), very dense, greenish gray -sand with a few clay seams, below 62.2m (64.6m)	IX	OBM/UAM
Fat CLAY (CH), hard, gray -dense sand, 66.6m to 67.5m (69.0m)	X	OBM/UAM
Fat CLAY (CH), hard, greenish gray -dense sand layer, 72.2m to 72.5m (78.6m)	XI	OBM/UAM
Lean CLAY (CL) with sand, hard, greenish gray -fine sand with clay seams, 81.5m to 82.1m (83.8m)	XII	LAA
Fine to Coarse SAND with silt (SP-SM), very dense, gray (90.8m)	XIII	LAA
Lean CLAY (CL), hard, greenish gray to gray (93.7m)	XIV	LAA
Silty Fine SAND (SM), very dense, yellowish greenish brown (96.6m)	XV	LAA
Fat CLAY (CH), hard, yellowish brown (99.7m)	XVI	LAA
Clayey GRAVEL (GC), very dense, yellowish red	XVII	LAA
TOTAL DEPTH: 101.8m BACKFILLED WITH: Cement Grout		FF





SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E06 EASTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m²)	ϕ	k (kN/m³)
0-3	Clay	0.02	10		
3-6	Clay	0.02	18		
6-9	Sand			30	16300
9-12	Sand			25	5440
12-15	Clay	0.01	40		
15-18	Clay	0.075	62		
18-21	Sand			35	5440
21-24	Sand			35	5440
24-27	Clay	0.005	160		
27 -30	Clay	0.005	140		
30-33	Clay	0.005	140		
33-36	Clay	0.005	140		
36-39	Clay	0.005	140		
39-42	Clay	0.005	140		
42-45	Clay	0.005	180		
45-51	Clay	0.005	165		
51-57	Clay	0.005	165		
57-63	Sand			25	5440
63-69	Clay	0.005	245		
69-75	Clay	0.005	245		
75-81	Clay	0.005	245		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	36	100.0	Clay
3.0	105	100.0	Clay
5.9	141	100.0	Clay
6.1	380	2.3	Sand
9.0	742	3.0	Sand
11.9	871	8.1	Sand
12.1	394	50.0	Clay
15.0	446	50.0	Clay
17.9	682	37.5	Clay
18.1	3876	23.7	Sand
21.0	5355	28.2	Sand
23.9	7047	32.6	Sand
24.1	1790	25.0	Clay
30.0	1561	25.0	Clay
36.0	1561	25.0	Clay
42.0	1561	25.0	Clay
51.0	1846	25.0	Clay
62.9	8833	15.5	Sand
63.1	2745	25.0	Clay
81.0	2745	25.0	Clay

LATERAL PILE DESIGN PARAMETERS

PIER E06 EASTBOUND

SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	32	1.6	64	12.5	92	37.5	129	100.0	129	249.9		
5.9	3	0	0	41	1.6	82	12.5	119	37.5	165	100.0	165	249.9		
6.1	4	0	0	56	0.1	259	0.6	429	1.1	514	1.7	565	3.4	565	5.7
9.0	5	0	0	94	0.1	436	0.6	721	1.3	863	1.9	948	3.9	948	6.5
11.9	6	0	0	104	0.3	479	1.6	791	3.2	947	4.8	1041	9.7	1041	16.1
12.1	7	0	0	104	0.8	209	6.2	301	18.7	418	50.0	418	125.0		
15.0	8	0	0	111	0.8	223	6.2	321	18.7	446	50.0	446	125.0		
17.9	9	0	0	110	0.6	221	4.7	318	14.1	442	37.5	442	93.7		
18.1	10	0	0	316	0.6	1457	3.2	2407	6.5	2882	9.7	3167	19.4	3167	32.3
21.0	11	0	0	421	0.7	1939	3.7	3204	7.4	3837	11.1	4216	22.2	4216	37.0
23.9	12	0	0	540	0.8	2484	4.2	4104	8.3	4914	12.5	5400	25.0	5400	41.6
24.1	13	0	0	448	0.4	896	3.1	1290	9.4	1792	25.0	1792	62.5		
30.0	14	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
36.0	15	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
42.0	16	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
51.0	17	0	0	461	0.4	923	3.1	1329	9.4	1846	25.0	1846	62.5		
62.9	18	0	0	1877	1.1	8634	5.5	14265	11.0	17080	16.5	18770	33.0	18770	55.0
63.1	19	0	0	685	0.4	1370	3.1	1972	9.4	2740	25.0	2740	62.5		
81.0	20	0	0	685	0.4	1370	3.1	1972	9.4	2740	25.0	2740	62.5		

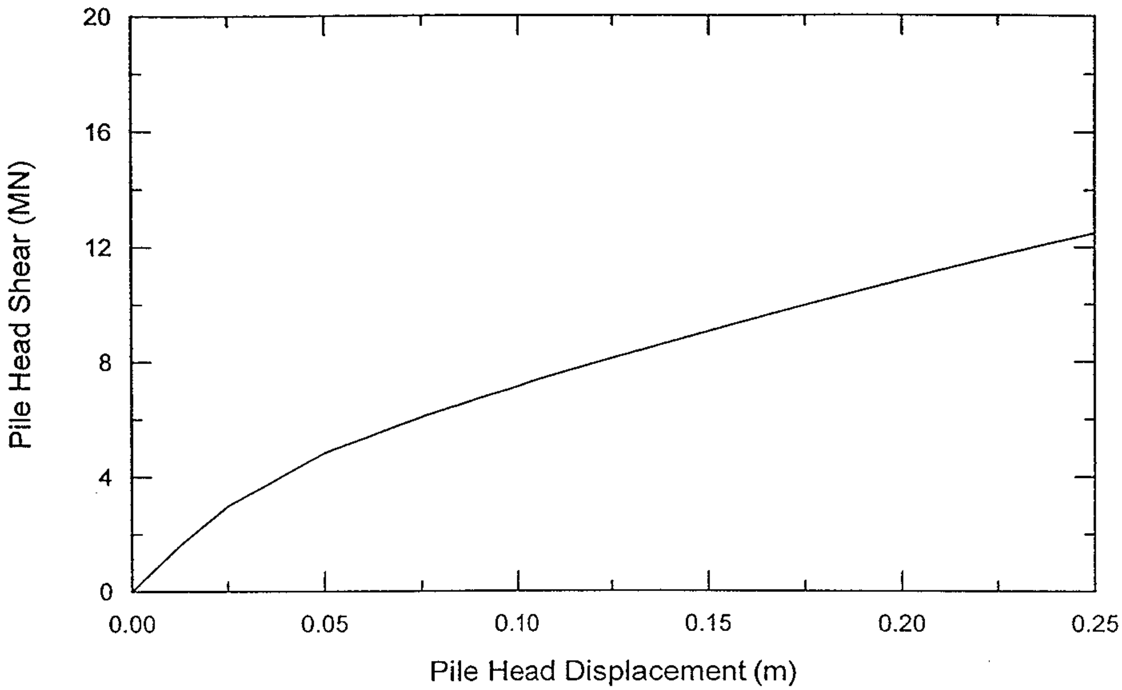
COORDINATES of p-y CURVES

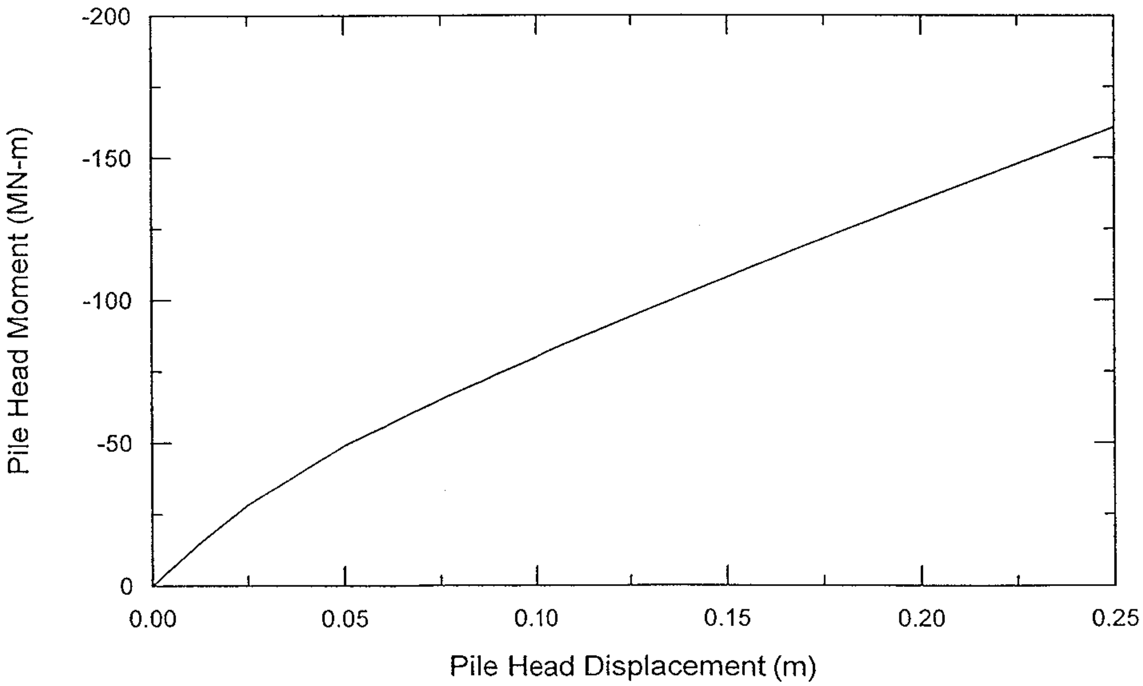
PIER E06 EASTBOUND

SFOBB East Span Seismic Safety Project

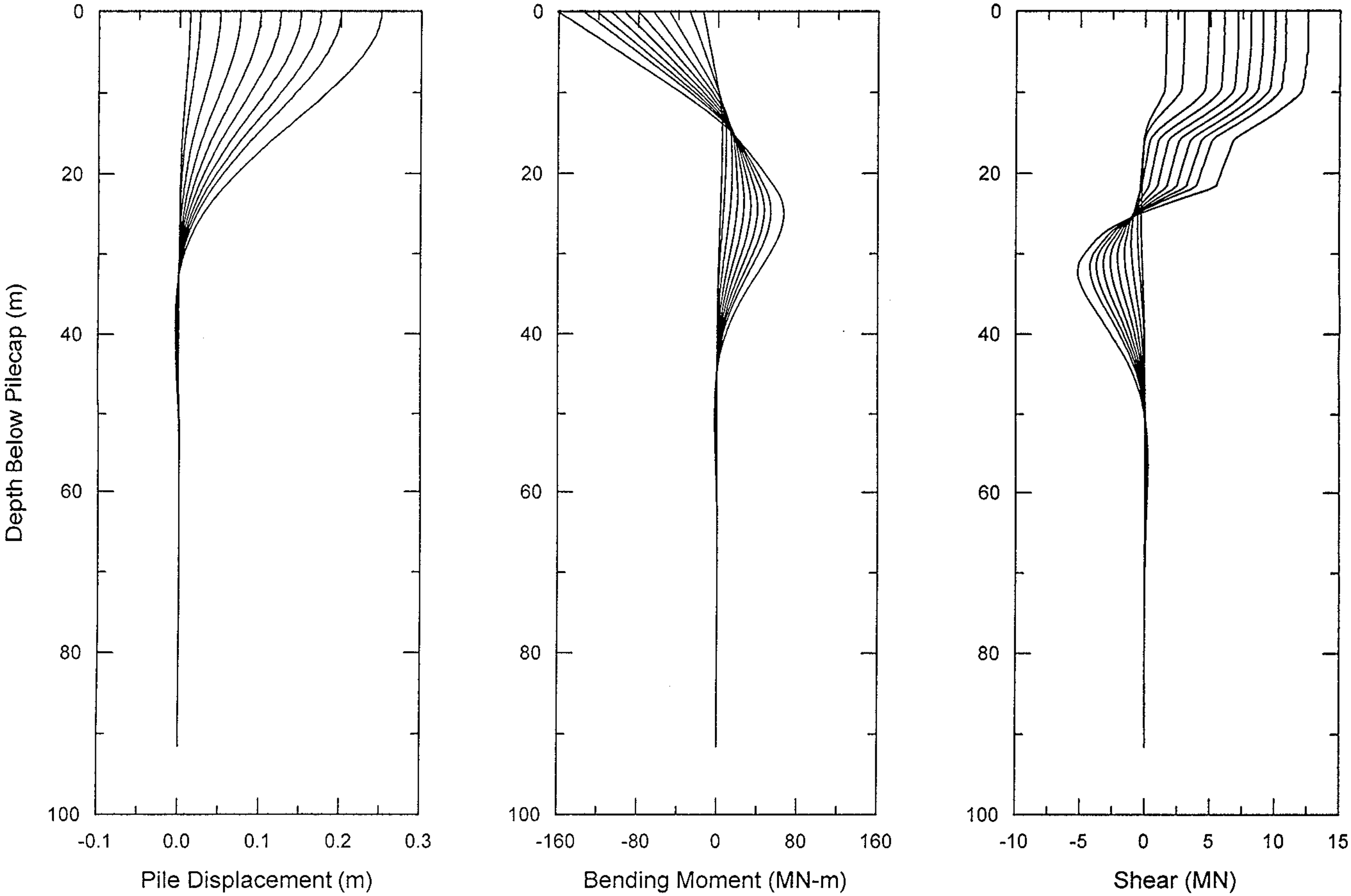
Earth Mechanics

FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E06 EASTBOUND
SFOBB East Span Seismic Safety Project



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E06 EASTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.616E+005	0.000E+000	0.000E+000	0.000E+000	6.350E+005	0.000E+000
0.000E+000	3.239E+005	0.000E+000	-9.560E+005	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.638E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-9.560E+005	0.000E+000	5.468E+008	0.000E+000	0.000E+000
6.350E+005	0.000E+000	0.000E+000	0.000E+000	3.973E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.938E+007

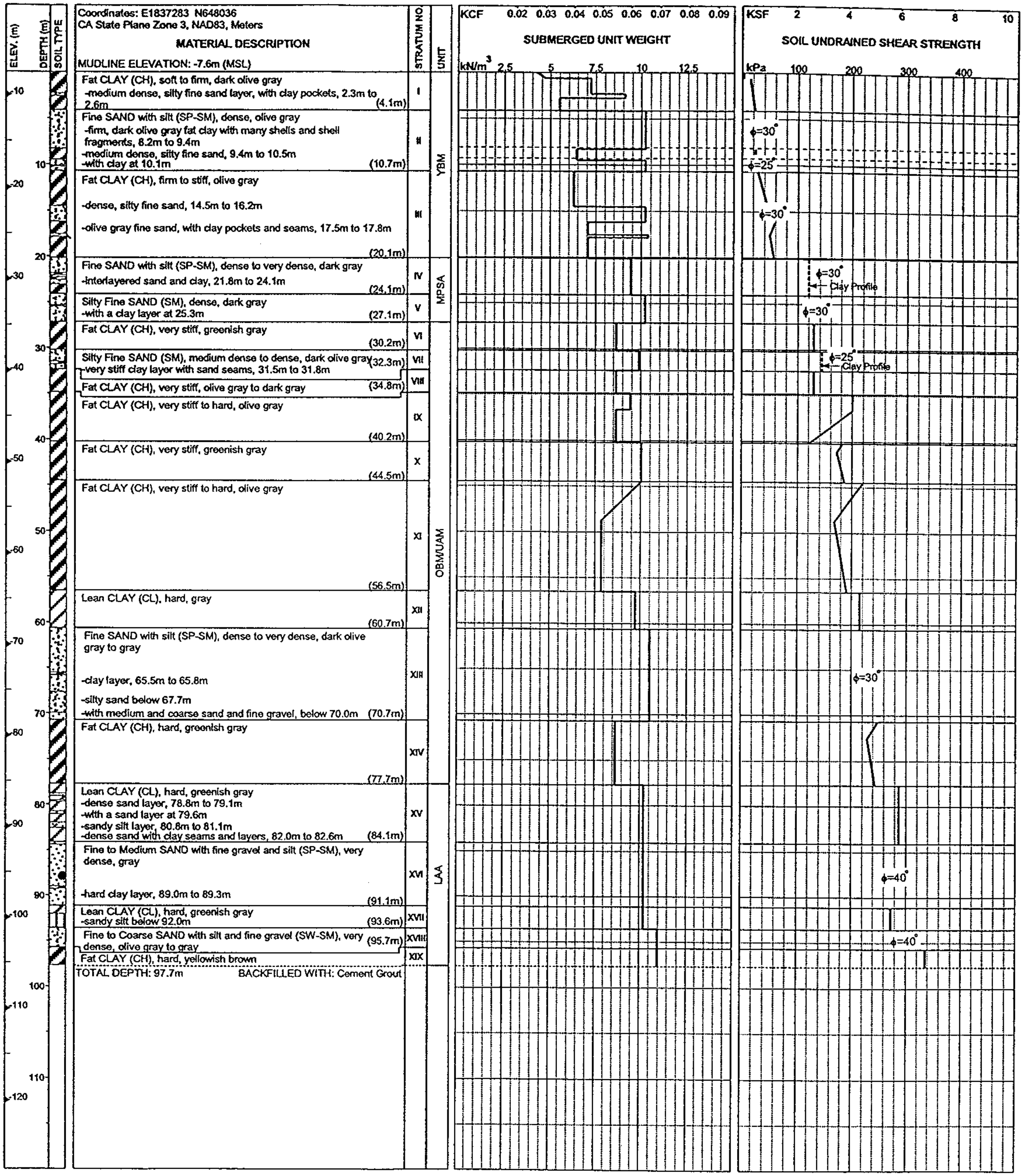
PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.301E+006	0.000E+000	0.000E+000	0.000E+000	-1.040E+007	0.000E+000
0.000E+000	1.253E+006	0.000E+000	9.978E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.187E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	9.978E+006	0.000E+000	8.848E+008	0.000E+000	0.000E+000
-1.040E+007	0.000E+000	0.000E+000	0.000E+000	6.845E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	7.823E+007

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. +3.0 m

CONDENSED STIFFNESS MATRICES
PIER E06 EASTBOUND
SFOBB East Span Seismic Safety Project

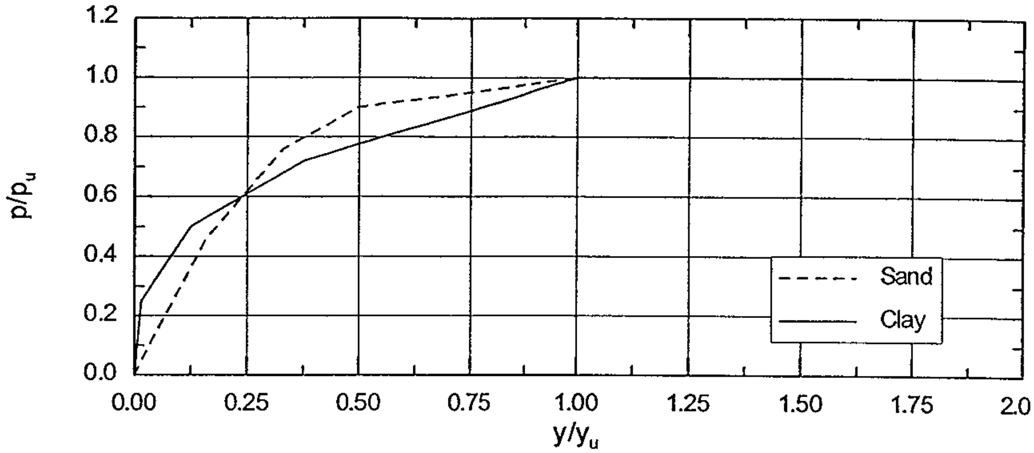
PLATE E06-EB.6



SUBSOIL CONDITION AND SOIL PROPERTIES

PIER E06 WESTBOUND

SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	18		
3-6	Clay	0.02	20		
6-9	Sand			30	16300
9-12	Sand			30	5440
12-15	Clay	0.0075	50		
15-18	Clay	0.0075	50		
18-21	Sand			30	5440
21-24	Sand			30	5440
24-27	Clay	0.005	115		
27 -30	Clay	0.005	125		
30-33	Clay	0.005	145		
33-36	Clay	0.005	150		
36-39	Clay	0.005	160		
39-42	Clay	0.005	160		
42-45	Clay	0.005	200		
45-51	Clay	0.005	180		
51-57	Clay	0.005	180		
57-63	Clay	0.005	210		
63-69	Sand			30	5440
69-75	Clay	0.005	230		
75-81	Clay	0.005	230		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	65	100.0	Clay
3.0	110	100.0	Clay
5.9	148	100.0	Clay
6.1	378	2.3	Sand
9.0	752	3.1	Sand
11.9	1325	4.1	Sand
12.1	448	50.0	Clay
15.0	448	50.0	Clay
17.9	367	50.0	Clay
18.1	2791	17.1	Sand
21.0	3800	20.0	Sand
23.9	4973	23.0	Sand
24.1	1292	25.0	Clay
27.0	1292	25.0	Clay
30.0	1399	25.0	Clay
36.0	1615	25.0	Clay
42.0	1790	25.0	Clay
51.0	2018	25.0	Clay
62.9	2352	25.0	Clay
63.1	17656	31.0	Sand
69.1	2573	25.0	Clay
81.0	2573	24.994	Clay

LATERAL PILE DESIGN PARAMETERS
PIER E06 WESTBOUND
SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	16	1.6	32	12.5	47	37.5	65	100	65	249.9		
3.0	2	0	0	27	1.6	55	12.5	79	37.5	110	100	110	249.9		
5.9	3	0	0	37	1.6	74	12.5	106	37.5	148	100	148	249.9		
6.1	4	0	0	37	0.1	174	0.4	287	0.8	344	1	378	2.3	378	3.9
9.0	5	0	0	75	0.1	346	0.5	572	1.0	684	2	752	3.1	752	5.1
11.9	6	0	0	132	0.1	609	0.7	1007	1.4	1206	2	1325	4.1	1325	6.8
12.1	7	0	0	112	0.8	224	6.2	323	18.7	448	50	448	125.0		
15.0	8	0	0	112	0.8	224	6.2	323	18.7	448	50	448	125.0		
17.9	9	0	0	91	0.8	183	6.2	264	18.7	367	50	367	125.0		
18.1	10	0	0	279	0.6	1284	2.9	2121	5.7	2540	9	2791	17.1	2791	28.6
21.0	11	0	0	380	0.7	1748	3.3	2888	6.7	3458	10	3800	20.0	3800	33.4
23.9	12	0	0	497	0.8	2287	3.8	3779	7.7	4525	11	4973	23.0	4973	38.3
24.1	13	0	0	323	0.4	646	3.1	930	9.4	1292	25	1292	62.5		
27.0	14	0	0	323	0.4	646	3.1	930	9.4	1292	25	1292	62.5		
30.0	15	0	0	349	0.4	699	3.1	1007	9.4	1399	25	1399	62.5		
36.0	16	0	0	403	0.4	807	3.1	1162	9.4	1615	25	1615	62.5		
42.0	17	0	0	447	0.4	895	3.1	1288	9.4	1790	25	1790	62.5		
51.0	18	0	0	504	0.4	1009	3.1	1453	9.4	2018	25	2018	62.5		
62.9	19	0	0	588	0.4	1176	3.1	1693	9.4	2352	25	2352	62.5		
63.1	20	0	0	1765	1.0	8122	5.2	13419	10.3	16067	15	17656	31.0	17656	51.6
69.1	25	0	0	643	0.4	1286	3.1	1852	9.4	2573	25	2573	62.5		
81.0	21	0	0	643	0.4	1286	3.1	1852	9.4	2573	25	2573	62.5		

COORDINATES of p-y CURVES

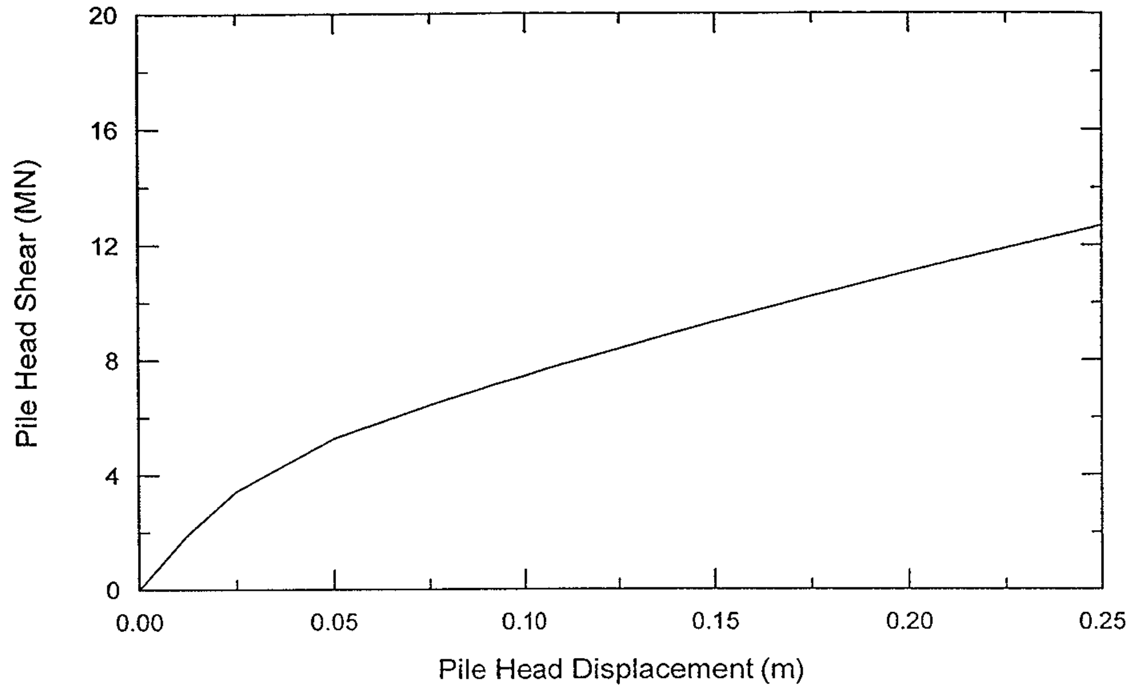
PIER E06 WESTBOUND

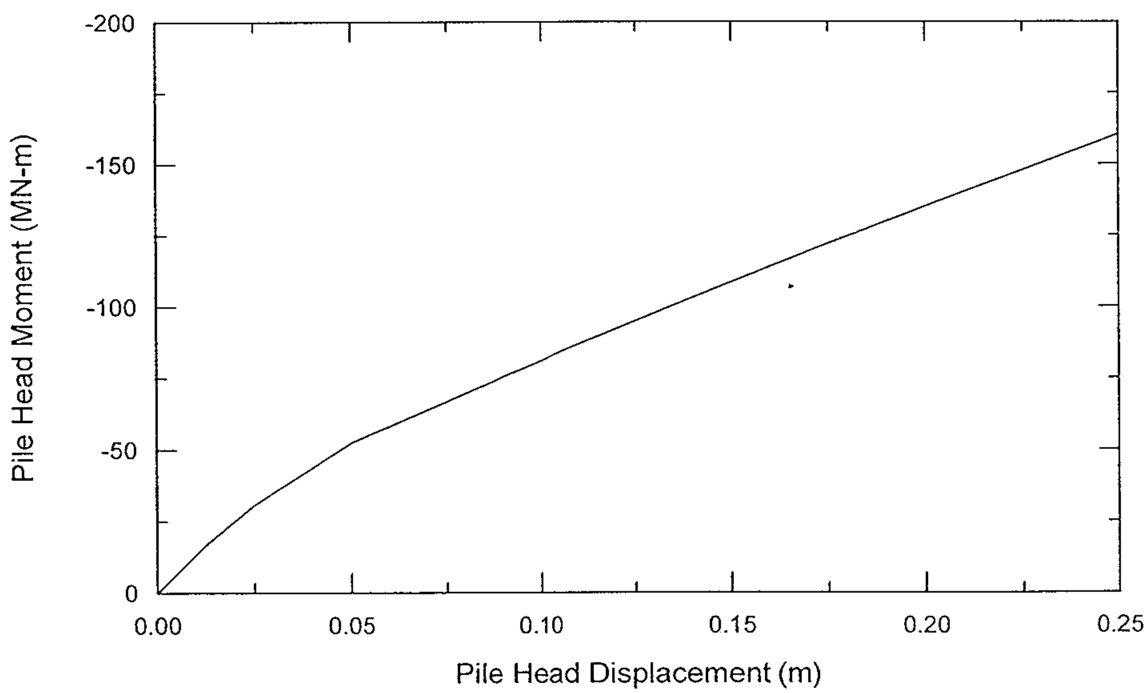
SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5
EMI Project No. 98-145

Earth Mechanics

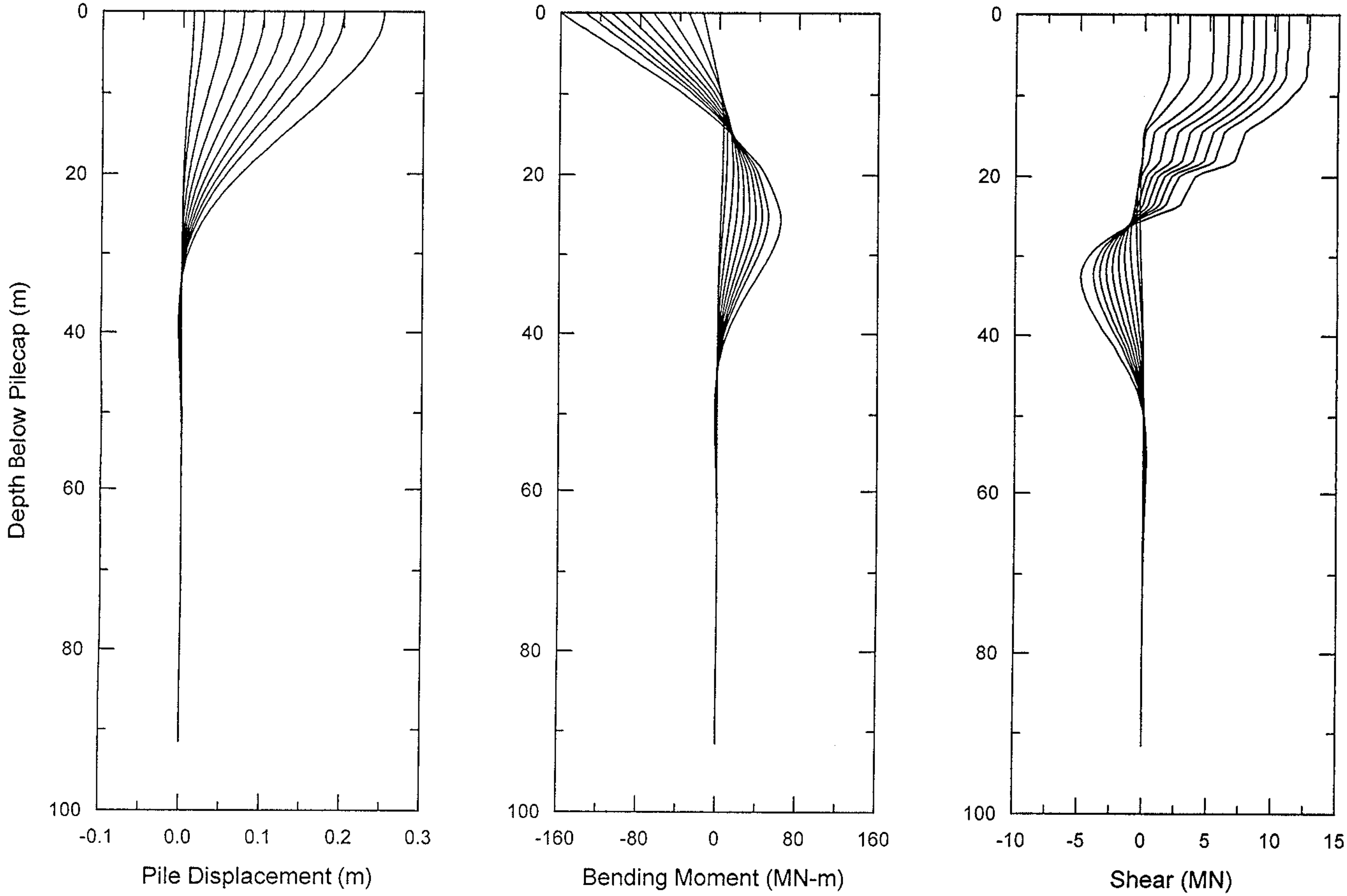
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E06 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E06-WB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E06 WESTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5
EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E06-WB.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.616E+005	0.000E+000	0.000E+000	0.000E+000	6.350E+005	0.000E+000
0.000E+000	3.239E+005	0.000E+000	-9.560E+005	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.638E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-9.560E+005	0.000E+000	5.468E+008	0.000E+000	0.000E+000
6.350E+005	0.000E+000	0.000E+000	0.000E+000	3.973E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.938E+007

PILE-GROUP STIFFNESS MATRIX (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.322E+006	0.000E+000	0.000E+000	0.000E+000	-1.066E+007	0.000E+000
0.000E+000	1.274E+006	0.000E+000	1.024E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.187E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.024E+007	0.000E+000	8.881E+008	0.000E+000	0.000E+000
-1.066E+007	0.000E+000	0.000E+000	0.000E+000	6.878E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	7.951E+007

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. +3.0 m

CONDENSED STIFFNESS MATRICES
PIER E06 WESTBOUND
SFOBB East Span Seismic Safety Project

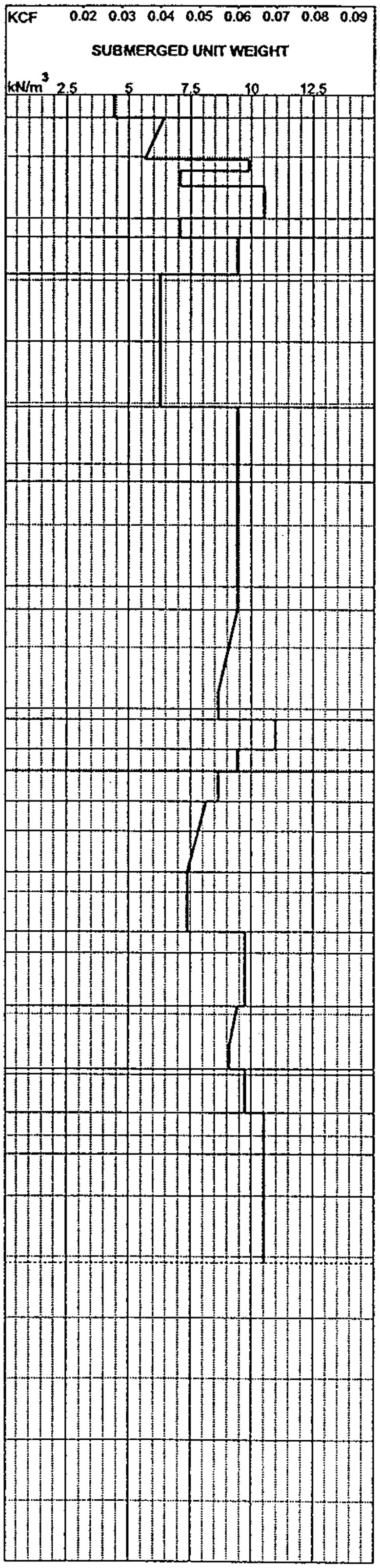
PLATE E06-WB.6

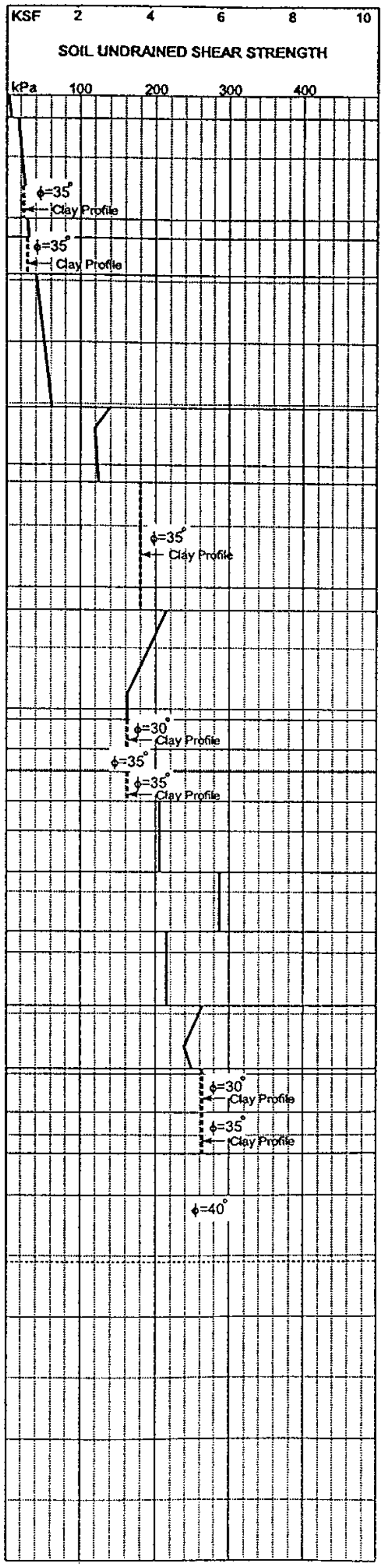
Coordinates: E1837438 N648013
CA State Plane Zone 3, NAD83, Meters

MUDLINE ELEVATION: -6.2m (MSL)

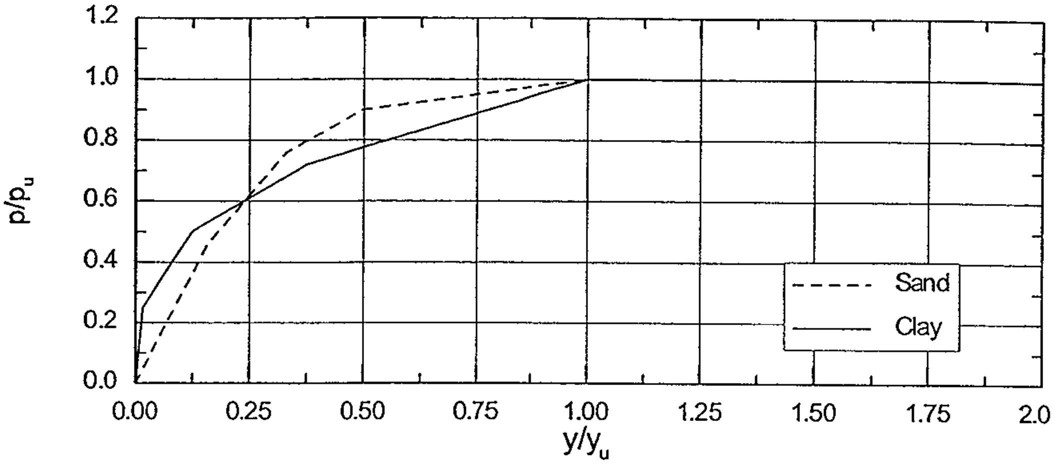
MATERIAL DESCRIPTION	Depth	STRATUM NO	UNIT
Fat CLAY (CH), very soft, dark gray	(1.8m)	I	YBM
Fat CLAY (CH), soft to firm, olive gray -interlayered silty fine sand and fat clay below 5.2m -dense to very dense sand, 7.3m to 9.9m	(11.5m)	II	YBM
Fine SAND (SP), dense, gray -clay with sand pockets and calcareous nodules, at 12.8m	(14.5m)	III	YBM
Fat CLAY (CH), firm to stiff, olive gray	(25.3m)	IV	YBM
Interlayered Silty Fine SAND (SP), SILT (ML) and CLAY (CH) -sand with large clay pockets, at 29.6m	(31.4m)	V	MPSA
Silty Fine SAND (SM), dense, gray -clay to 31.7m -clay layer, 36.0m to 36.3m -fine sand with silt, below 38.1m -clay layer, 39.8m to 39.9m -clay layer, 40.2m to 40.8m	(41.9m)	VI	OBM/UAM
Fat CLAY (CH), very stiff to hard, dark greenish gray	(50.9m)	VII	OBM/UAM
Clayey SAND (SC), dense, greenish gray	(53.3m)	VIII	OBM/UAM
Silty Fine SAND (SM), dense to very dense, greenish gray	(55.2m)	IX	OBM/UAM
Silty Fine SAND (SM), very dense, gray -clay layer, 55.2m to 55.8m -clay layer, 56.1m to 56.5m	(57.6m)	X	OBM/UAM
Fat CLAY (CH), hard, dark greenish gray	(63.4m)	XI	OBM/UAM
Fat CLAY (CH), hard, gray	(68.3m)	XII	OBM/UAM
Lean CLAY (CL), hard, gray	(74.4m)	XIII	OBM/UAM
Fat CLAY (CH), hard, gray -sand layer, 76.0m to 76.2m	(79.6m)	XIV	OBM/UAM
Interlayered Silty Fine SAND (SM), and Hard Lean CLAY (CL), dark greenish gray	(83.1m)	XV	LAA
Silty Fine SAND (SM), very dense, gray	(86.6m)	XVI	LAA
Fine to Coarse SAND (SW-SM) with silt and gravel, dense to very dense, gray		XVII	LAA

TOTAL DEPTH: 95.5m BACKFILLED WITH: Cement Grout





SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E07 EASTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m²)	ϕ	k (kN/m³)
0-3	Clay	0.02	10		
3-6	Clay	0.02	22		
6-9	Clay	0.02	22		
9-12	Sand			35	5440
12-15	Sand			35	5440
15-18	Clay	0.01	45		
18-21	Clay	0.0075	50		
21-24	Clay	0.0075	58		
24-27	Clay	0.0075	90		
27 -30	Clay	0.005	110		
30-33	Sand			35	5440
33-36	Sand			35	5440
36-39	Sand			35	5440
39-42	Sand			35	5440
42-45	Clay	0.005	200		
45-51	Clay	0.005	180		
51-57	Sand			35	5440
57-63	Clay	0.005	200		
63-69	Clay	0.005	280		
69-75	Clay	0.005	220		
75-81	Clay	0.005	240		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	38	100.0	Clay
3.0	116	100.0	Clay
6.0	158	100.0	Clay
8.9	199	100.0	Clay
9.1	933	11.4	Sand
12.0	1746	16.1	Sand
14.9	2765	20.6	Sand
15.1	314	50.0	Clay
18.0	336	50.0	Clay
21.0	646	37.5	Clay
24.0	646	37.5	Clay
29.9	1238	25.0	Clay
30.1	10146	37.3	Sand
36.0	14862	45.6	Sand
41.9	20427	53.9	Sand
42.1	2234	25.0	Clay
50.9	2018	25.0	Clay
51.1	25653	55.5	Sand
63.0	2234	25.0	Clay
81.0	2691	25.0	Clay

LATERAL PILE DESIGN PARAMETERS
PIER E07 EASTBOUND
SFOBB East Span Seismic Safety Project

PLATE E07-EB.2

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	29	1.6	58	12.5	83	37.5	116	100.0	116	249.9		
6.0	3	0	0	39	1.6	79	12.5	114	37.5	158	100.0	158	249.9		
8.9	4	0	0	49	1.6	99	12.5	143	37.5	199	100.0	199	249.9		
9.1	5	0	0	93	0.4	429	1.9	709	3.8	849	5.7	933	11.4	933	18.9
12.0	6	0	0	174	0.5	803	2.7	1327	5.4	1589	8.0	1746	16.1	1746	26.8
14.9	7	0	0	276	0.7	1272	3.4	2102	6.9	2516	10.3	2765	20.6	2765	34.3
15.1	8	0	0	78	0.8	157	6.2	226	18.7	314	50.0	314	125.0		
18.0	9	0	0	84	0.8	168	6.2	242	18.7	336	50.0	336	125.0		
21.0	10	0	0	161	0.6	323	4.7	465	14.1	646	37.5	646	93.7		
24.0	11	0	0	161	0.6	323	4.7	465	14.1	646	37.5	646	93.7		
29.9	12	0	0	309	0.4	619	3.1	891	9.4	1238	25.0	1238	62.5		
30.1	13	0	0	1014	1.2	4667	6.2	7711	12.4	9233	18.6	10146	37.3	10146	62.1
36.0	14	0	0	1486	1.5	6836	7.6	11295	15.2	13524	22.8	14862	45.6	14862	76.1
41.9	15	0	0	2042	1.8	9396	9.0	15524	18.0	18588	27.0	20427	53.9	20427	89.9
42.1	16	0	0	558	0.4	1117	3.1	1608	9.4	2234	25.0	2234	62.5		
50.9	17	0	0	504	0.4	1009	3.1	1453	9.4	2018	25.0	2018	62.5		
51.1	18	0	0	2565	1.9	11800	9.3	19496	18.5	23344	27.8	25653	55.5	25653	92.5
63.0	19	0	0	558	0.4	1117	3.1	1608	9.4	2234	25.0	2234	62.5		
81.0	20	0	0	672	0.4	1345	3.1	1938	9.4	2691	25.0	2691	62.5		

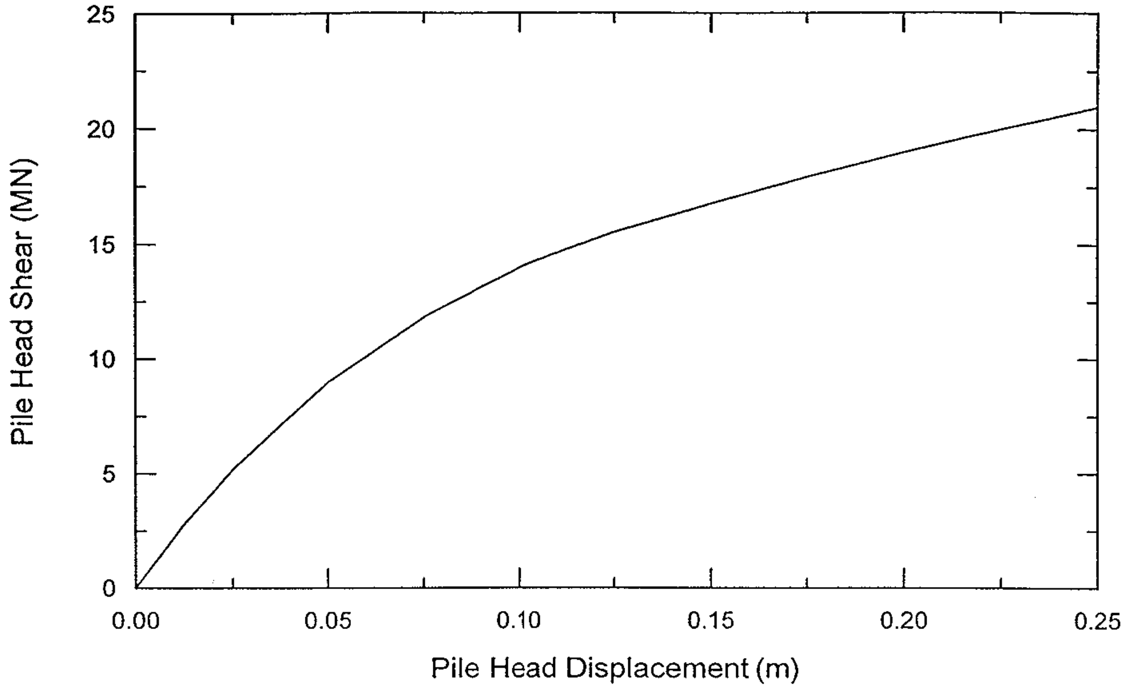
COORDINATES of p-y CURVES

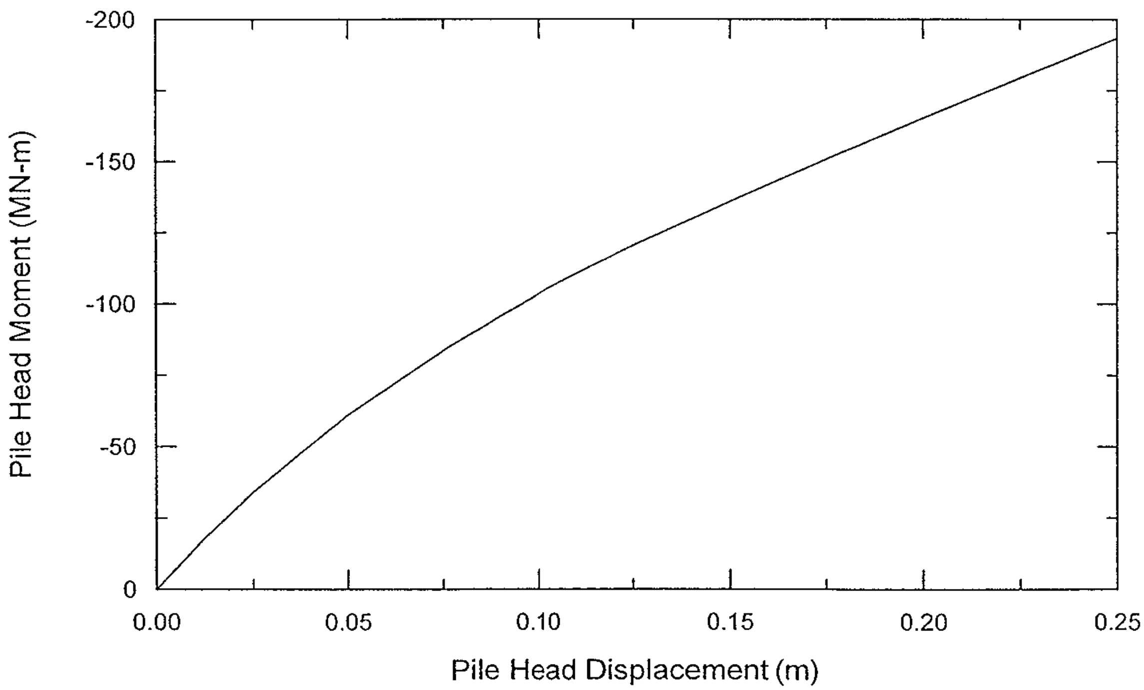
PIER E07 EASTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

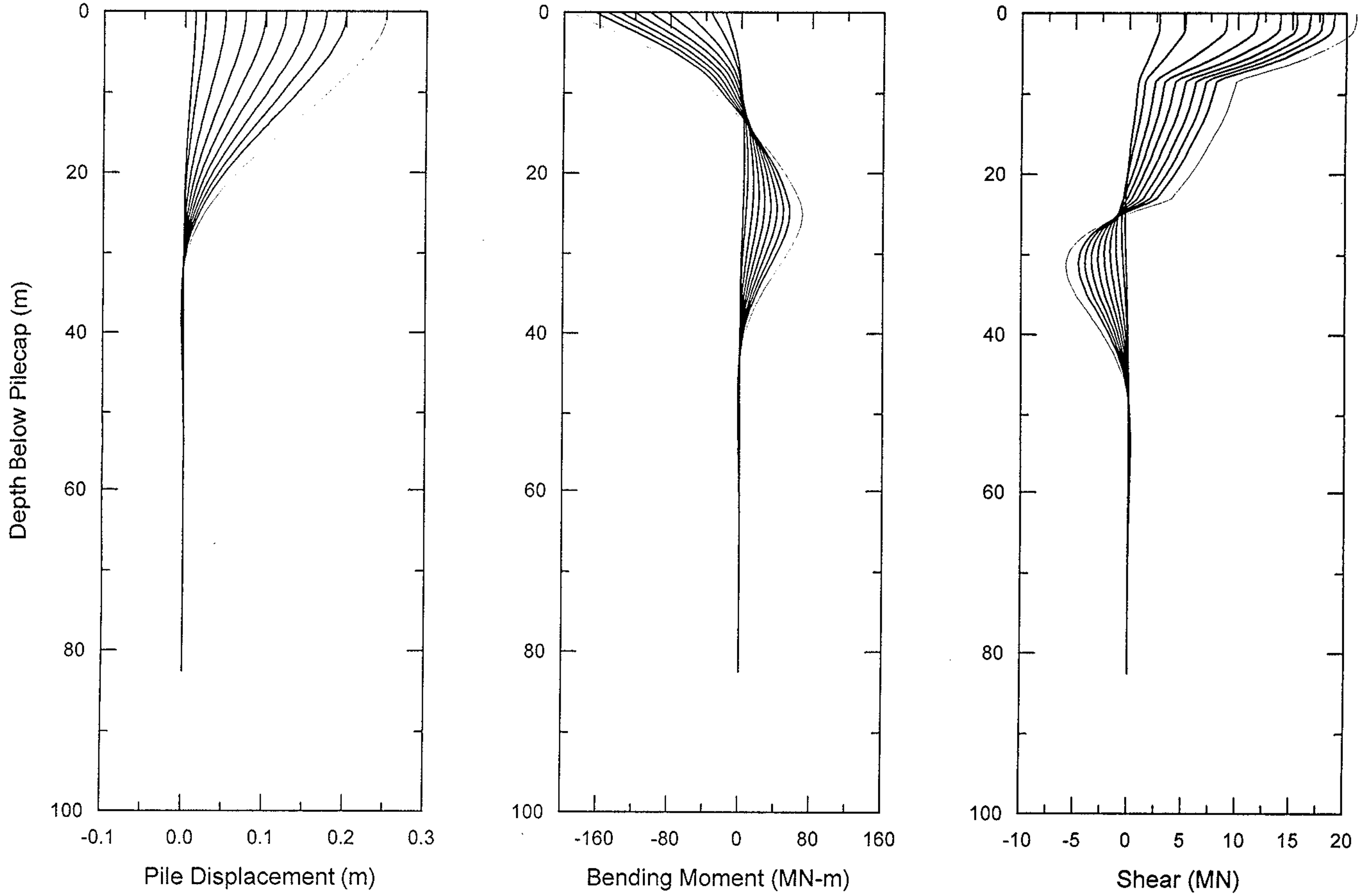
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E07 EASTBOUND
SFOBB East Span Seismic Safety Project

PLATE E07-EB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E07 EASTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.804E+005	0.000E+000	0.000E+000	0.000E+000	-1.158E+007	0.000E+000
0.000E+000	7.441E+005	0.000E+000	1.127E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.624E+007	0.000E+000	1.863E-009	0.000E+000
0.000E+000	1.127E+007	0.000E+000	9.047E+008	0.000E+000	0.000E+000
-1.158E+007	0.000E+000	0.000E+000	0.000E+000	7.567E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	5.887E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.724E+006	0.000E+000	0.000E+000	0.000E+000	-2.383E+007	0.000E+000
0.000E+000	2.679E+006	0.000E+000	2.344E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.189E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	2.344E+007	0.000E+000	1.017E+009	0.000E+000	0.000E+000
-2.383E+007	0.000E+000	0.000E+000	0.000E+000	8.162E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.591E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -6.0 m

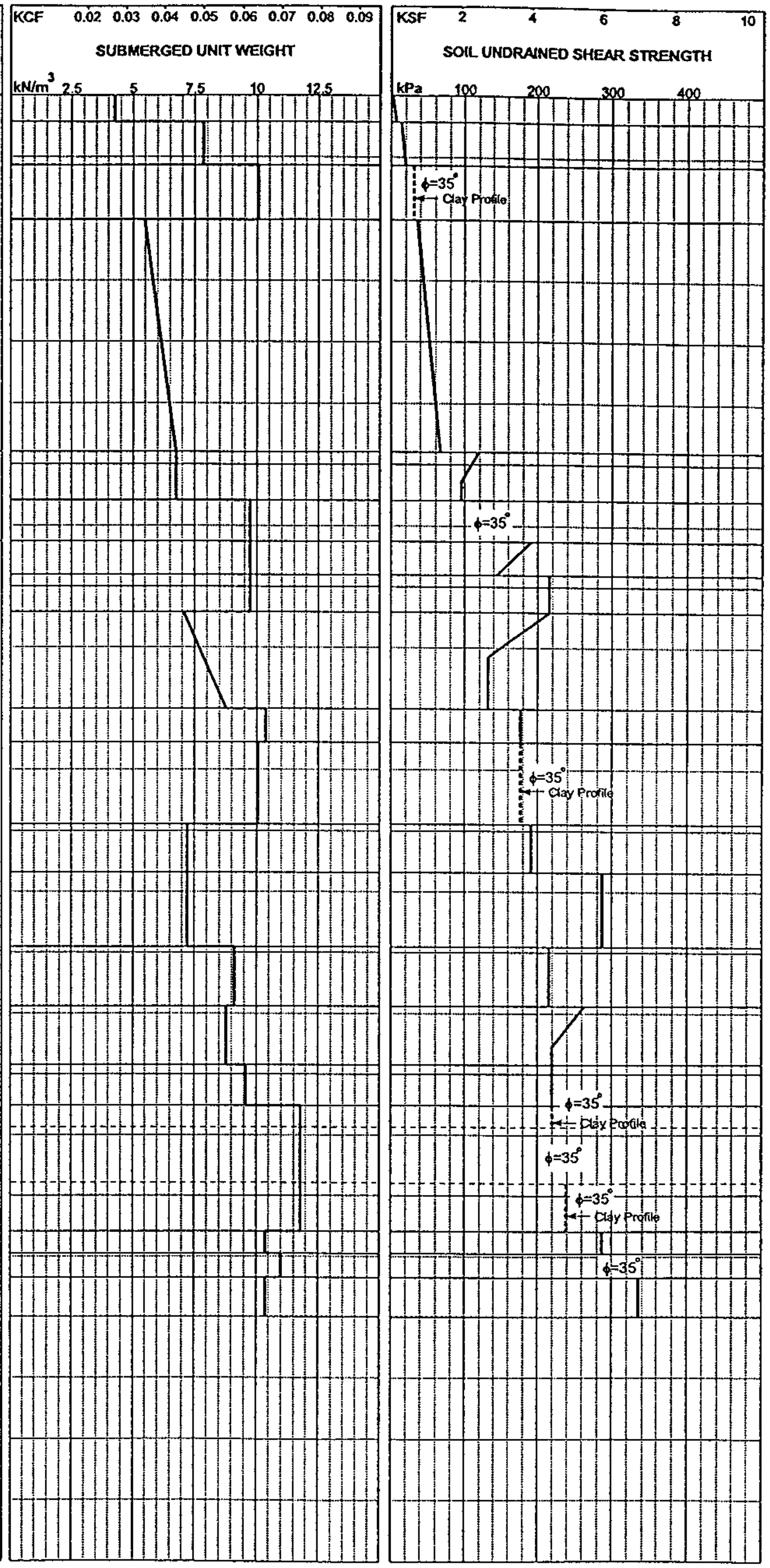
CONDENSED STIFFNESS MATRICES
PIER E07 EASTBOUND
SFOBB East Span Seismic Safety Project

Coordinates: E1837441 N648059
CA State Plane Zone 3, NAD83, Meters

MUDLINE ELEVATION: -5.6m (MSL)

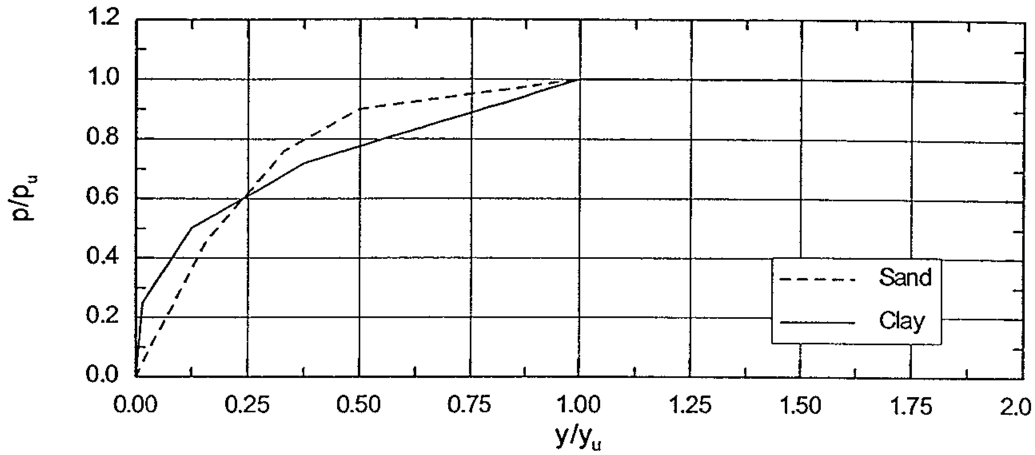
MATERIAL DESCRIPTION	Bottom depth	STRATUM NO.	UNIT
Fat CLAY (CH), very soft, olive gray	(2.1m)	I	YBM
Fat CLAY (CH), soft, olive gray -clay with fine sand, 4.3m to 5.0m	(5.6m)	II	YBM
Fine SAND (SP), very dense, gray	(10.1m)	III	YBM
Fat CLAY (CH), firm to stiff, olive gray -sand layer, 10.5m to 11.1m	(29.0m)	IV	YBM
Fat CLAY (CH), stiff to very stiff, greenish gray -organic clay to 30.6m	(32.9m)	V	MPSA
Fine SAND with silt (SP-SM), very dense, olive gray	(36.3m)	VI	MPSA
Fat CLAY (CH), very stiff to hard, greenish gray	(39.0m)	VII	OBM/UAM
Fat CLAY (CH), hard, greenish gray	(42.1m)	VIII	OBM/UAM
Fat CLAY (CH), very stiff to hard, greenish gray	(50.0m)	IX	OBM/UAM
Sandy Lean CLAY (CL), very stiff, greenish gray	(52.7m)	X	OBM/UAM
Fine SAND (SP), dense to very dense, greenish gray	(59.4m)	XI	OBM/UAM
Fat CLAY (CH), hard, greenish gray	(63.4m)	XII	OBM/UAM
Fat CLAY (CH), hard, greenish gray	(69.5m)	XIII	OBM/UAM
Lean CLAY (CL), hard, greenish gray	(74.4m)	XIV	OBM/UAM
Interlayered Silty Fine SAND (SM), dense, and Fat CLAY (CH), hard, dark greenish gray	(79.2m)	XV	OBM/UAM
Lean CLAY (CL), hard, greenish gray -with silt seams, 79.9m to 80.5m -silty sand with clay layers, below 81.4m	(82.6m)	XVI	LAA
Fine to Medium SAND (SP-SM) with silt, very dense, gray -greenish gray, lean clay with sand, 83.4m to 84.4m -with clay seams and layers, below 89.0m	(93.0m)	XVII	LAA
Sandy SILT (ML), hard, brownish yellow	(94.8m)	XVIII	LAA
Medium SAND (SP-SM) with silt, very dense, dark brown	(96.8m)	XIX	LAA
Lean CLAY (CL), hard, brown		XX	LAA

TOTAL DEPTH: 100.0m   BACKFILLED WITH: Cement Grout



SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E07 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E07-WB.1



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	8		
3-6	Clay	0.02	20		
6-9	Sand			35	16300
9-12	Sand			35	5440
12-15	Clay	0.01	40		
15-18	Clay	0.01	45		
18-21	Clay	0.0075	50		
21-24	Clay	0.0075	60		
24-27	Clay	0.0075	62		
27 -30	Clay	0.0075	80		
30-33	Clay	0.005	100		
33-36	Sand			35	5440
36-39	Clay	0.005	160		
39-42	Clay	0.005	210		
42-45	Clay	0.005	170		
45-51	Clay	0.005	130		
51-57	Sand			35	5440
57-63	Sand			35	5440
63-69	Clay	0.005	280		
69-75	Clay	0.005	210		
75-81	Clay	0.005	220		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	29	100.0	Clay
3.0	107	100.0	Clay
5.9	151	100.0	Clay
6.1	540	9.8	Sand
9.0	1075	13.2	Sand
11.9	1912	17.8	Sand
12.1	272	50.0	Clay
15.0	292	50.0	Clay
18.0	500	50.0	Clay
21.0	672	37.5	Clay
24.0	672	37.5	Clay
30.0	888	37.5	Clay
35.9	13094	40.6	Sand
36.1	1792	25.0	Clay
42.0	1900	25.0	Clay
50.9	1453	25.0	Clay
51.1	23460	50.8	Sand
62.9	30633	53.9	Sand
63.1	3122	25.0	Clay
81.0	2460	25.0	Clay

LATERAL PILE DESIGN PARAMETERS
PIER E07 WESTBOUND
SFOBB East Span Seismic Safety Project

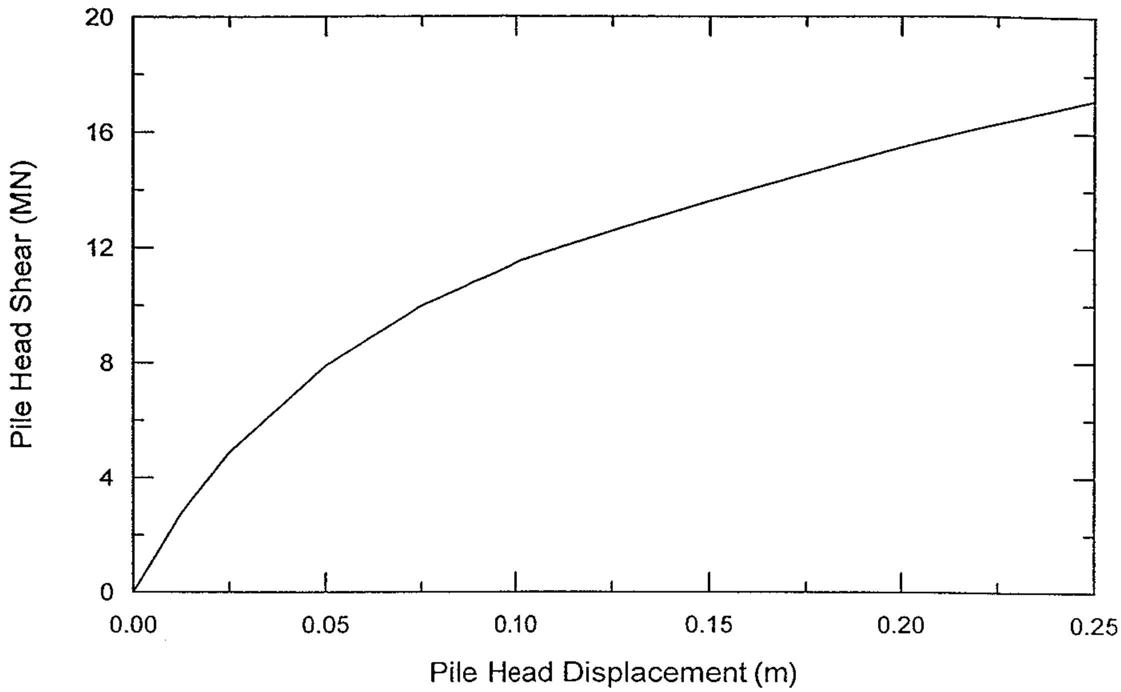
Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	7	1.6	14	12.5	21	37.5	29	100.0	29	249.9		
3.0	2	0	0	26	1.6	53	12.5	77	37.5	107	100.0	107	249.9		
5.9	3	0	0	37	1.6	75	12.5	108	37.5	151	100.0	151	249.9		
6.1	4	0	0	54	0.3	248	1.6	410	3.3	492	4.9	540	9.8	540	16.3
9.0	5	0	0	107	0.4	494	2.2	817	4.4	978	6.6	1075	13.2	1075	22.0
11.9	6	0	0	191	0.6	879	3.0	1453	5.9	1740	8.9	1912	17.8	1912	29.6
12.1	7	0	0	68	0.8	136	6.2	195	18.7	272	50.0	272	125.0		
15.0	8	0	0	73	0.8	146	6.2	210	18.7	292	50.0	292	125.0		
18.0	9	0	0	125	0.8	250	6.2	360	18.7	500	50.0	500	125.0		
21.0	10	0	0	168	0.6	336	4.7	484	14.1	672	37.5	672	93.7		
24.0	11	0	0	168	0.6	336	4.7	484	14.1	672	37.5	672	93.7		
30.0	12	0	0	222	0.6	444	4.7	639	14.1	888	37.5	888	93.7		
35.7	13	0	0	1309	1.4	6023	6.8	9952	13.5	11916	20.3	13094	40.6	13094	67.6
36.1	14	0	0	448	0.4	896	3.1	1290	9.4	1792	25.0	1792	62.5		
42.0	15	0	0	475	0.4	950	3.1	1368	9.4	1900	25.0	1900	62.5		
50.9	16	0	0	363	0.4	726	3.1	1046	9.4	1453	25.0	1453	62.5		
51.1	17	0	0	2346	1.7	10791	8.5	17829	16.9	21348	25.4	23460	50.8	23460	84.6
62.9	18	0	0	3063	1.8	14091	9.0	23281	18.0	27876	26.9	30633	53.9	30633	89.8
63.1	19	0	0	780	0.4	1561	3.1	2248	9.4	3122	25.0	3122	62.5		
81.0	20	0	0	615	0.4	1230	3.1	1771	9.4	2460	25.0	2460	62.5		

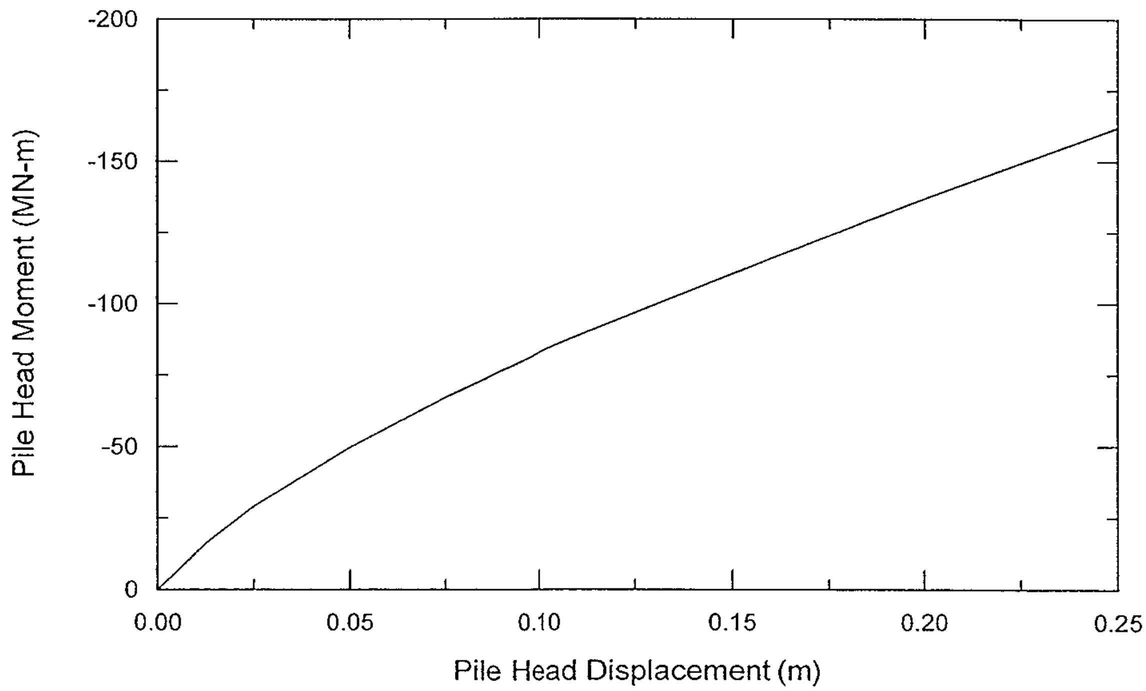
COORDINATES of p-y CURVES
PIER E07 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E07-WB.3

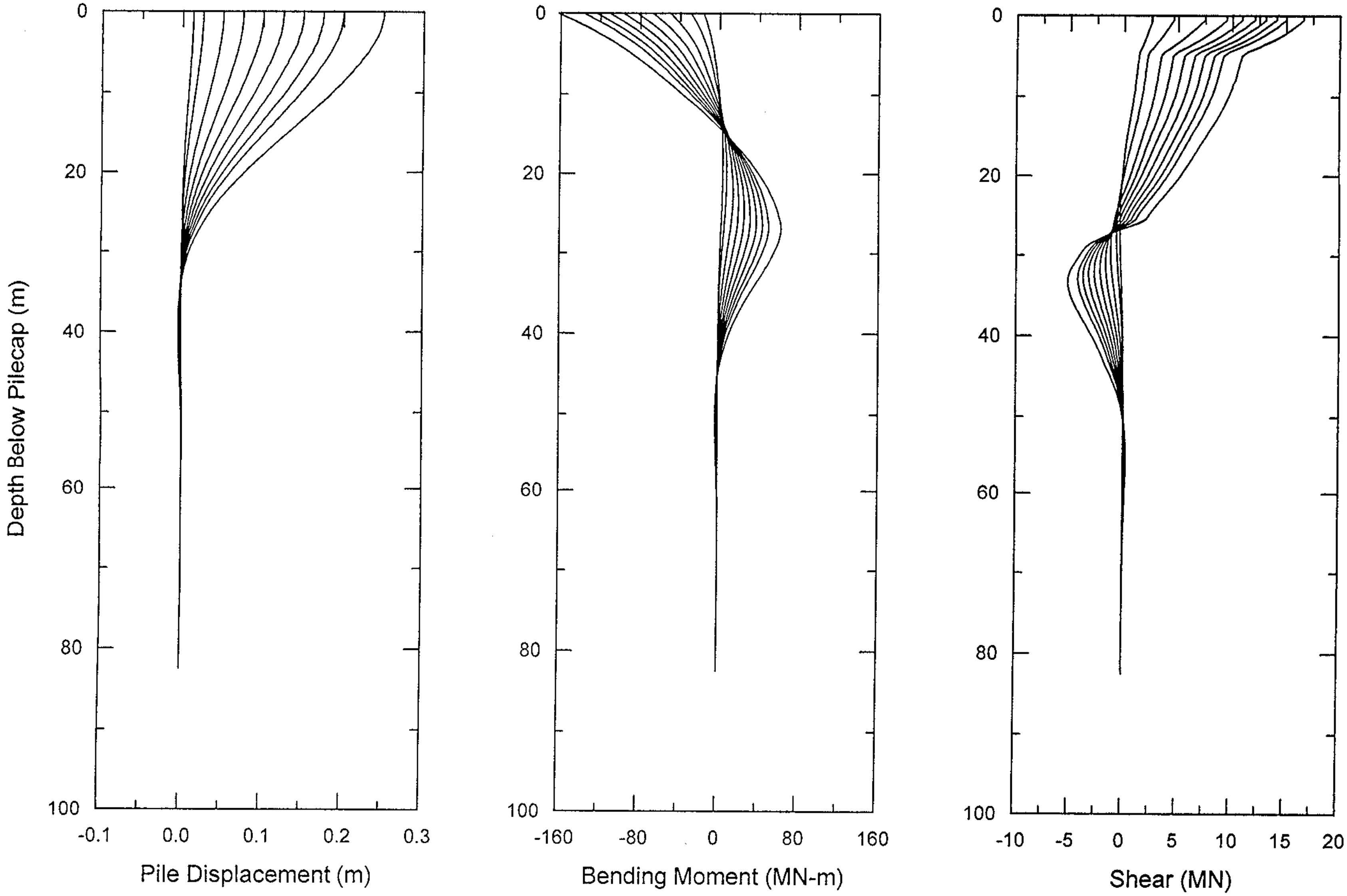
SFOBB Task Order No. 5
EMI Project No. 98-145

Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E07 WESTBOUND
SFOBB East Span Seismic Safety Project



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E07 WESTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5

EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E07-WB.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

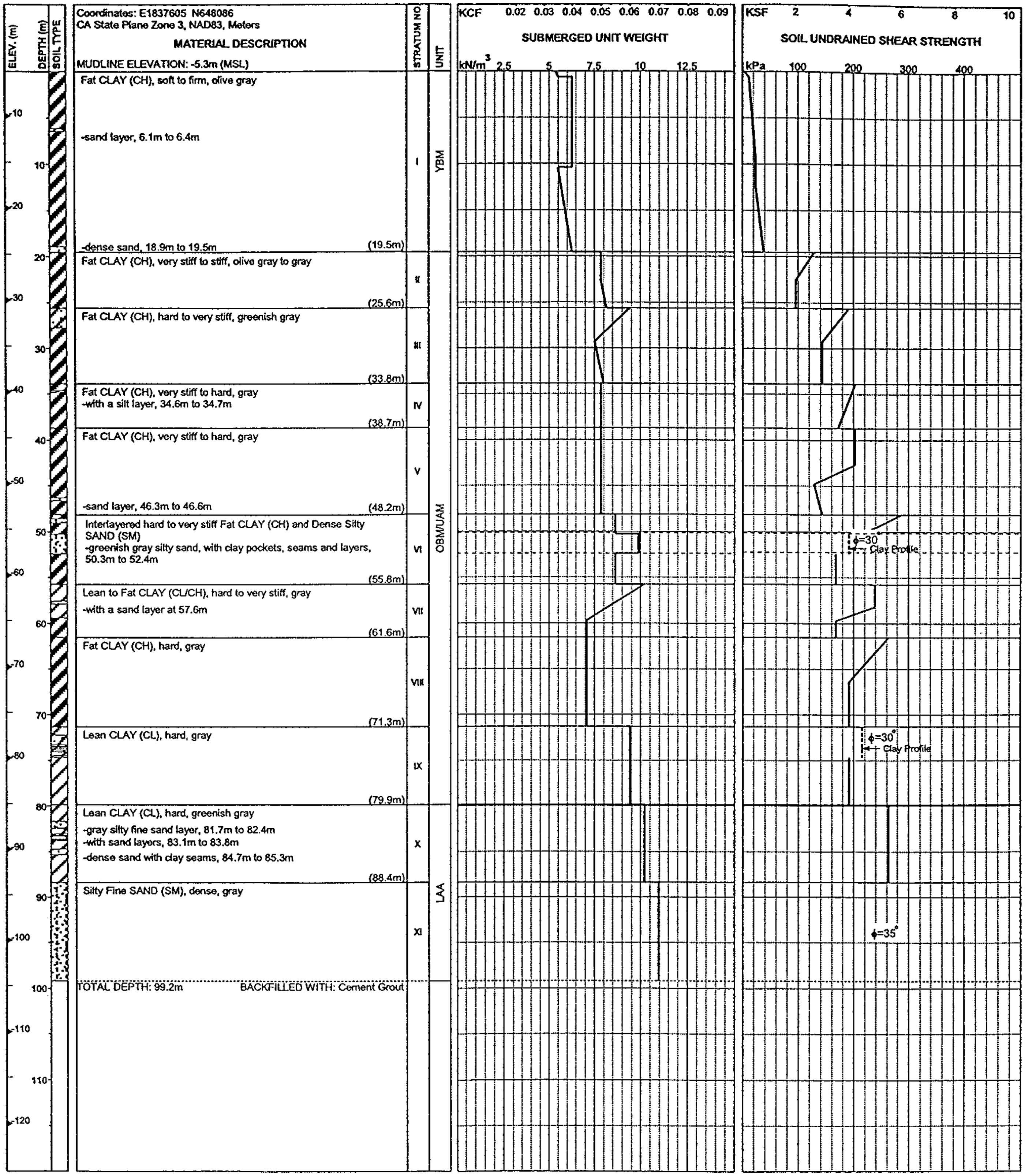
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.804E+005	0.000E+000	0.000E+000	0.000E+000	-1.158E+007	0.000E+000
0.000E+000	7.441E+005	0.000E+000	1.127E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.624E+007	0.000E+000	1.863E-009	0.000E+000
0.000E+000	1.127E+007	0.000E+000	9.047E+008	0.000E+000	0.000E+000
-1.158E+007	0.000E+000	0.000E+000	0.000E+000	7.567E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	5.887E+007

PILE-GROUP STIFFNESS MATRIX (SERVICE CONDITION)

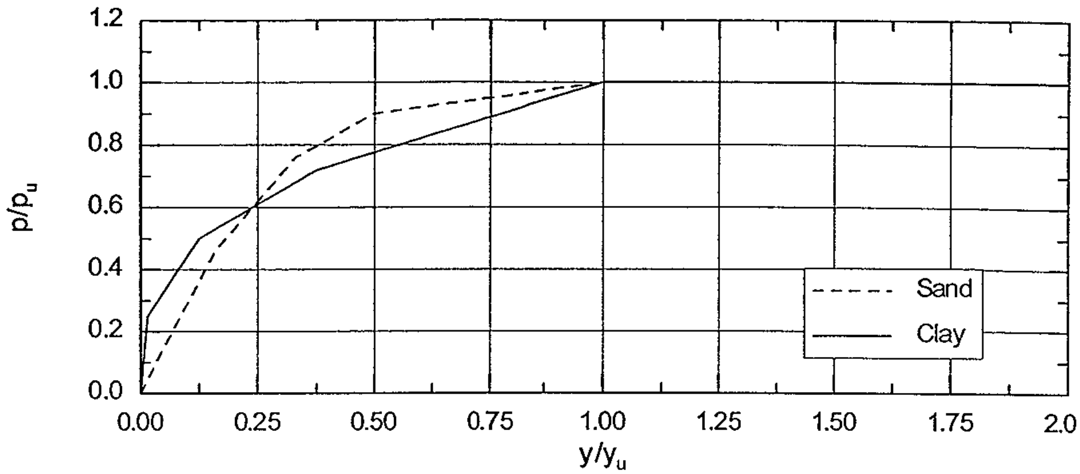
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.038E+006	0.000E+000	0.000E+000	0.000E+000	-3.302E+007	0.000E+000
0.000E+000	3.996E+006	0.000E+000	3.266E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.191E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	3.266E+007	0.000E+000	1.077E+009	0.000E+000	0.000E+000
-3.302E+007	0.000E+000	0.000E+000	0.000E+000	8.748E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.285E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -6.0 m

CONDENSED STIFFNESS MATRICES
PIER E07 WESTBOUND
SFOBB East Span Seismic Safety Project



SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E08 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.02	22		
9-12	Clay	0.02	22		
12-15	Clay	0.01	30		
15-18	Clay	0.01	35		
18-21	Clay	0.01	40		
21-24	Clay	0.005	105		
24-27	Clay	0.005	140		
27 -30	Clay	0.005	160		
30-33	Clay	0.005	140		
33-36	Clay	0.005	190		
36-39	Clay	0.005	190		
39-42	Clay	0.005	200		
42-45	Clay	0.005	160		
45-51	Clay	0.005	200		
51-57	Clay	0.005	200		
57-63	Clay	0.005	200		
63-69	Clay	0.005	210		
69-75	Sand			30	5440
75-81	Clay	0.005	190		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	37.684	100.0	Clay
3.0	113	100.0	Clay
6.0	128	100.0	Clay
9.0	149	100.0	Clay
12.0	290	50.0	Clay
15.0	370	50.0	Clay
18.0	446	50.0	Clay
21.0	446	50.0	Clay
24.0	1173	25.0	Clay
30.0	1561	25.0	Clay
36.0	2126	25.0	Clay
42.0	1792	25.0	Clay
51.0	2239	25.0	Clay
63.0	2239	25.0	Clay
81.0	2126	25.0	Clay

LATERAL PILE DESIGN PARAMETERS
PIER E08 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	28	1.6	56	12.5	81	37.5	113	100.0	113	249.9		
6.0	3	0	0	32	1.6	64	12.5	92	37.5	128	100.0	128	249.9		
9.0	4	0	0	37	1.6	74	12.5	107	37.5	149	100.0	149	249.9		
12.0	5	0	0	72	0.8	145	6.2	209	18.7	290	50.0	290	125.0		
15.0	6	0	0	92	0.8	185	6.2	266	18.7	370	50.0	370	125.0		
18.0	7	0	0	111	0.8	223	6.2	321	18.7	446	50.0	446	125.0		
21.0	8	0	0	111	0.8	223	6.2	321	18.7	446	50.0	446	125.0		
24.0	9	0	0	293	0.4	586	3.1	844	9.4	1173	25.0	1173	62.5		
30.0	10	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
36.0	11	0	0	531	0.4	1063	3.1	1531	9.4	2126	25.0	2126	62.5		
42.0	12	0	0	448	0.4	896	3.1	1290	9.4	1792	25.0	1792	62.5		
51.0	13	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		
63.0	14	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		
81.0	16	0	0	531	0.4	1063	3.1	1531	9.4	2126	25.0	2126	62.5		

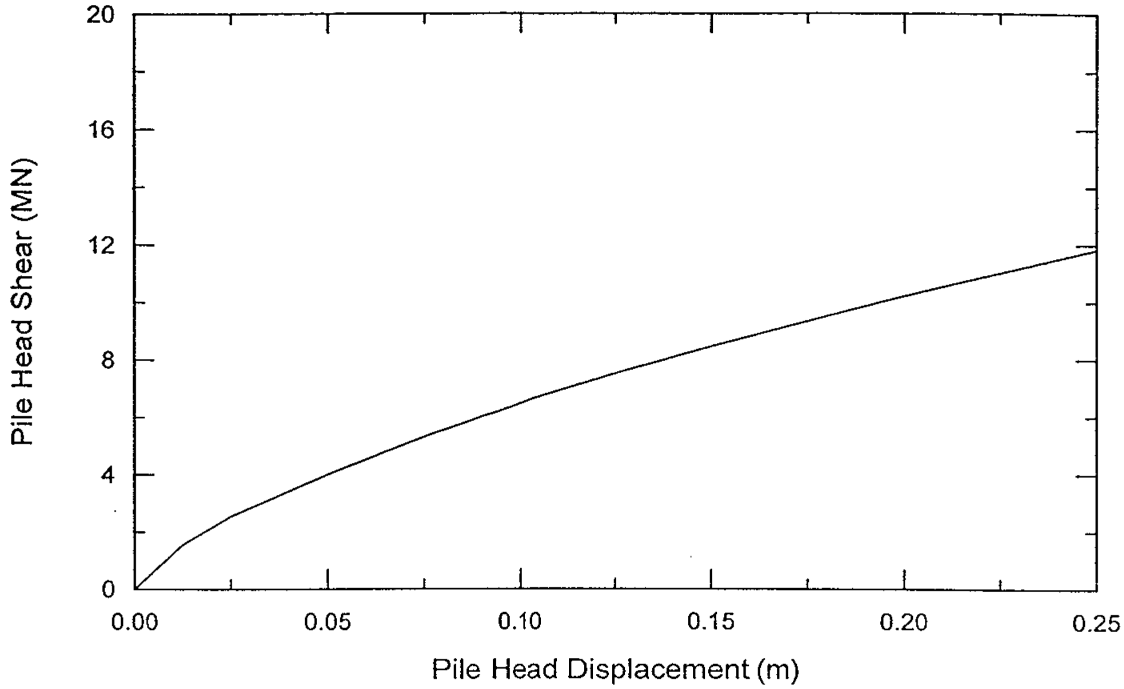
COORDINATES of p-y CURVES

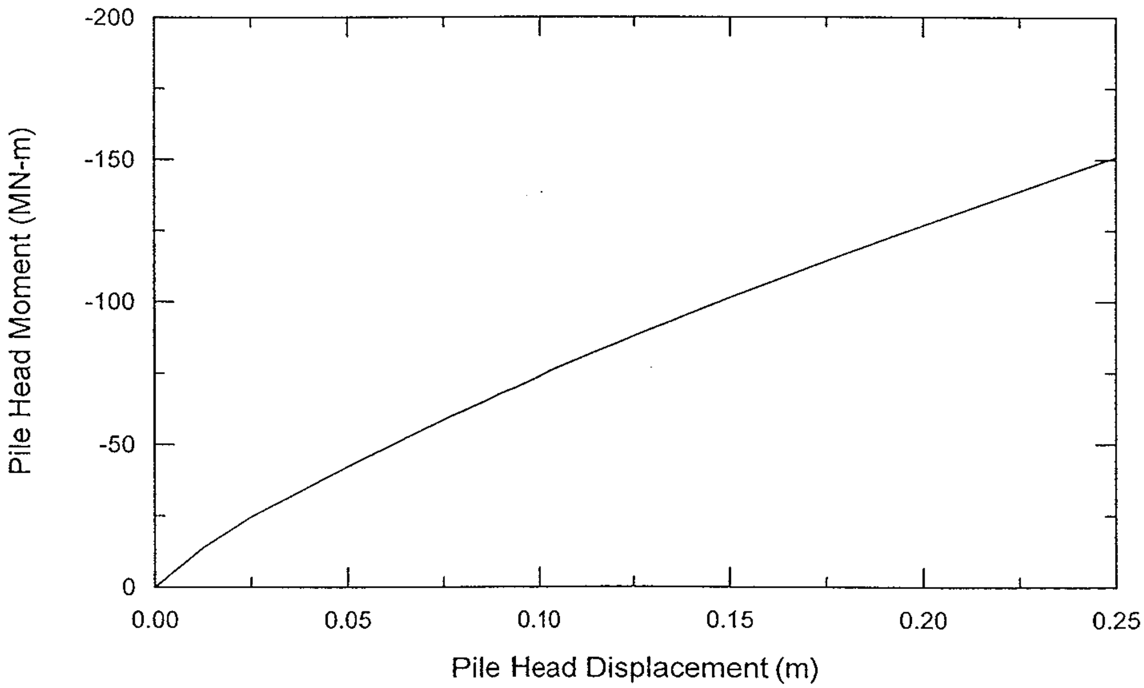
PIER E08 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

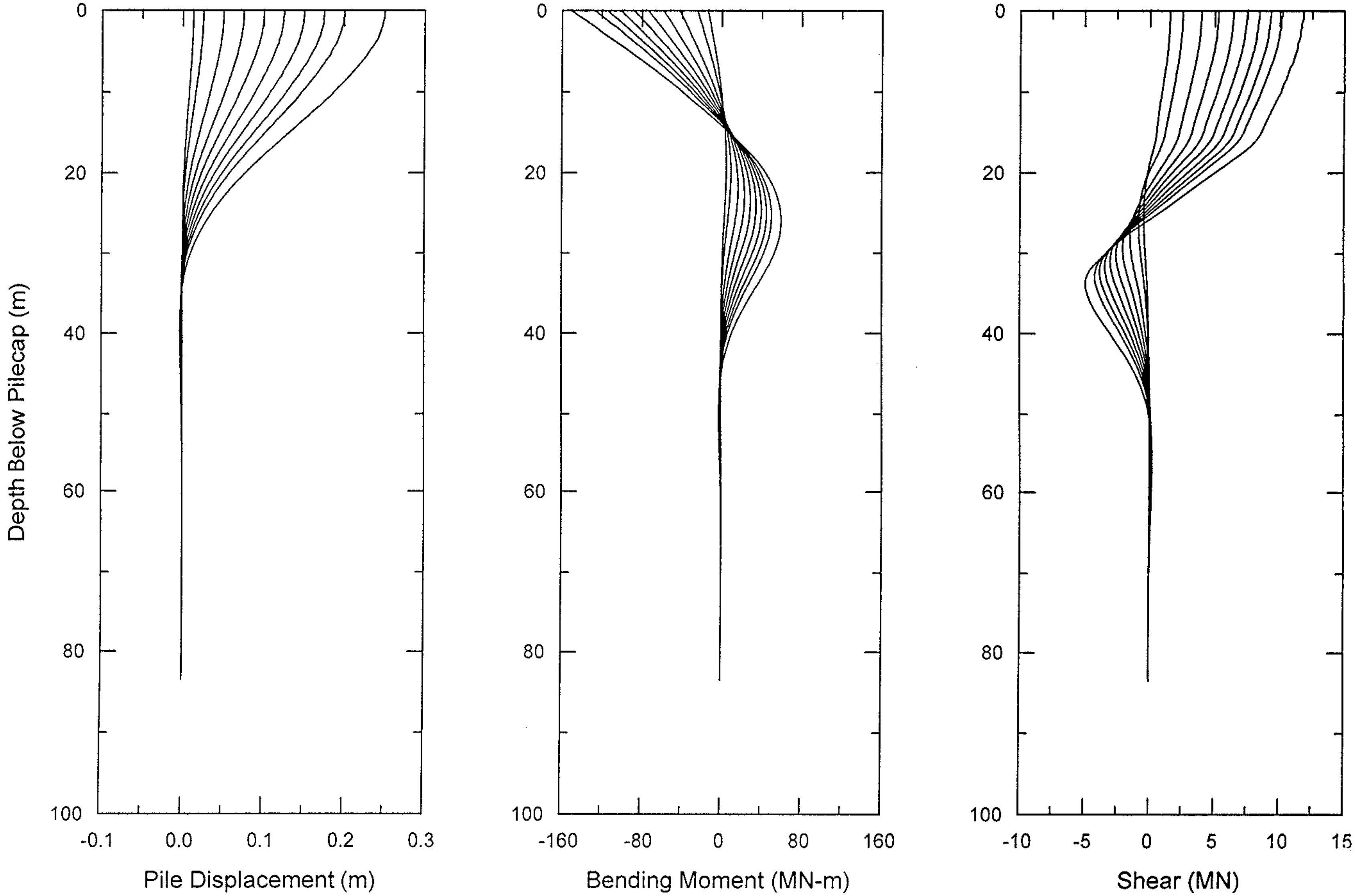
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E08 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E08.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E08 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.972E+005	0.000E+000	0.000E+000	0.000E+000	-2.132E+006	0.000E+000
0.000E+000	5.596E+005	0.000E+000	1.811E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.660E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.811E+006	0.000E+000	5.908E+008	0.000E+000	0.000E+000
-2.132E+006	0.000E+000	0.000E+000	0.000E+000	4.391E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	3.377E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.620E+006	0.000E+000	0.000E+000	0.000E+000	-1.170E+007	0.000E+000
0.000E+000	1.573E+006	0.000E+000	1.131E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.188E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.131E+007	0.000E+000	8.897E+008	0.000E+000	0.000E+000
-1.170E+007	0.000E+000	0.000E+000	0.000E+000	6.887E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	9.491E+007

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -4.8 m

CONDENSED STIFFNESS MATRICES
PIER E08 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

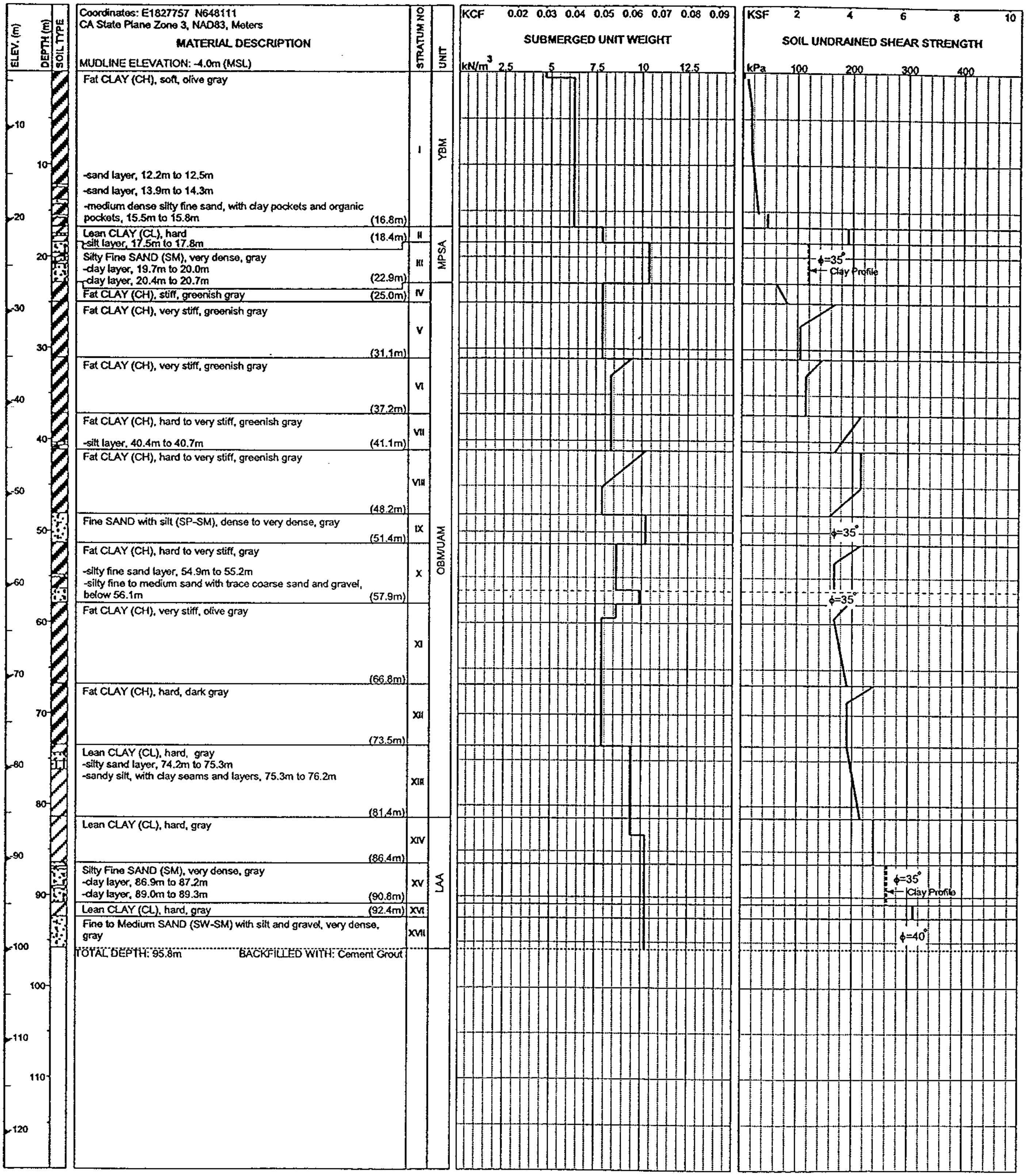
PLATE E08.6

Coordinates: E1827757 N648111
CA State Plane Zone 3, NAD83, Meters

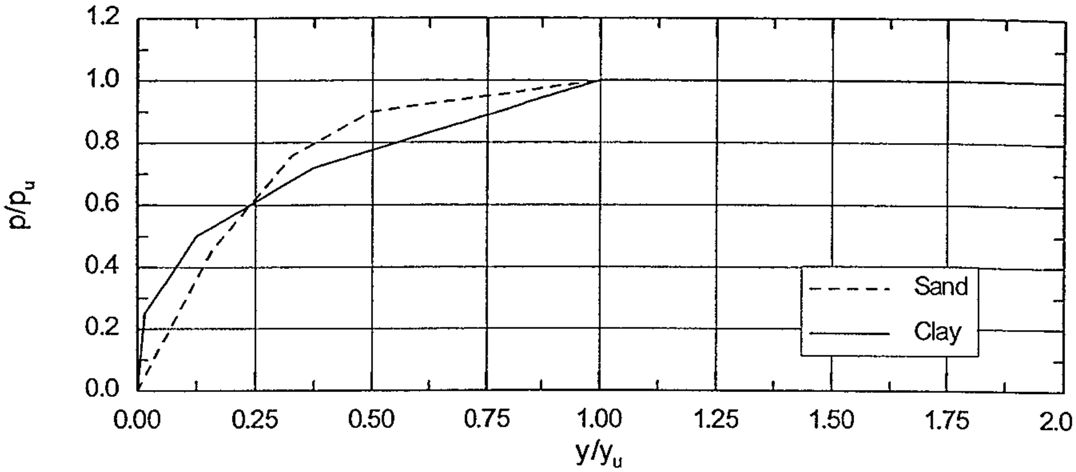
MUDLINE ELEVATION: -4.0m (MSL)

MATERIAL DESCRIPTION	STRATUM NO	UNIT
Fat CLAY (CH), soft, olive gray -sand layer, 12.2m to 12.5m -sand layer, 13.9m to 14.3m -medium dense silty fine sand, with clay pockets and organic pockets, 15.5m to 15.8m (16.8m)	I	YBM
Lean CLAY (CL), hard -silt layer, 17.5m to 17.8m (18.4m)	II	MPSA
Silty Fine SAND (SM), very dense, gray -clay layer, 19.7m to 20.0m -clay layer, 20.4m to 20.7m (22.9m)	III	MPSA
Fat CLAY (CH), stiff, greenish gray (25.0m)	IV	OBM/UAM
Fat CLAY (CH), very stiff, greenish gray (31.1m)	V	OBM/UAM
Fat CLAY (CH), very stiff, greenish gray (37.2m)	VI	OBM/UAM
Fat CLAY (CH), hard to very stiff, greenish gray -silt layer, 40.4m to 40.7m (41.1m)	VII	OBM/UAM
Fat CLAY (CH), hard to very stiff, greenish gray (48.2m)	VIII	OBM/UAM
Fine SAND with silt (SP-SM), dense to very dense, gray (51.4m)	IX	OBM/UAM
Fat CLAY (CH), hard to very stiff, gray -silty fine sand layer, 54.9m to 55.2m -silty fine to medium sand with trace coarse sand and gravel, below 56.1m (57.9m)	X	OBM/UAM
Fat CLAY (CH), very stiff, olive gray (66.8m)	XI	OBM/UAM
Fat CLAY (CH), hard, dark gray (73.5m)	XII	OBM/UAM
Lean CLAY (CL), hard, gray -silty sand layer, 74.2m to 75.3m -sandy silt, with clay seams and layers, 75.3m to 76.2m (81.4m)	XIII	OBM/UAM
Lean CLAY (CL), hard, gray (86.4m)	XIV	LAA
Silty Fine SAND (SM), very dense, gray -clay layer, 86.9m to 87.2m -clay layer, 89.0m to 89.3m (90.8m)	XV	LAA
Lean CLAY (CL), hard, gray (92.4m)	XVI	LAA
Fine to Medium SAND (SW-SM) with silt and gravel, very dense, gray	XVII	LAA

TOTAL DEPTH: 95.8m BACKFILLED WITH: Cement Grout



SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E09 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.02	20		
9-12	Clay	0.02	20		
12-15	Clay	0.01	25		
15-18	Clay	0.075	60		
18-21	Sand			35	5440
21-24	Clay	0.005	110		
24-27	Clay	0.005	110		
27 -30	Clay	0.005	100		
30-33	Clay	0.005	120		
33-36	Clay	0.005	120		
36-39	Clay	0.005	200		
39-42	Clay	0.005	200		
42-45	Clay	0.005	220		
45-51	Sand			35	5440
51-57	Clay	0.005	170		
57-63	Clay	0.005	170		
63-69	Clay	0.005	200		
69-75	Clay	0.005	190		
75-81	Clay	0.005	200		

p-y DATA

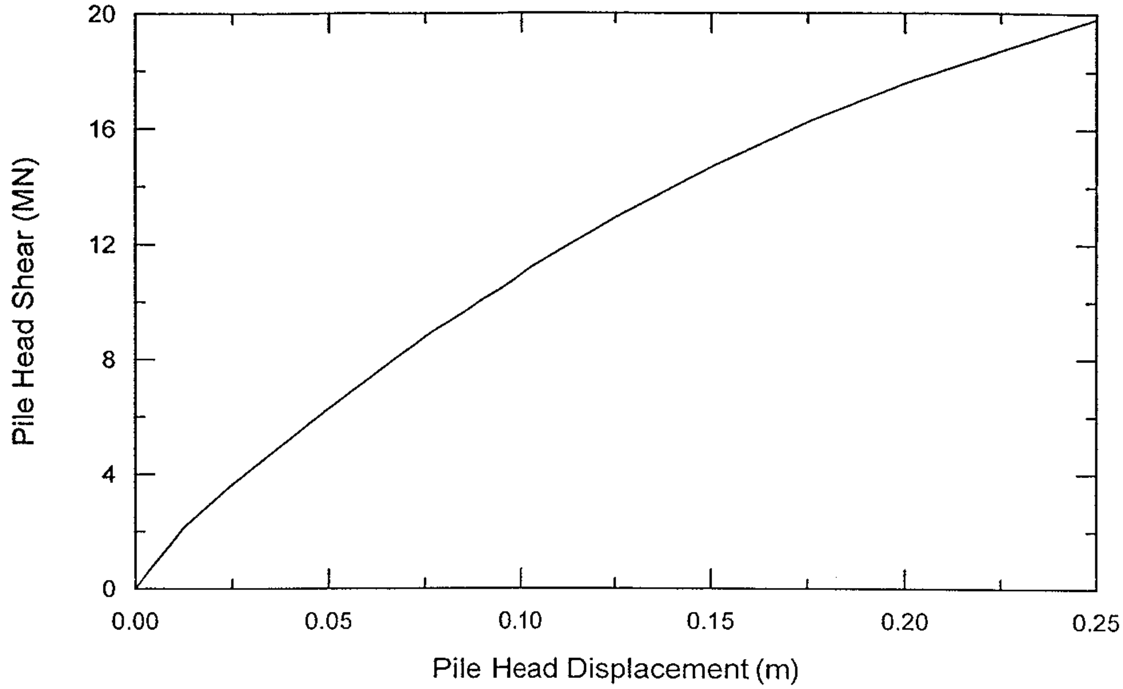
Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	38	100.0	Clay
3.0	113	100.0	Clay
6.0	150	100.0	Clay
9.0	187	100.0	Clay
12.0	183	50.0	Clay
15.0	561	37.5	Clay
17.9	625	37.5	Clay
18.1	3031	18.5	Sand
20.9	4331	22.9	Sand
21.1	1166	25.0	Clay
24.0	1238	25.0	Clay
30.0	1345	25.0	Clay
36.0	2234	25.0	Clay
42.0	2462	25.0	Clay
50.9	23956	52.1	Sand
51.1	1900	25.0	Clay
63.0	1900	25.0	Clay
81.0	2239	25.0	Clay

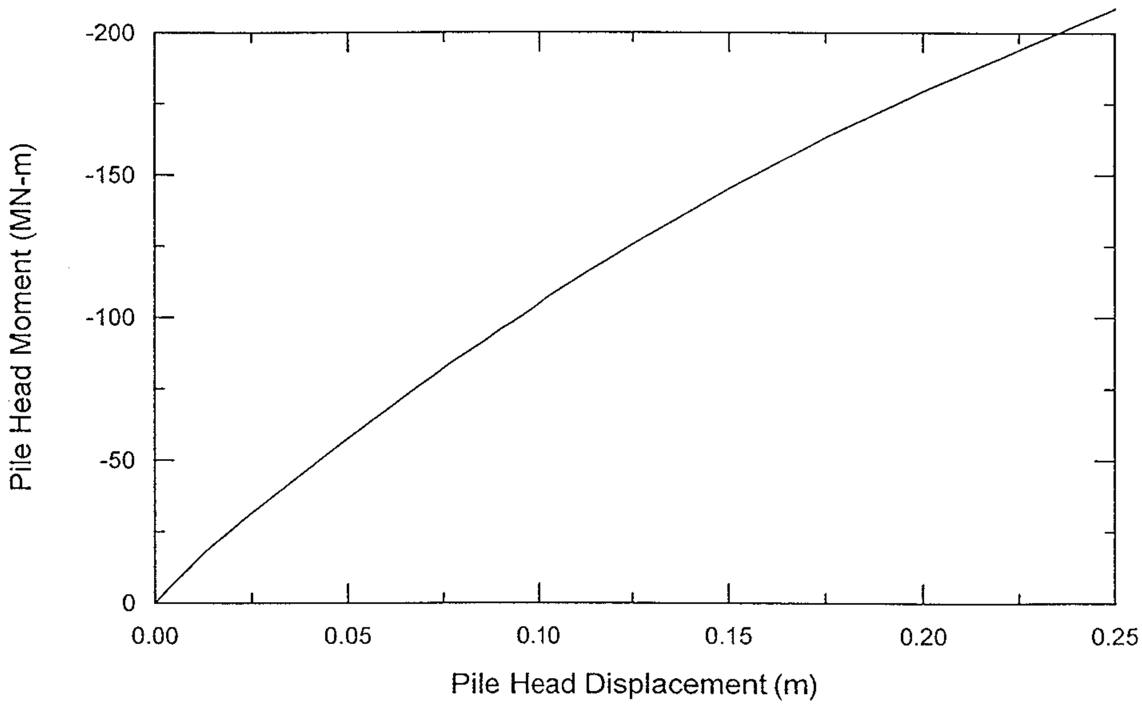
LATERAL PILE DESIGN PARAMETERS
PIER E09 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	28	1.6	56	12.5	81	37.5	113	100.0	113	249.9		
6.0	3	0	0	37	1.6	75	12.5	108	37.5	150	100.0	150	249.9		
9.0	4	0	0	46	1.6	93	12.5	135	37.5	187	100.0	187	249.9		
12.0	5	0	0	45	0.8	91	6.2	131	18.7	183	50.0	183	125.0		
15.0	6	0	0	140	0.6	280	4.7	404	14.1	561	37.5	561	93.7		
17.9	7	0	0	156	0.6	312	4.7	450	14.1	625	37.5	625	93.7		
18.1	8	0	0	303	0.6	1394	3.1	2303	6.2	2758	9.3	3031	18.5	3031	30.9
20.9	9	0	0	433	0.8	1992	3.8	3292	7.6	3941	11.5	4331	22.9	4331	38.2
21.1	10	0	0	291	0.4	583	3.1	839	9.4	1166	25.0	1166	62.5		
24.0	11	0	0	309	0.4	619	3.1	891	9.4	1238	25.0	1238	62.5		
30.0	12	0	0	336	0.4	672	3.1	969	9.4	1345	25.0	1345	62.5		
36.0	13	0	0	558	0.4	1117	3.1	1608	9.4	2234	25.0	2234	62.5		
42.0	14	0	0	615	0.4	1231	3.1	1773	9.4	2462	25.0	2462	62.5		
50.9	15	0	0	2395	1.7	11020	8.7	18207	17.4	21800	26.0	23956	52.1	23956	86.8
51.1	16	0	0	475	0.4	950	3.1	1368	9.4	1900	25.0	1900	62.5		
63.0	17	0	0	475	0.4	950	3.1	1368	9.4	1900	25.0	1900	62.5		
81.0	18	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		

COORDINATES of p-y CURVES
PIER E09 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

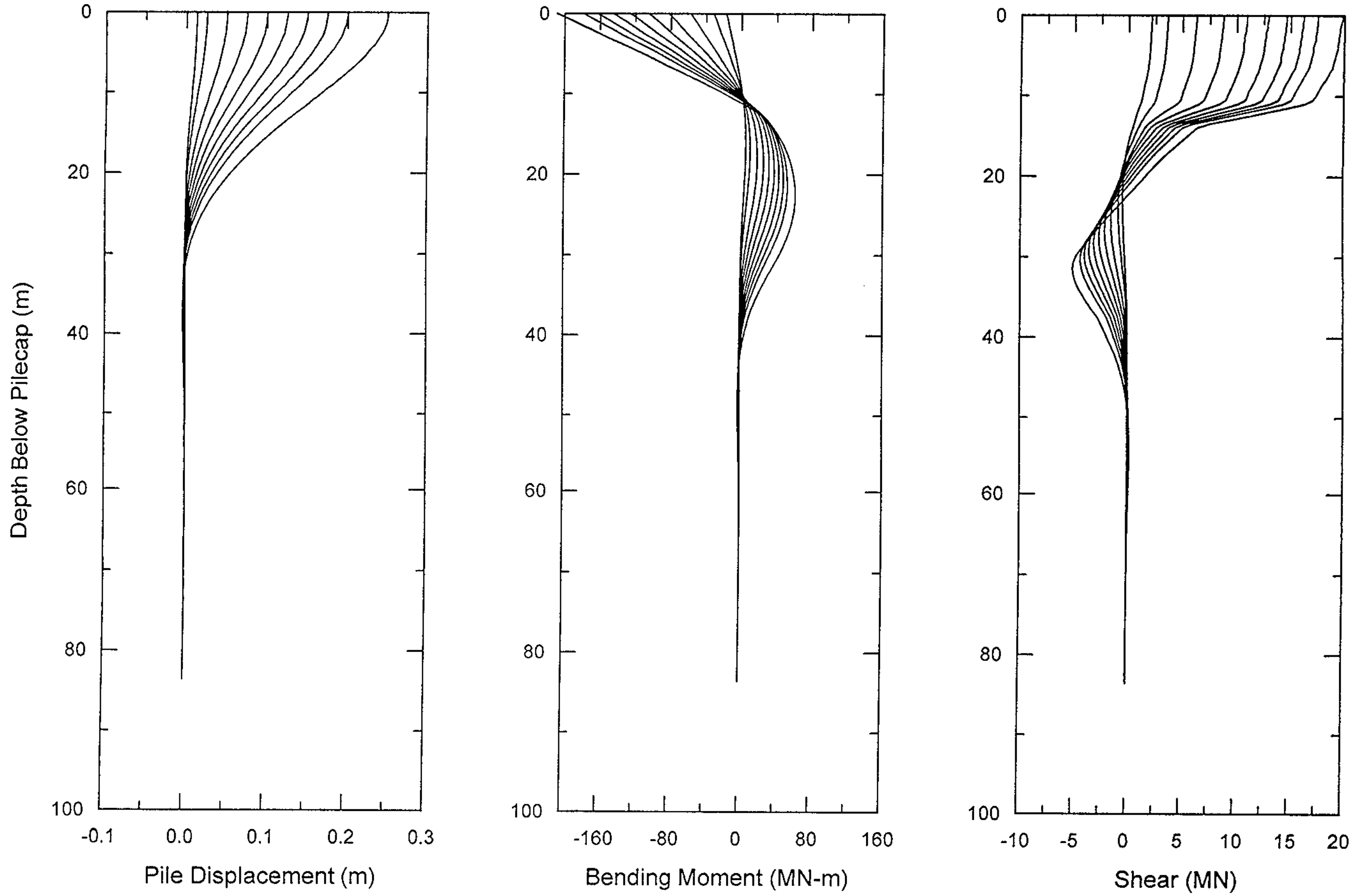
Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E09 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E09.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E09 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5

EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E09.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.073E+005	0.000E+000	0.000E+000	0.000E+000	-4.609E+006	0.000E+000
0.000E+000	7.699E+005	0.000E+000	4.291E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.674E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	4.291E+006	0.000E+000	6.255E+008	0.000E+000	0.000E+000
-4.609E+006	0.000E+000	0.000E+000	0.000E+000	4.724E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	4.659E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.844E+006	0.000E+000	0.000E+000	0.000E+000	-1.527E+007	0.000E+000
0.000E+000	1.798E+006	0.000E+000	1.486E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.188E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.486E+007	0.000E+000	9.377E+008	0.000E+000	0.000E+000
-1.527E+007	0.000E+000	0.000E+000	0.000E+000	7.369E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.088E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -4.4 m

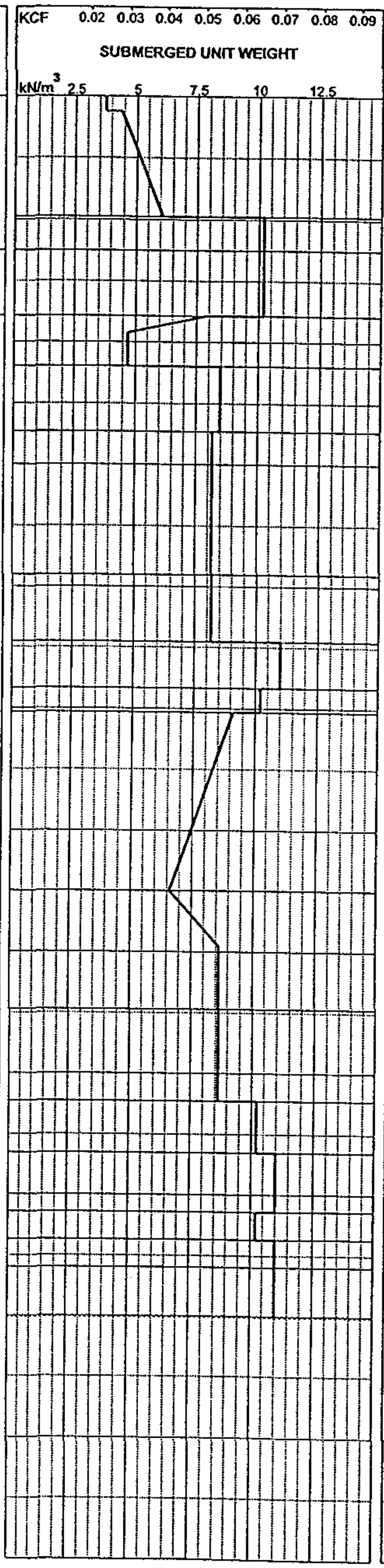
CONDENSED STIFFNESS MATRICES
PIER E09 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

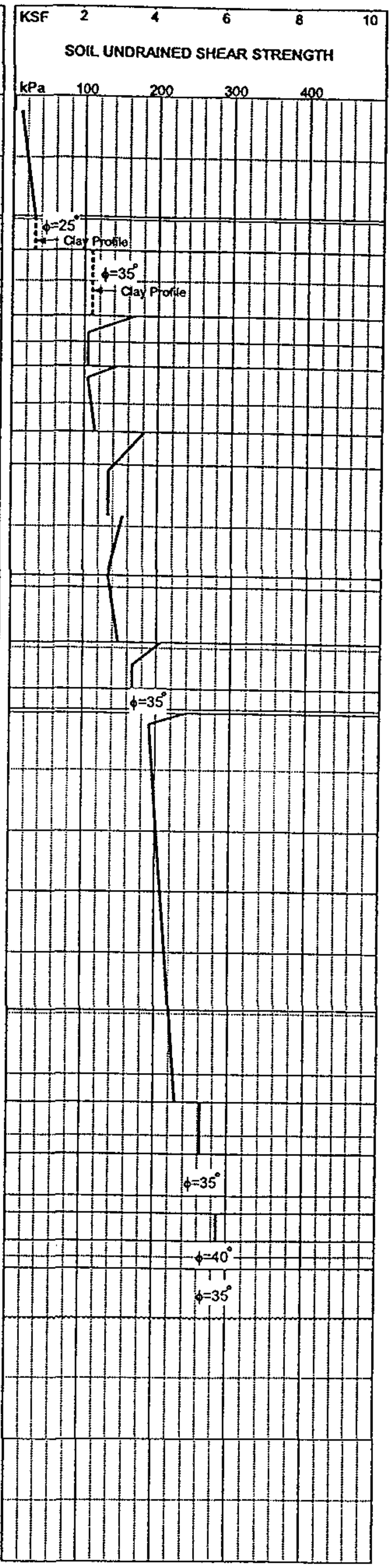
Coordinates: E1837925 N648095
CA State Plane Zone 3, NAD83, Meters

MUDLINE ELEVATION: -3.8m (MSL)

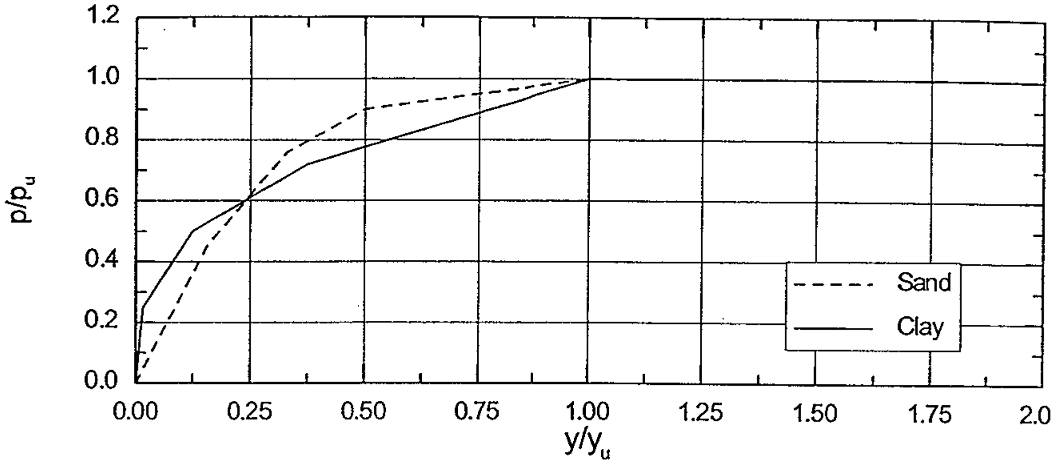
MATERIAL DESCRIPTION	Bottom depth	STRATUM NO	UNIT
Fat CLAY (CH), soft to firm, gray	(9.8m)	I	YBM
Fine SAND with silt (SP-SM), loose to medium dense, gray -firm clay layer, 10.5m to 10.8m -firm clay below 12.2m	(12.5m)	II	MPSA
Fine SAND (SP), very dense, gray -with a stiff clay layer, 12.8m to 13.7m	(17.8m)	III	MPSA
Fat CLAY (CH), very stiff, gray -stiff to very stiff dark brown organic clay, with a few gray clay pockets, below 20.1m	(21.9m)	IV	OBM/UAM
Fat CLAY (CH), very stiff, gray	(27.3m)	V	OBM/UAM
Fat CLAY (CH), very stiff, gray	(39.0m)	VI	OBM/UAM
Fat CLAY (CH), very stiff, gray	(44.5m)	VII	OBM/UAM
Lean CLAY (CL), hard to very stiff, greenish gray	(48.3m)	VIII	OBM/UAM
Fine SAND with silt (SP-SM), dense, greenish gray	(50.3m)	IX	OBM/UAM
Fat CLAY (CH), hard, olive gray	(64.9m)	X	OBM/UAM
Fat CLAY (CH), hard, olive gray	(74.7m)	XI	OBM/UAM
Lean CLAY (CL), hard, gray -sandy silt with clay seams, 75.3m to 76.4m	(82.3m)	XII	OBM/UAM
Lean CLAY (CL), hard, olive gray to gray -dense sand layer, 85.5m to 85.8m	(86.6m)	XIII	LAA
Silty Fine SAND (SM), dense, dark gray -fine to medium sand, with silt and fine gravel, at 89.6m	(91.4m)	XIV	LAA
Lean CLAY (CL), hard, greenish gray	(93.7m)	XV	LAA
Medium to Coarse SAND (SW-SM) with silt and gravel	(96.0m)	XVI	LAA
Silty Fine to Medium SAND (SM) with coarse sand and fine gravel, very dense, gray -hard, yellowish brown lean clay layer with gravel and silt pockets, 97.5m to 98.1m		XVII	LAA

TOTAL DEPTH: 100.1m BACKFILLED WITH: Cement Grout





SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E10 EASTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.01	25		
9-12	Sand			25	5440
12-15	Sand			35	5440
15-18	Clay	0.005	100		
18-21	Clay	0.005	115		
21-24	Clay	0.005	120		
24-27	Clay	0.005	115		
27 -30	Clay	0.005	150		
30-33	Clay	0.005	140		
33-36	Clay	0.005	140		
36-39	Clay	0.005	140		
39-42	Clay	0.005	140		
42-45	Clay	0.005	145		
45-51	Clay	0.005	165		
51-57	Clay	0.005	195		
57-63	Clay	0.005	200		
63-69	Clay	0.005	210		
69-75	Clay	0.005	220		
75-81	Clay	0.005	225		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	38	100.0	Clay
3.0	107	100.0	Clay
6.0	129	50.0	Clay
8.9	149	50.0	Clay
9.1	339	4.1	Sand
12.0	1530	14.1	Sand
14.9	2508	18.6	Sand
15.1	881	25.0	Clay
18.0	1100	25.0	Clay
21.0	1217	25.0	Clay
24.0	1345	25.0	Clay
30.0	1566	25.0	Clay
36.0	1566	25.0	Clay
42.0	1625	25.0	Clay
51.0	1846	25.0	Clay
63.0	2239	25.0	Clay
81.0	2519	25.0	Clay

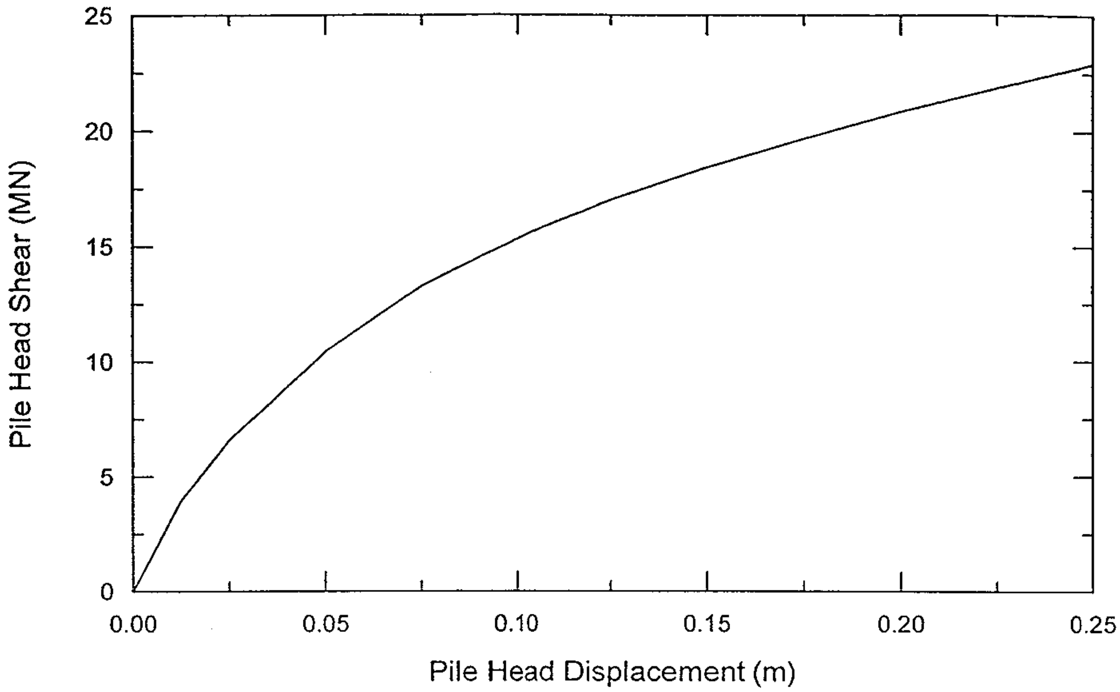
LATERAL PILE DESIGN PARAMETERS
PIER E10 EASTBOUND
SFOBB East Span Seismic Safety Project

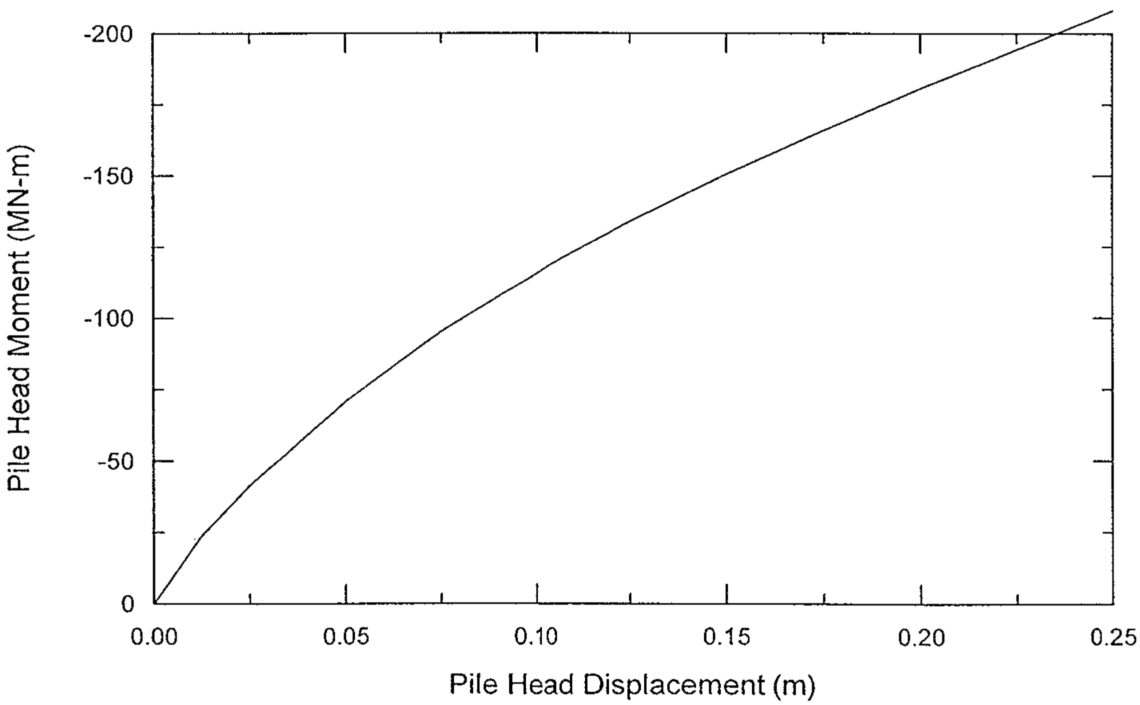
PLATE E10-EB.2

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	26	1.6	53	12.5	77	37.5	107	100.0	107	249.9		
6.0	3	0	0	32	0.8	64	6.2	93	18.7	129	50.0	129	125.0		
8.9	4	0	0	37	0.8	74	6.2	107	18.7	149	50.0	149	125.0		
9.1	5	0	0	33	0.1	156	0.7	258	1.4	309	2.1	339	4.1	339	6.9
12.0	6	0	0	153	0.5	704	2.3	1163	4.7	1392	7.0	1530	14.1	1530	23.4
14.9	7	0	0	250	0.6	1153	3.1	1906	6.2	2282	9.3	2508	18.6	2508	31.1
15.1	8	0	0	220	0.4	440	3.1	634	9.4	881	25.0	881	62.5		
18.0	9	0	0	275	0.4	550	3.1	792	9.4	1100	25.0	1100	62.5		
21.0	10	0	0	304	0.4	608	3.1	876	9.4	1217	25.0	1217	62.5		
24.0	11	0	0	336	0.4	672	3.1	969	9.4	1345	25.0	1345	62.5		
30.0	12	0	0	391	0.4	783	3.1	1127	9.4	1566	25.0	1566	62.5		
36.0	13	0	0	391	0.4	783	3.1	1127	9.4	1566	25.0	1566	62.5		
42.0	14	0	0	406	0.4	812	3.1	1170	9.4	1625	25.0	1625	62.5		
51.0	15	0	0	461	0.4	923	3.1	1329	9.4	1846	25.0	1846	62.5		
63.0	16	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		
81.0	17	0	0	629	0.4	1259	3.1	1814	9.4	2519	25.0	2519	62.5		

COORDINATES of p-y CURVES
PIER E10 EASTBOUND
SFOBB East Span Seismic Safety Project

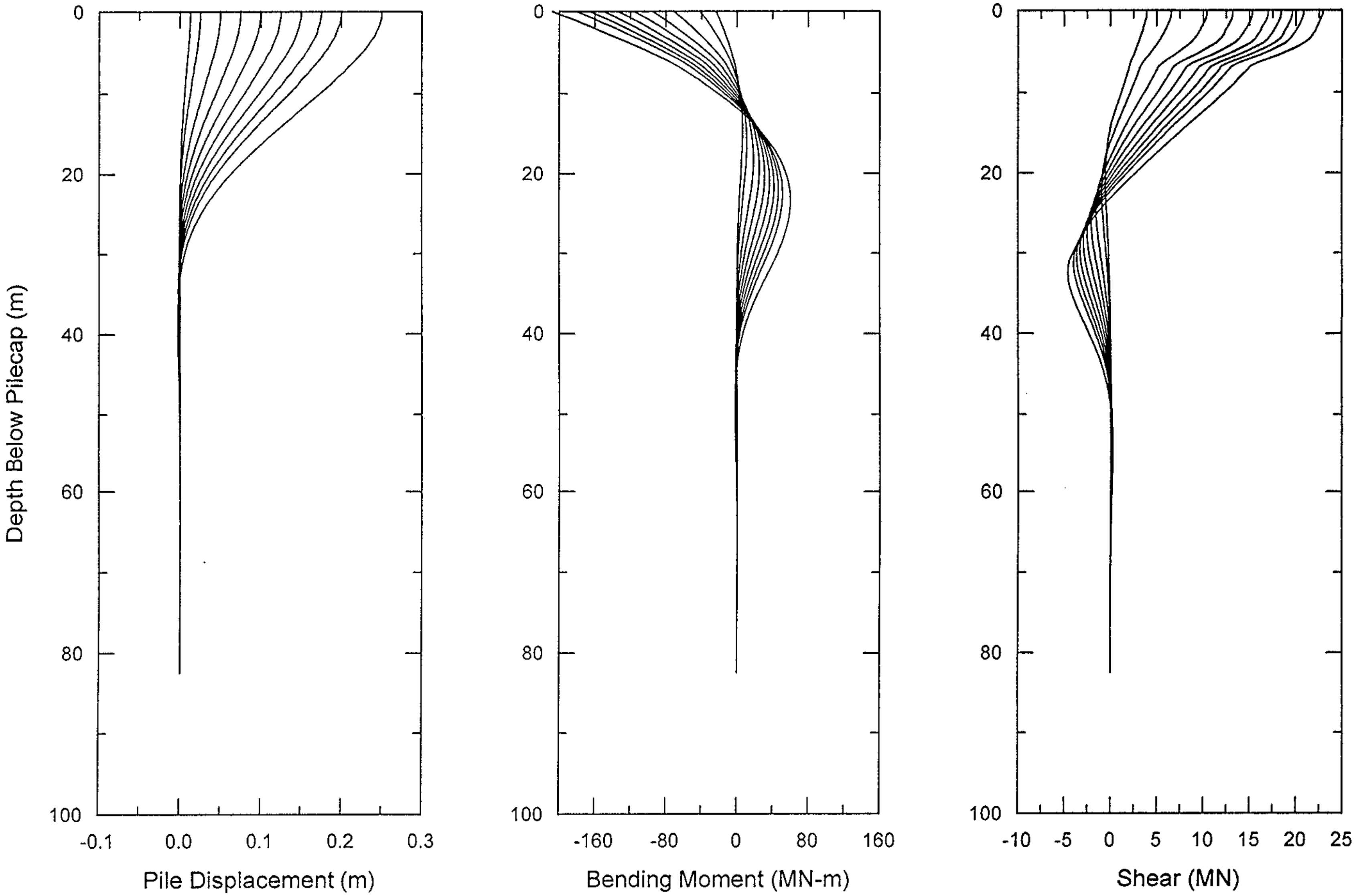
Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E10 EASTBOUND
SFOBB East Span Seismic Safety Project

PLATE E10-EB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E10 EASTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

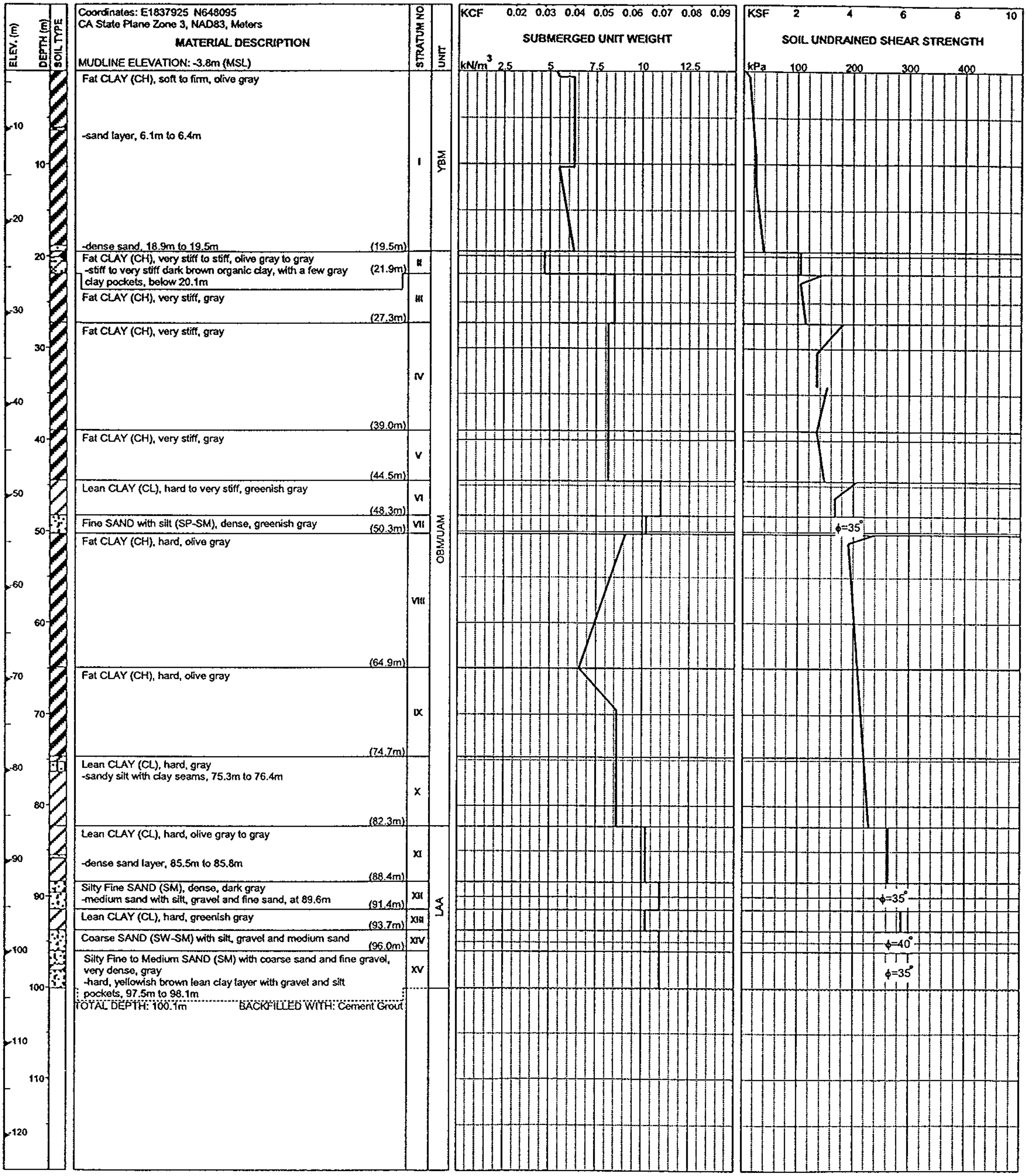
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.127E+006	0.000E+000	0.000E+000	0.000E+000	-8.050E+006	0.000E+000
0.000E+000	1.089E+006	0.000E+000	7.729E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.716E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	7.729E+006	0.000E+000	6.801E+008	0.000E+000	0.000E+000
-8.050E+006	0.000E+000	0.000E+000	0.000E+000	5.231E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	6.563E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

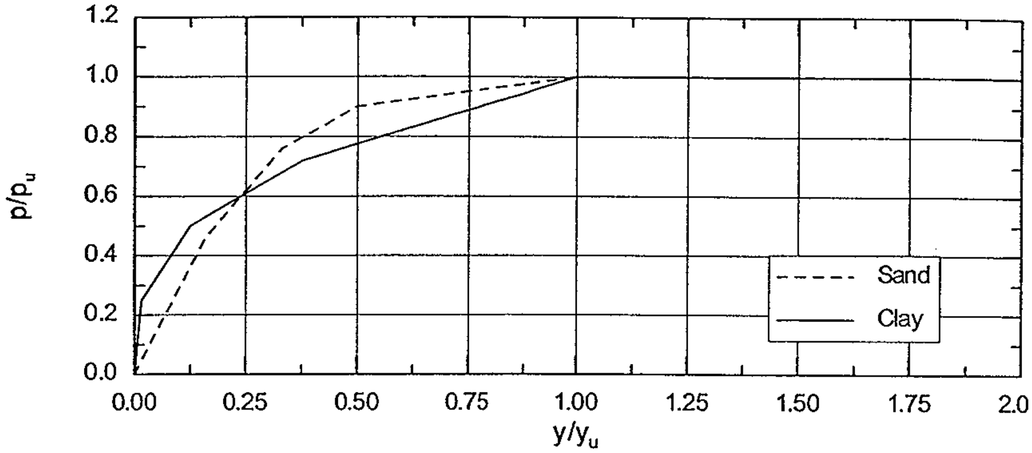
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.656E+006	0.000E+000	0.000E+000	0.000E+000	-3.349E+007	0.000E+000
0.000E+000	3.613E+006	0.000E+000	3.312E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.190E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	3.312E+007	0.000E+000	1.127E+009	0.000E+000	0.000E+000
-3.349E+007	0.000E+000	0.000E+000	0.000E+000	9.253E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.133E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -5.25 m

CONDENSED STIFFNESS MATRICES
PIER E10 EASTBOUND
SFOBB East Span Seismic Safety Project



SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E10 WESTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.02	20		
9-12	Clay	0.02	20		
12-15	Clay	0.01	25		
15-18	Clay	0.01	30		
18-21	Clay	0.01	35		
21-24	Clay	0.005	110		
24-27	Clay	0.005	110		
27 -30	Clay	0.005	160		
30-33	Clay	0.005	135		
33-36	Clay	0.005	145		
36-39	Clay	0.005	140		
39-42	Clay	0.005	140		
42-45	Clay	0.005	150		
45-51	Clay	0.005	175		
51-57	Clay	0.005	195		
57-63	Clay	0.005	200		
63-69	Clay	0.005	210		
69-75	Clay	0.005	220		
75-81	Clay	0.005	225		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	37.684	100.0	Clay
3.0	113	100.0	Clay
6.0	151	100.0	Clay
9.0	189	100.0	Clay
12.0	185	50.0	Clay
15.0	336	50.0	Clay
18.0	392	50.0	Clay
21.0	392	50.0	Clay
24.0	1227	25.0	Clay
30.0	1512	25.0	Clay
36.0	1566	25.0	Clay
42.0	1679	25.0	Clay
51.0	1959	25.0	Clay
63.0	2239	25.0	Clay
81.0	2519	25.0	Clay

LATERAL PILE DESIGN PARAMETERS
PIER E10 WESTBOUND
SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	28	1.6	56	12.5	81	37.5	113	100.0	113	249.9		
6.0	3	0	0	37	1.6	75	12.5	109	37.5	151	100.0	151	249.9		
9.0	4	0	0	47	1.6	94	12.5	136	37.5	189	100.0	189	249.9		
12.0	5	0	0	46	0.8	92	6.2	133	18.7	185	50.0	185	125.0		
15.0	6	0	0	84	0.8	168	6.2	242	18.7	336	50.0	336	125.0		
18.0	7	0	0	98	0.8	196	6.2	282	18.7	392	50.0	392	125.0		
21.0	8	0	0	98	0.8	196	6.2	282	18.7	392	50.0	392	125.0		
24.0	9	0	0	306	0.4	613	3.1	883	9.4	1227	25.0	1227	62.5		
30.0	10	0	0	378	0.4	756	3.1	1089	9.4	1512	25.0	1512	62.5		
36.0	11	0	0	391	0.4	783	3.1	1127	9.4	1566	25.0	1566	62.5		
42.0	12	0	0	419	0.4	839	3.1	1209	9.4	1679	25.0	1679	62.5		
51.0	13	0	0	489	0.4	979	3.1	1410	9.4	1959	25.0	1959	62.5		
63.0	14	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		
81.0	15	0	0	629	0.4	1259	3.1	1814	9.4	2519	25.0	2519	62.5		

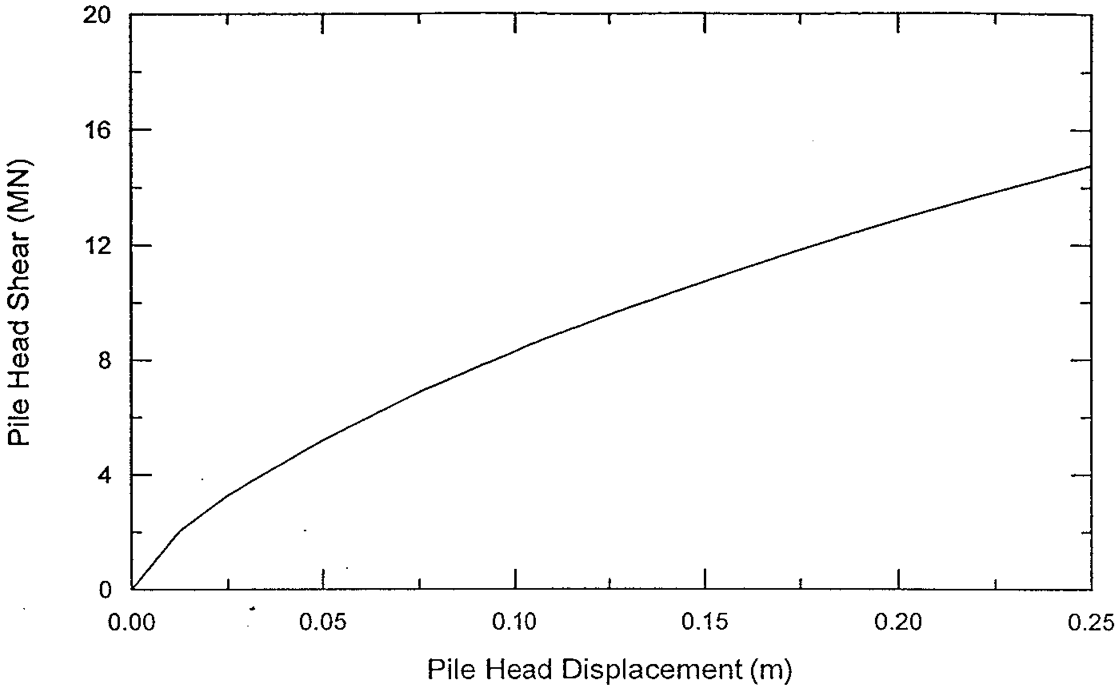
COORDINATES of p-y CURVES

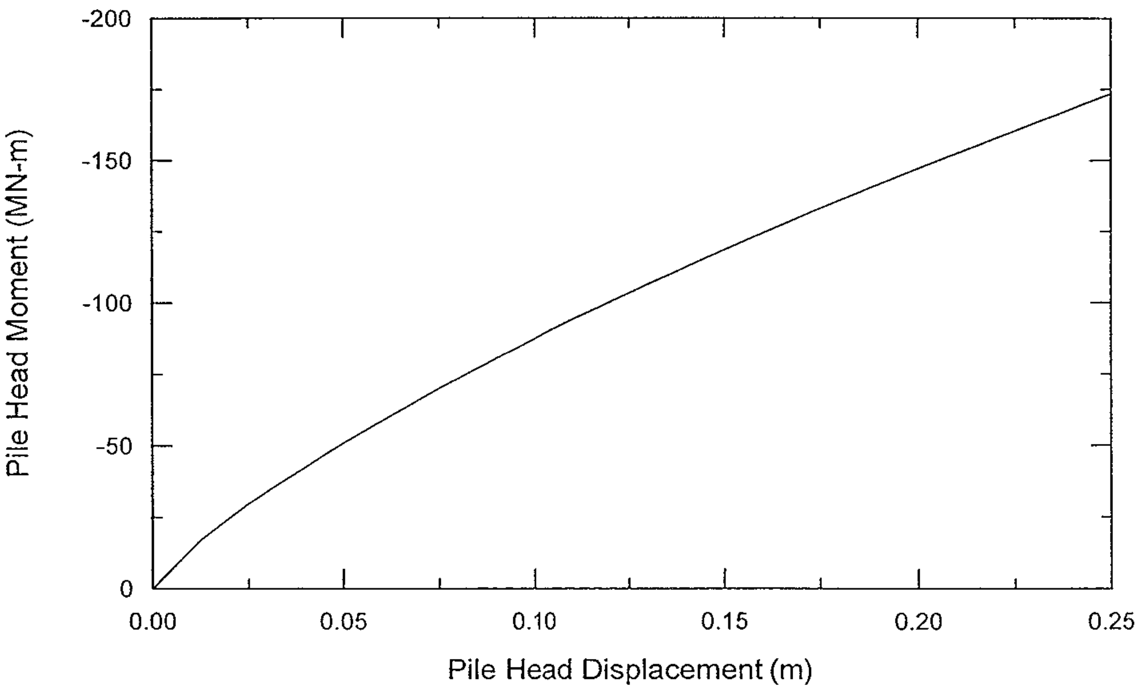
PIER E10 WESTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

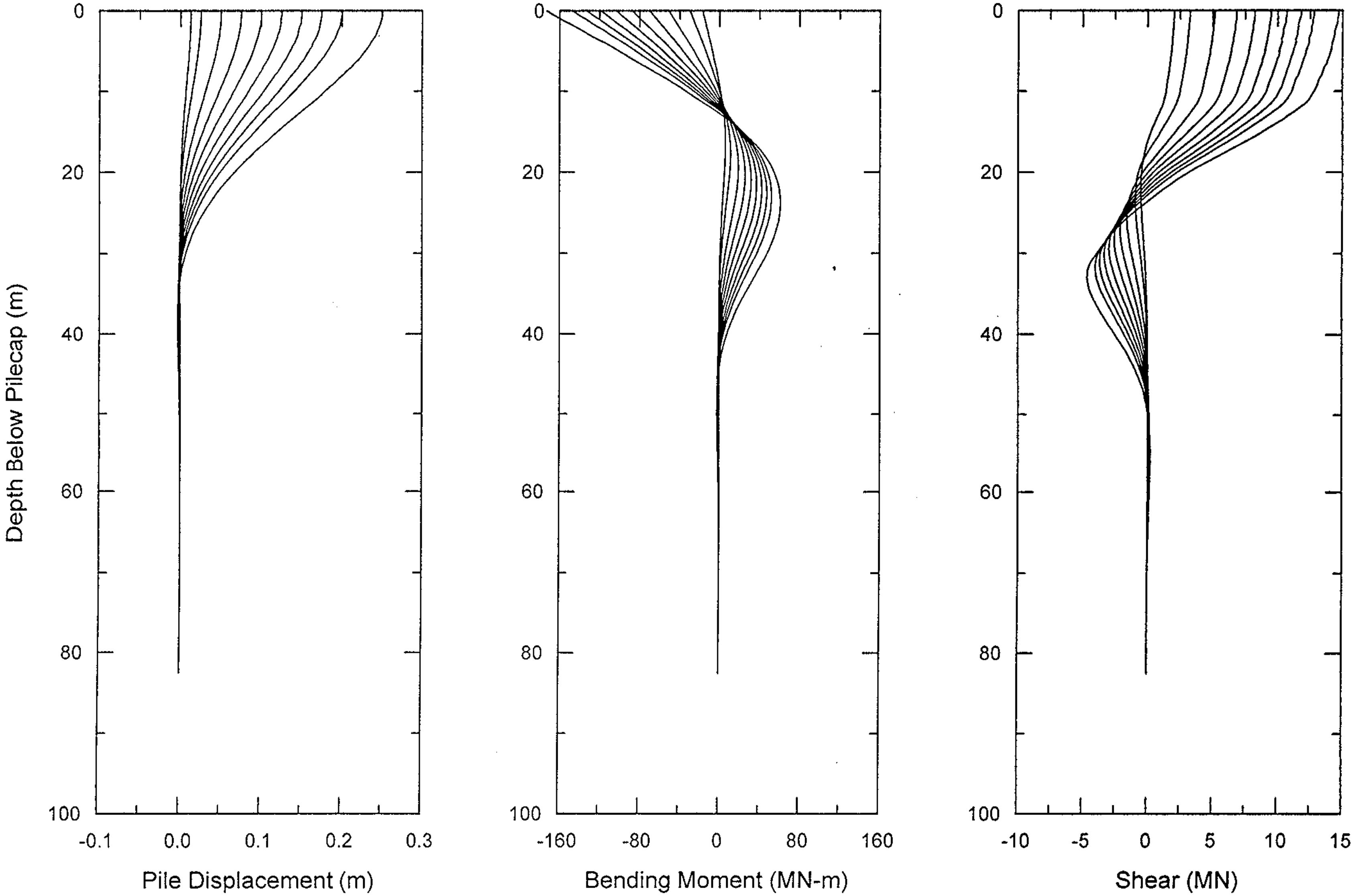




PILE HEAD SHEAR AND BENDING MOMENT
PIER E10 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E10-WB.4

SFOBB Task Order No. 5
EMI Project No. 98-145



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH
PIER E10 WESTBOUND
SFOBB East Span Seismic Safety Project

Earth Mechanics
FUGRO

PLATE E10-WB.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.127E+006	0.000E+000	0.000E+000	0.000E+000	-8.050E+006	0.000E+000
0.000E+000	1.089E+006	0.000E+000	7.729E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.716E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	7.729E+006	0.000E+000	6.801E+008	0.000E+000	0.000E+000
-8.050E+006	0.000E+000	0.000E+000	0.000E+000	5.231E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	6.563E+007

PILE-GROUP STIFFNESS MATRIX (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.844E+006	0.000E+000	0.000E+000	0.000E+000	-1.508E+007	0.000E+000
0.000E+000	1.797E+006	0.000E+000	1.467E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.188E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.467E+007	0.000E+000	9.341E+008	0.000E+000	0.000E+000
-1.508E+007	0.000E+000	0.000E+000	0.000E+000	7.333E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.083E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -5.25 m

CONDENSED STIFFNESS MATRICES
PIER E10 WESTBOUND
SFOBB East Span Seismic Safety Project

Earth Mechanics FUGRO

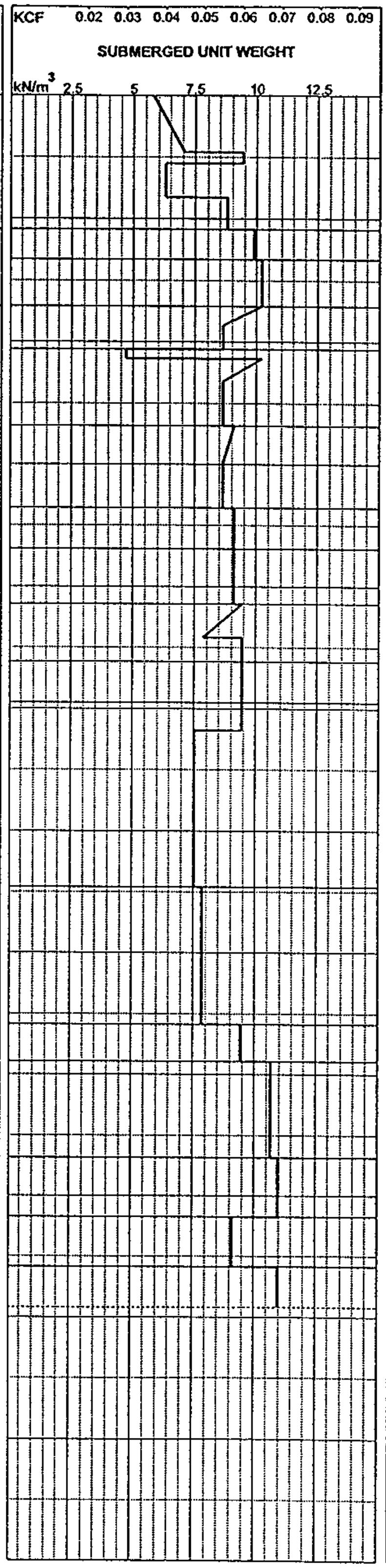
Coordinates: E1838079 N648123
CA State Plane Zone 3, NAD83, Meters

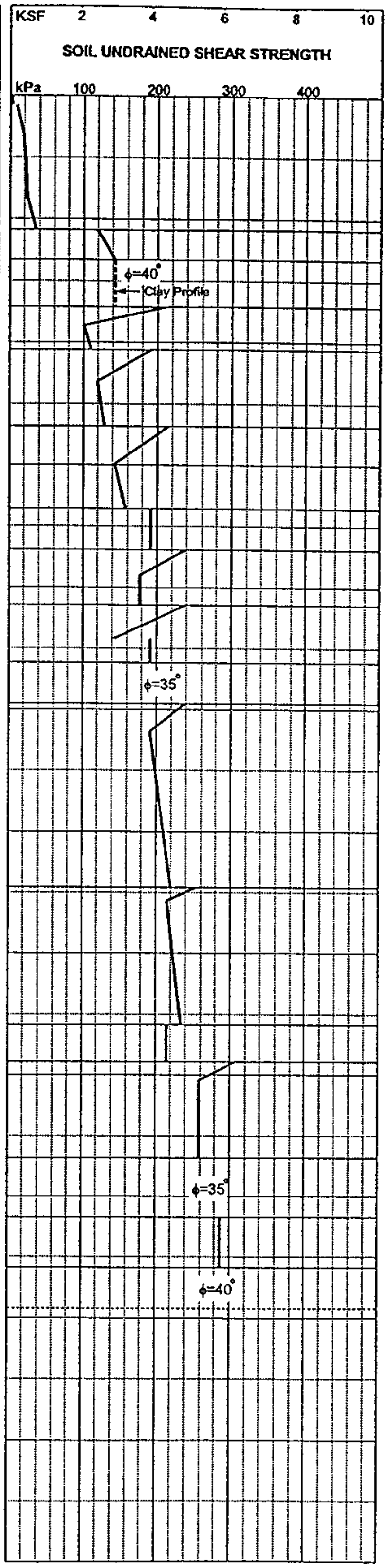
MUDLINE ELEVATION: -3.9m (MSL)

MATERIAL DESCRIPTION	STRATUM NO	UNIT
Fat CLAY (CH), very soft to firm, olive gray -silty sand with clay pockets, 4.6m to 5.5m -medium dense olive gray silty fine sand, with clay pockets, partings, and seams, 8.5m to 10.1m -clay layer with many sand pockets, partings, and seams, 9.3m to 9.6m (10.8m)	I	YBM
Fat CLAY (CH), very stiff, olive gray to dark gray (13.3m)	II	MPSA
Fine SAND (SP), very dense, dark gray (17.1m)	III	MPSA
Fat CLAY (CH), hard to very stiff, dark greenish gray (20.6m)	IV	OBM/UAM
Fat CLAY (CH), very stiff, gray -greenish gray lean clay, 21.3m to 23.2m (26.8m)	V	OBM/UAM
Fat CLAY (CH), hard to very stiff, olive gray -silt layer with clay seams, 30.2m to 30.5m (33.5m)	VI	OBM/UAM
Lean CLAY (CL), hard to very stiff, dark greenish gray (36.9m)	VII	OBM/UAM
Fat CLAY (CH), hard to very stiff, dark greenish gray (41.5m)	VIII	OBM/UAM
Fat CLAY (CH), hard to very stiff, greenish gray -lean clay below 44.2m (46.2m)	IX	OBM/UAM
Silty fine SAND (SM), dense, dark gray -clay layer, 46.5m to 46.8m -fine to coarse sand, with silt and gravel, below 48.6m (49.5m)	X	OBM/UAM
Fat CLAY (CH), hard, dark greenish gray (64.6m)	XI	OBM/UAM
Fat CLAY (CH), hard, dark greenish gray -sand layer, 64.9m to 65.7m -silt layer, 71.0m to 71.3m (75.9m)	XII	OBM/UAM
Lean CLAY (CL), hard, dark greenish gray (78.9m)	XIII	OBM/UAM
Lean CLAY (CL), hard, greenish gray -silt layer, 85.3m to 86.1m (86.9m)	XIV	LAA
Fine to Medium SAND with silt (SP-SM), dense, gray -gravel with sand, silt and clay pockets, below 90.8m (91.7m)	XV	LAA
Fat CLAY (CH), hard, olive gray (95.9m)	XVI	LAA
Fine SAND with medium sand (SP), very dense, light brown to olive gray	XVII	LAA

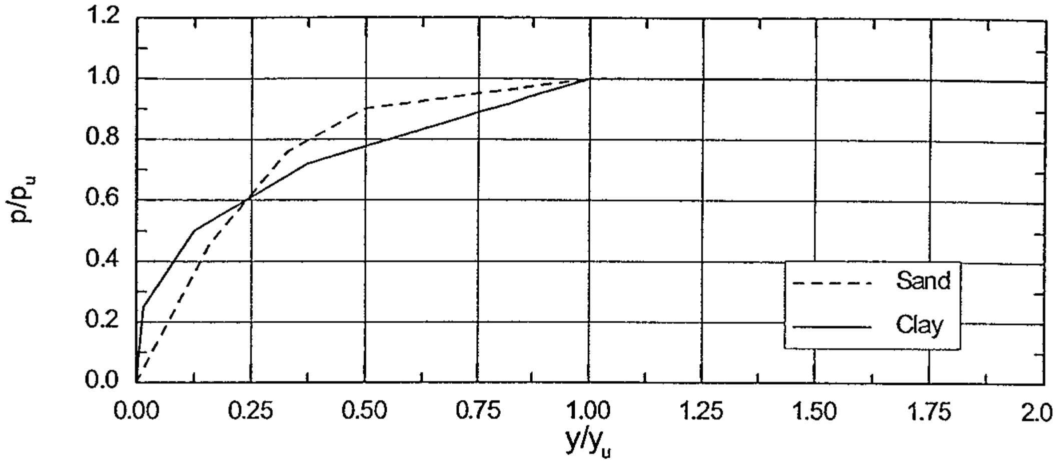
TOTAL DEPTH: 99.2m BACKFILLED WITH: Cement Grout

ELEV. (m): -10, -20, -30, -40, -50, -60, -70, -80, -90, -100, -110, -120
DEPTH (m): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110





SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E11 EASTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m²)	ϕ	k (kN/m³)
0-3	Clay	0.02	12		
3-6	Clay	0.02	20		
6-9	Clay	0.02	20		
9-12	Clay	0.01	40		
12-15	Sand			40	5440
15-18	Sand			40	5440
18-21	Clay	0.005	105		
21-24	Clay	0.005	145		
24-27	Clay	0.005	145		
27 -30	Clay	0.005	160		
30-33	Clay	0.005	150		
33-36	Clay	0.005	190		
36-39	Clay	0.005	210		
39-42	Clay	0.005	200		
42-45	Clay	0.005	200		
45-51	Sand			35	5440
51-57	Clay	0.005	205		
57-63	Clay	0.005	210		
63-69	Clay	0.005	215		
69-75	Clay	0.005	225		
75-81	Clay	0.005	230		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	45	100.0	Clay
3.0	113	100.0	Clay
6.0	156	100.0	Clay
9.0	197	100.0	Clay
11.9	247	50.0	Clay
12.1	2412	22.1	Sand
15.0	3963	29.2	Sand
17.9	5851	36.2	Sand
18.1	1040	25.0	Clay
21.0	1147	25.0	Clay
24.0	1623	25.0	Clay
30.0	1679	25.0	Clay
36.0	2352	25.0	Clay
42.0	2239	25.0	Clay
50.9	25492	55.4	Sand
51.1	2296	25.0	Clay
63.0	2352	25.0	Clay
81.0	2573	25.0	Clay

LATERAL PILE DESIGN PARAMETERS

PIER E11 EASTBOUND

SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.2	1	0	0	12	1.6	23	12.5	33	37.5	46	100.0	46	249.9		
3.0	2	0	0	28	1.6	56	12.5	81	37.5	113	100.0	113	249.9		
6.0	3	0	0	39	1.6	78	12.5	112	37.5	156	100.0	156	249.9		
9.0	4	0	0	49	1.6	98	12.5	142	37.5	197	100.0	197	249.9		
11.9	5	0	0	61	0.8	123	6.2	178	18.7	247	50.0	247	125.0		
12.1	6	0	0	241	0.7	1109	3.7	1833	7.4	2195	11.0	2412	22.1	2412	36.8
15.0	7	0	0	396	1.0	1823	4.9	3012	9.7	3606	14.6	3963	29.2	3963	48.7
17.9	8	0	0	585	1.2	2691	6.0	4447	12.1	5324	18.1	5851	36.2	5851	60.3
18.1	9	0	0	260	0.4	520	3.1	748	9.4	1040	25.0	1040	62.5		
21.0	10	0	0	286	0.4	573	3.1	826	9.4	1147	25.0	1147	62.5		
24.0	11	0	0	405	0.4	811	3.1	1168	9.4	1623	25.0	1623	62.5		
30.0	12	0	0	419	0.4	839	3.1	1209	9.4	1679	25.0	1679	62.5		
36.0	13	0	0	588	0.4	1176	3.1	1693	9.4	2352	25.0	2352	62.5		
42.0	14	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		
50.9	15	0	0	2549	1.8	11726	9.2	19374	18.5	23198	27.7	25492	55.4	25492	92.3
51.1	16	0	0	574	0.4	1148	3.1	1653	9.4	2296	25.0	2296	62.5		
63.0	17	0	0	588	0.4	1176	3.1	1693	9.4	2352	25.0	2352	62.5		
81.0	18	0	0	643	0.4	1286	3.1	1852	9.4	2573	25.0	2573	62.5		

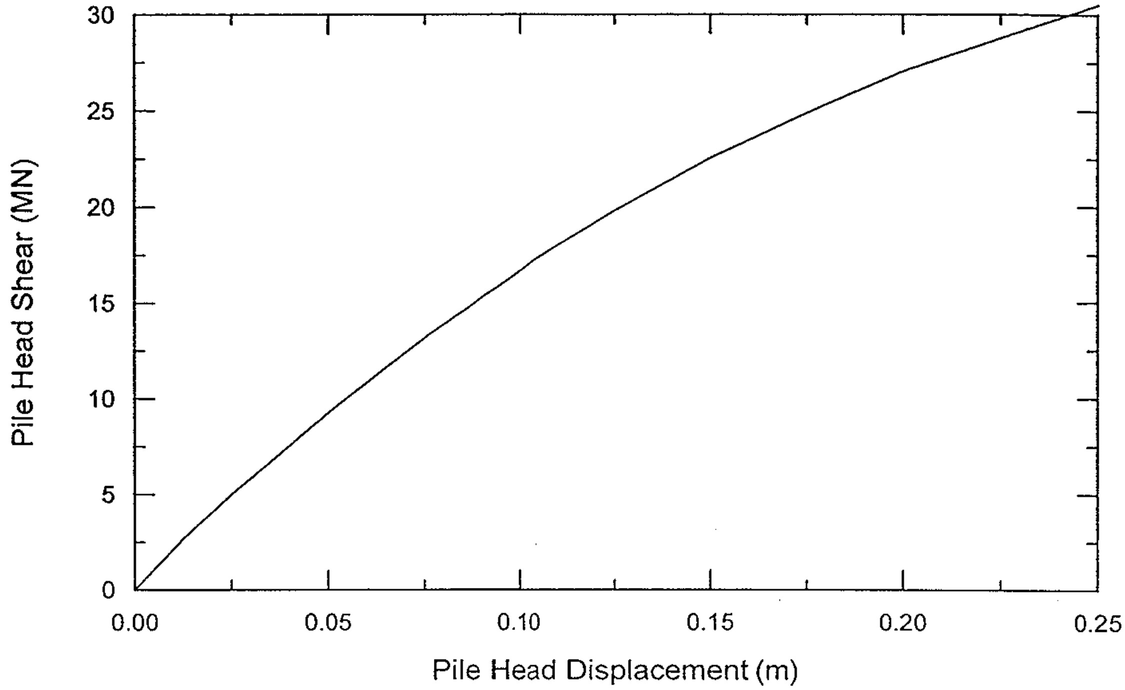
COORDINATES of p-y CURVES

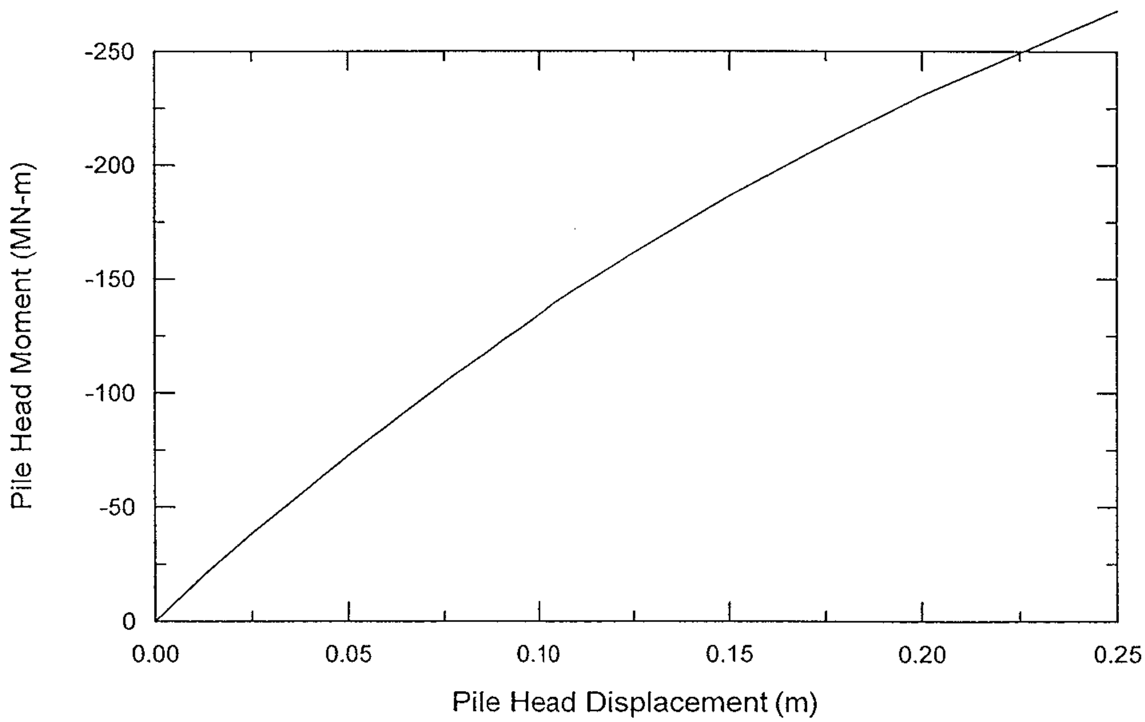
PIER E11 EASTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

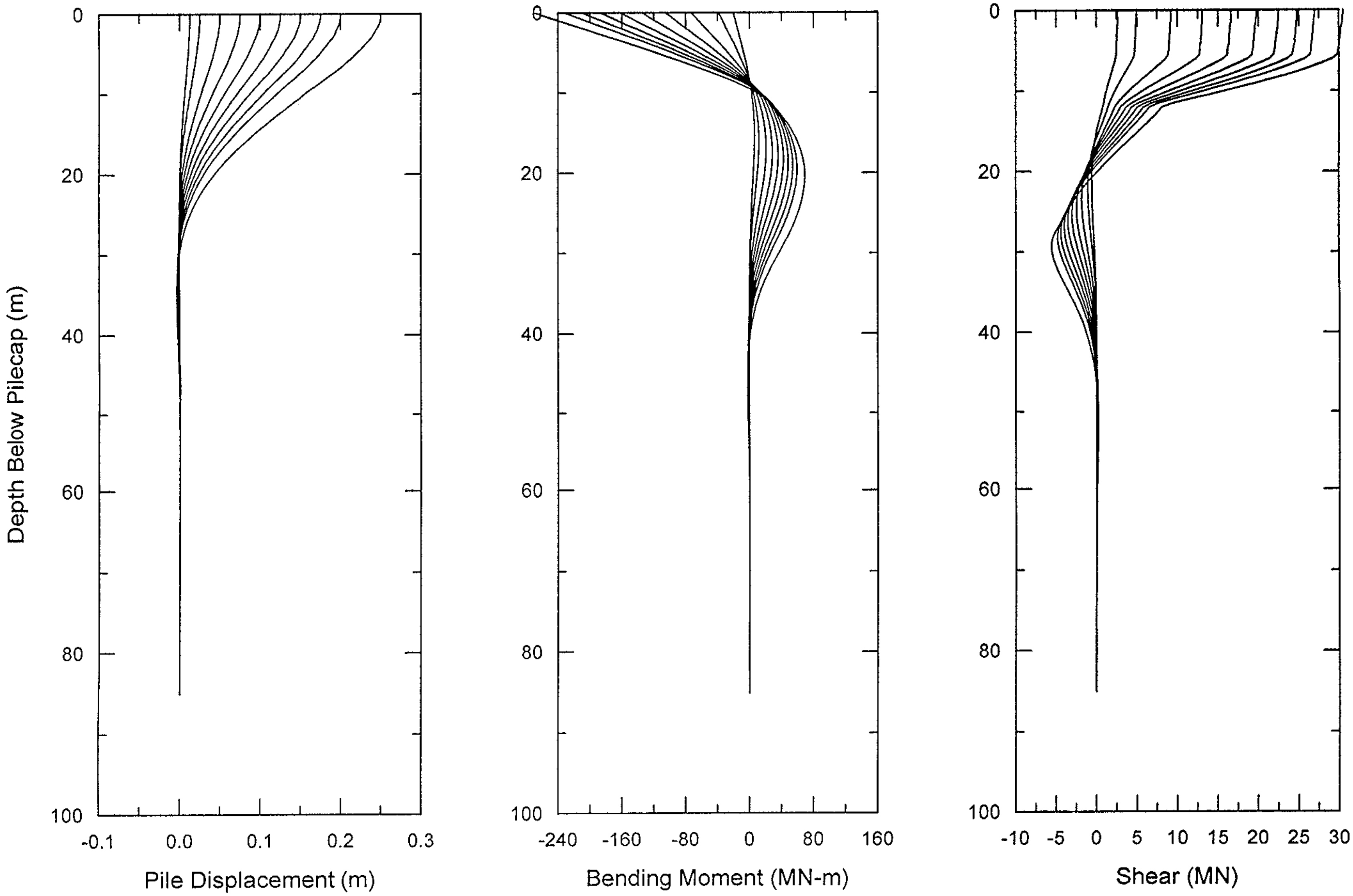
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E11 EASTBOUND
SFOBB East Span Seismic Safety Project

PLATE E11-EB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E11 EASTBOUND

SFOBB East Span Seismic Safety Project

PLATE E11-EB.5

Earth Mechanics
FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.152E+006	0.000E+000	0.000E+000	0.000E+000	-6.661E+006	0.000E+000
0.000E+000	1.101E+006	0.000E+000	6.229E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.273E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	6.229E+006	0.000E+000	8.368E+008	0.000E+000	0.000E+000
-6.661E+006	0.000E+000	0.000E+000	0.000E+000	6.291E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	6.602E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.404E+006	0.000E+000	0.000E+000	0.000E+000	-2.028E+007	0.000E+000
0.000E+000	2.359E+006	0.000E+000	1.991E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.188E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.991E+007	0.000E+000	9.868E+008	0.000E+000	0.000E+000
-2.028E+007	0.000E+000	0.000E+000	0.000E+000	7.855E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.429E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -3.1 m

CONDENSED STIFFNESS MATRICES
PIER E11 EASTBOUND
SFOBB East Span Seismic Safety Project

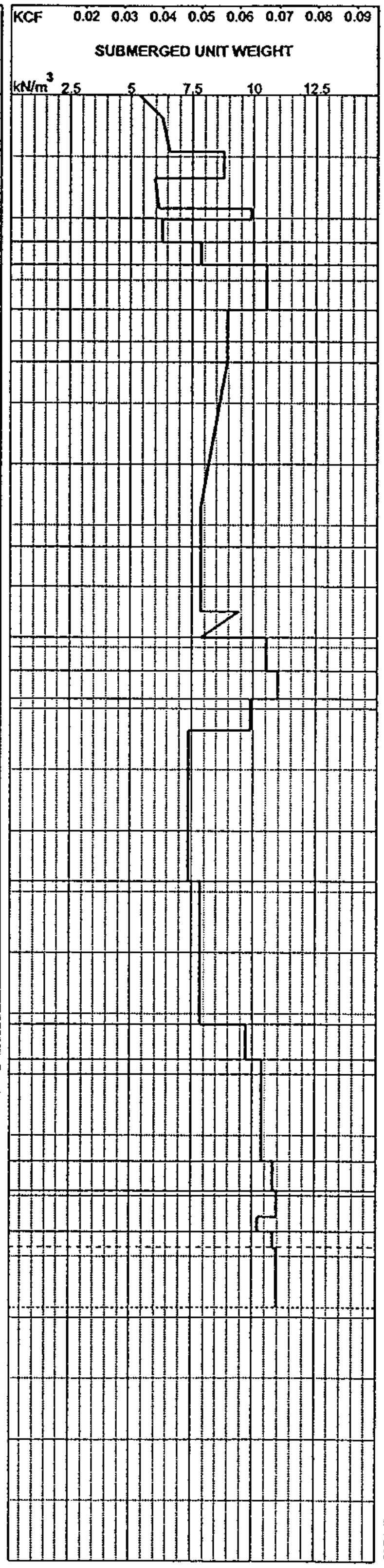
Coordinates: E1838072 N648163
CA State Plane Zone 3, NAD83, Meters

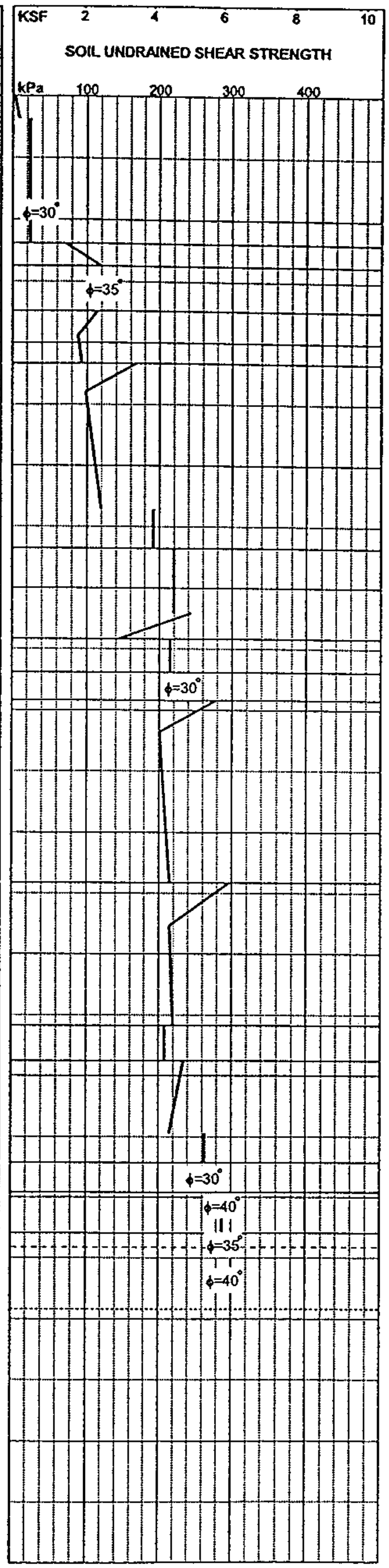
MUDLINE ELEVATION: -3.8m (MSL)

MATERIAL DESCRIPTION	Bottom depth	STRATUM NO	UNIT
Fat CLAY (CH), soft to firm, olive gray -dense fine sand with silt, a few clay pockets, and a few shell fragments, 9.1m to 10.1m	(11.9m)	I	YBM
Fat CLAY (CH), stiff to very stiff, olive gray	(13.7m)	II	MPSA
Fine SAND (SP-SM) with silt, very dense, gray	(17.4m)	III	MPSA
Fat CLAY (CH), stiff to very stiff, gray	(21.6m)	IV	OBM/UAM
Fat CLAY (CH), very stiff, gray -lean olive gray clay below 34.4m	(36.7m)	V	OBM/UAM
Fat CLAY (CH), hard, greenish gray	(44.2m)	VI	OBM/UAM
Lean CLAY (CL), hard, greenish gray	(46.9m)	VII	OBM/UAM
Silty fine SAND (SM), dense to very dense, greenish gray	(49.2m)	VIII	OBM/UAM
Fat CLAY (CH), hard, greenish gray to gray	(64.2m)	IX	OBM/UAM
Fat CLAY (CH), hard, dark greenish gray	(75.9m)	X	OBM/UAM
Lean CLAY (CL), hard, dark greenish gray	(78.8m)	XI	OBM/UAM
Lean CLAY (CL), hard, greenish gray	(87.2m)	XII	LAA
Sandy SILT (ML), very dense, gray	(89.6m)	XIII	LAA
Fine to Coarse GRAVEL with medium to coarse sand (GW), very dense, dark greenish gray -hard gray fat clay below 91.7m	(93.0m)	XIV	LAA
Medium SAND (SW-SM) with silt and fine gravel, very dense, yellowish to reddish brown		XV	LAA

TOTAL DEPTH: 99.2m BACKFILLED WITH: Cement Grout

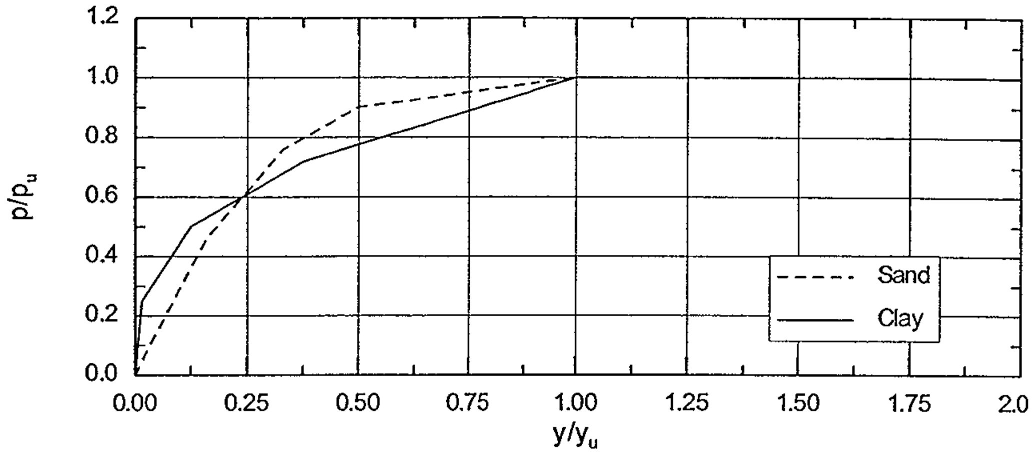
ELEV. (m): -10, -20, -30, -40, -50, -60, -70, -80, -90, -100, -110, -120
DEPTH (m): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110





SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E11 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E11-WB.1



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m²)	ϕ	k (kN/m³)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.02	20		
9-12	Clay	0.02	22		
12-15	Clay	0.005	100		
15-18	Sand			35	20
18-21	Clay	0.075	90		
21-24	Clay	0.005	125		
24-27	Clay	0.005	105		
27 -30	Clay	0.005	110		
30-33	Clay	0.005	115		
33-36	Clay	0.005	190		
36-39	Clay	0.005	220		
39-42	Clay	0.005	220		
42-45	Clay	0.005	180		
45-51	Clay	0.005	220		
51-57	Clay	0.005	205		
57-63	Clay	0.005	205		
63-69	Clay	0.005	240		
69-75	Clay	0.005	220		
75-81	Clay	0.005	220		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	38	100.0	Clay
3.0	113	100.0	Clay
6.0	157	100.0	Clay
9.0	199	100.0	Clay
12.0	481	25.0	Clay
14.9	508	25.0	Clay
15.1	2635	19.3	Sand
17.9	3828	23.7	Sand
18.1	914	37.5	Clay
21.0	1006	37.5	Clay
24.0	1399	25.0	Clay
30.0	1286	25.0	Clay
36.0	2462	25.0	Clay
42.0	2016	25.0	Clay
51.0	2462	25.0	Clay
63.0	2296	25.0	Clay
81.0	2462	25.0	Clay

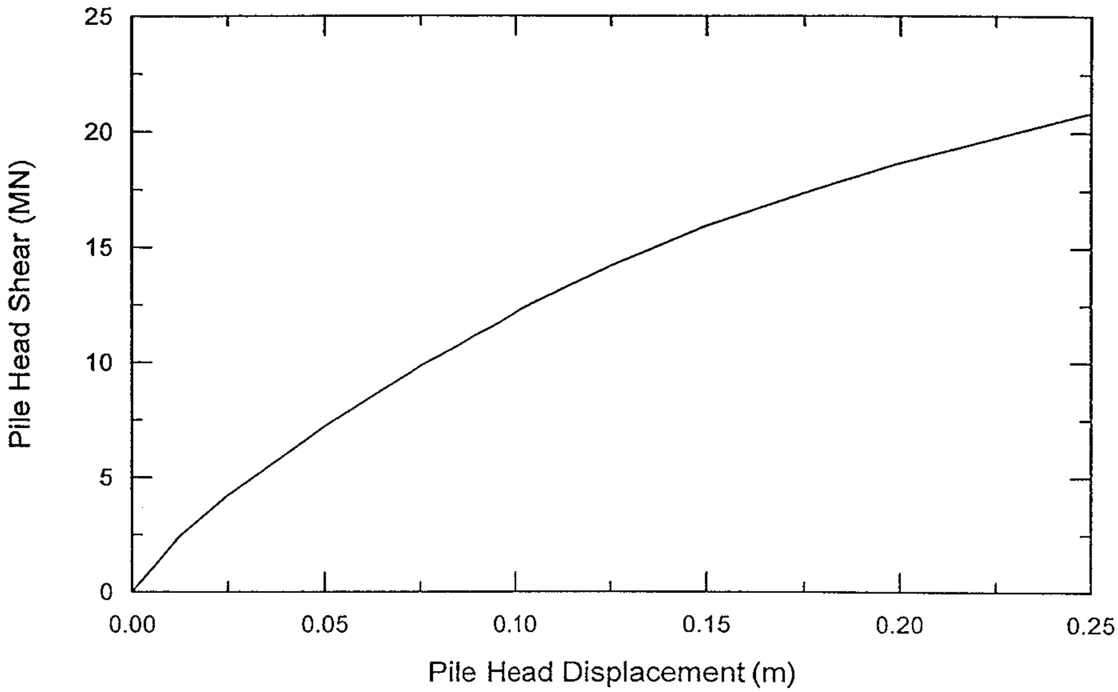
LATERAL PILE DESIGN PARAMETERS
PIER E11 WESTBOUND
SFOBB East Span Seismic Safety Project

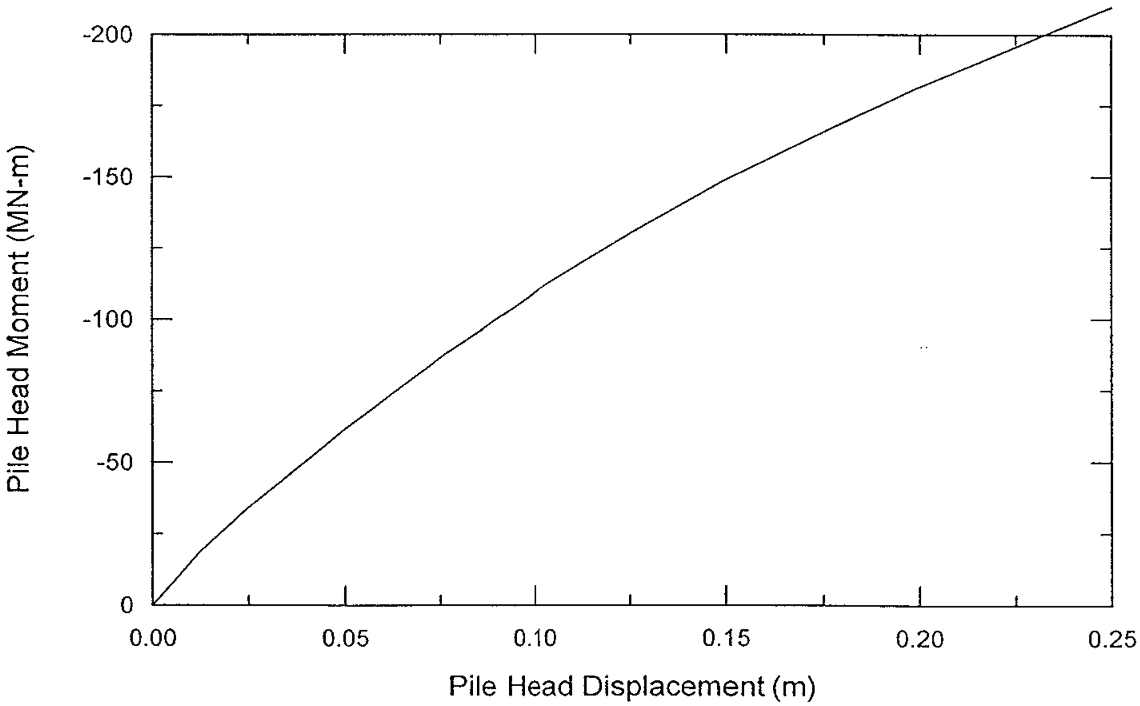
PLATE E11-WB.2

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	28	1.6	56	12.5	81	37.5	113	100.0	113	249.9		
6.0	3	0	0	39	1.6	78	12.5	113	37.5	157	100.0	157	249.9		
9.0	4	0	0	49	1.6	99	12.5	143	37.5	199	100.0	199	249.9		
12.0	5	0	0	120	0.4	240	3.1	346	9.4	481	25.0	481	62.5		
14.9	6	0	0	127	0.4	254	3.1	365	9.4	508	25.0	508	62.5		
15.1	7	0	0	263	0.6	1212	3.2	2002	6.4	2397	9.7	2635	19.3	2635	32.2
17.9	8	0	0	382	0.8	1761	3.9	2909	7.9	3484	11.8	3828	23.7	3828	39.4
18.1	9	0	0	228	0.6	457	4.7	658	14.1	914	37.5	914	93.7		
21.0	10	0	0	251	0.6	503	4.7	724	14.1	1006	37.5	1006	93.7		
24.0	11	0	0	349	0.4	699	3.1	1007	9.4	1399	25.0	1399	62.5		
30.0	12	0	0	321	0.4	643	3.1	926	9.4	1286	25.0	1286	62.5		
36.0	13	0	0	615	0.4	1231	3.1	1773	9.4	2462	25.0	2462	62.5		
42.0	14	0	0	504	0.4	1008	3.1	1451	9.4	2016	25.0	2016	62.5		
51.0	15	0	0	615	0.4	1231	3.1	1773	9.4	2462	25.0	2462	62.5		
63.0	16	0	0	574	0.4	1148	3.1	1653	9.4	2296	25.0	2296	62.5		
81.0	17	0	0	615	0.4	1231	3.1	1773	9.4	2462	25.0	2462	62.5		

COORDINATES of p-y CURVES
PIER E11 WESTBOUND
SFOBB East Span Seismic Safety Project

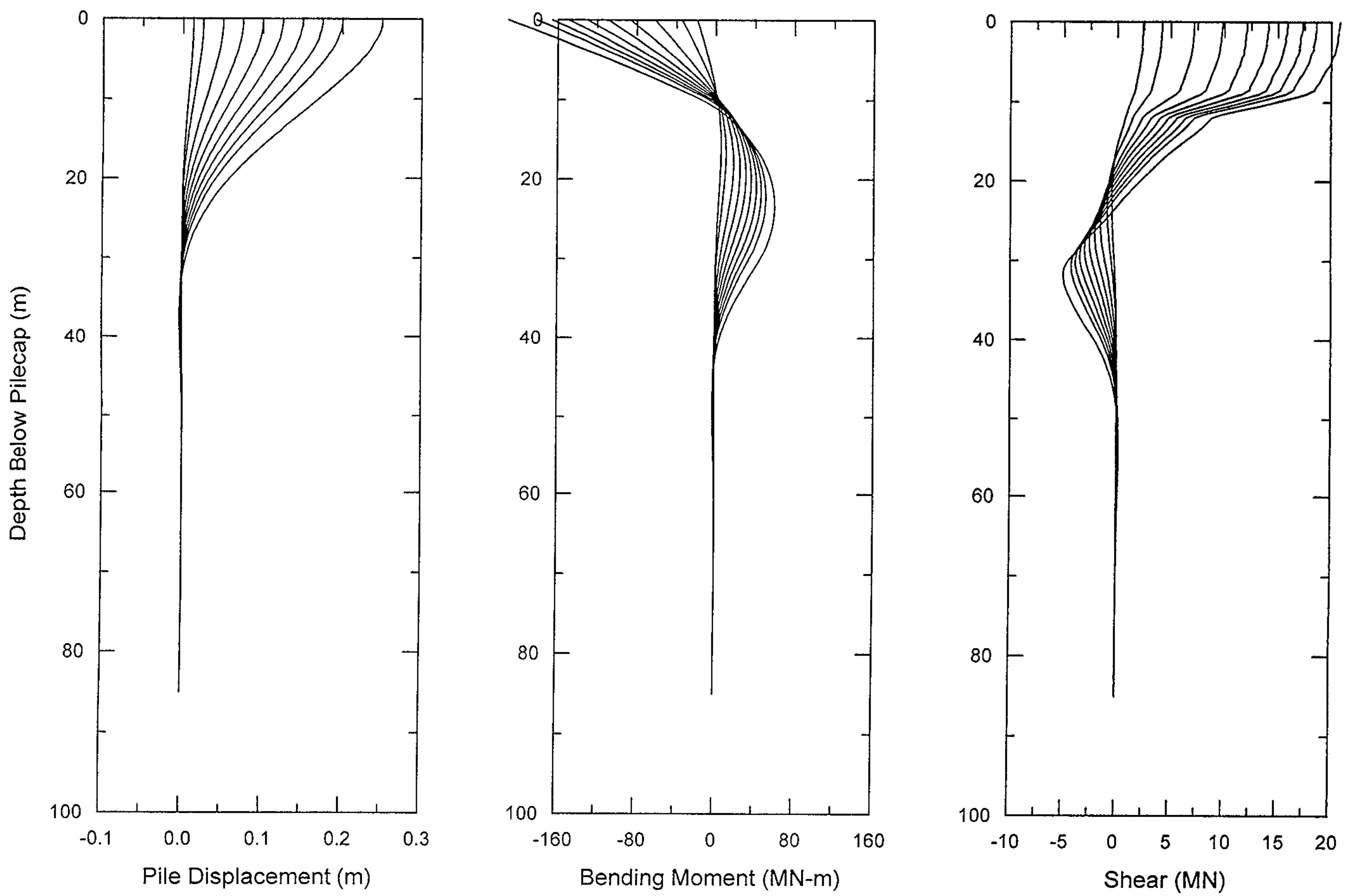
Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E11 WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E11-WB.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E11 WESTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5

EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E11-WB.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.152E+006	0.000E+000	0.000E+000	0.000E+000	-6.661E+006	0.000E+000
0.000E+000	1.101E+006	0.000E+000	6.229E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.273E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	6.229E+006	0.000E+000	8.368E+008	0.000E+000	0.000E+000
-6.661E+006	0.000E+000	0.000E+000	0.000E+000	6.291E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	6.602E+007

PILE-GROUP STIFFNESS MATRIX (SERVICE CONDITION)

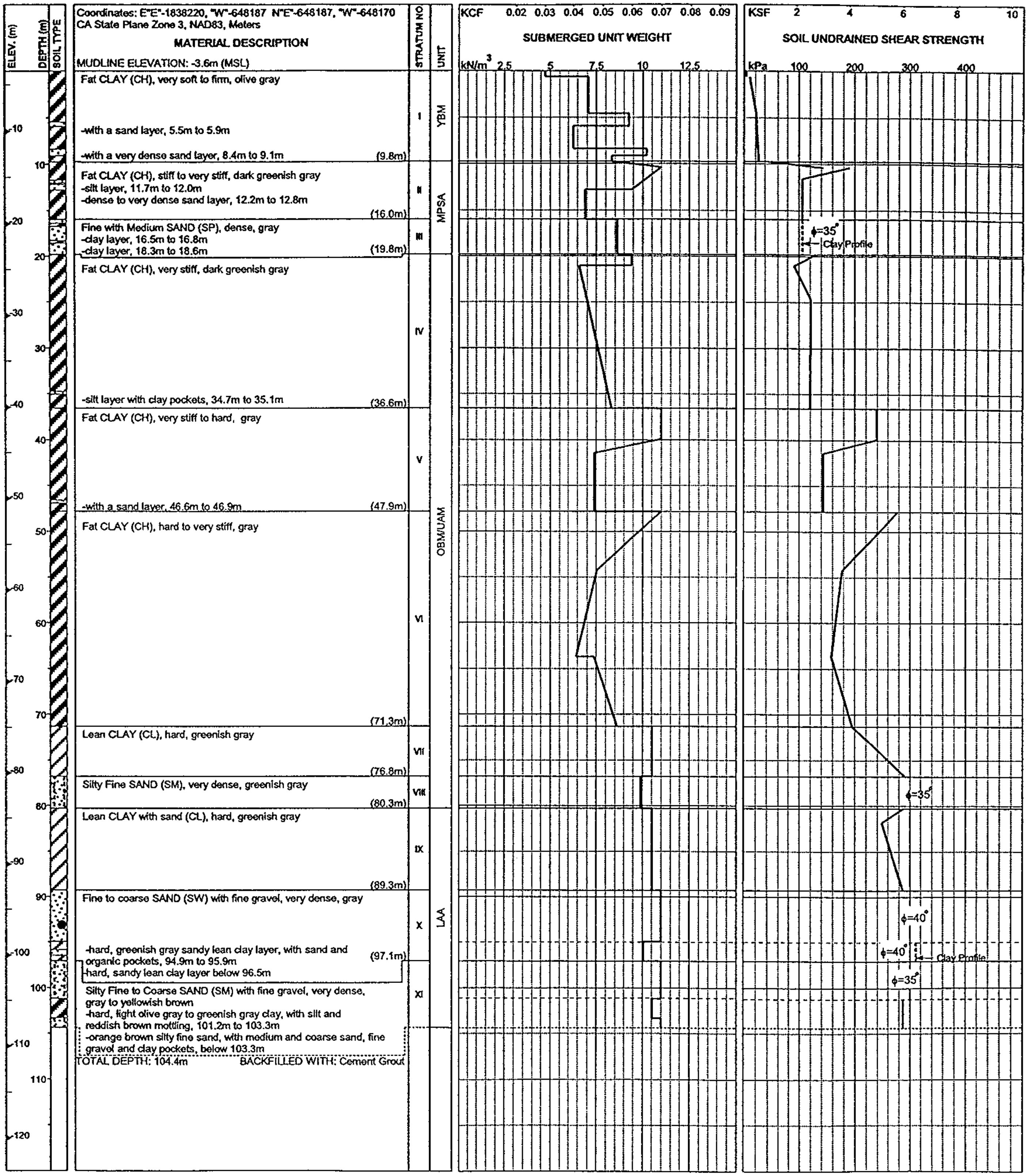
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.410E+006	0.000E+000	0.000E+000	0.000E+000	-2.040E+007	0.000E+000
0.000E+000	2.364E+006	0.000E+000	2.003E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.188E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	2.003E+007	0.000E+000	9.878E+008	0.000E+000	0.000E+000
-2.040E+007	0.000E+000	0.000E+000	0.000E+000	7.865E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.433E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -3.1 m

CONDENSED STIFFNESS MATRICES

PIER E11 WESTBOUND

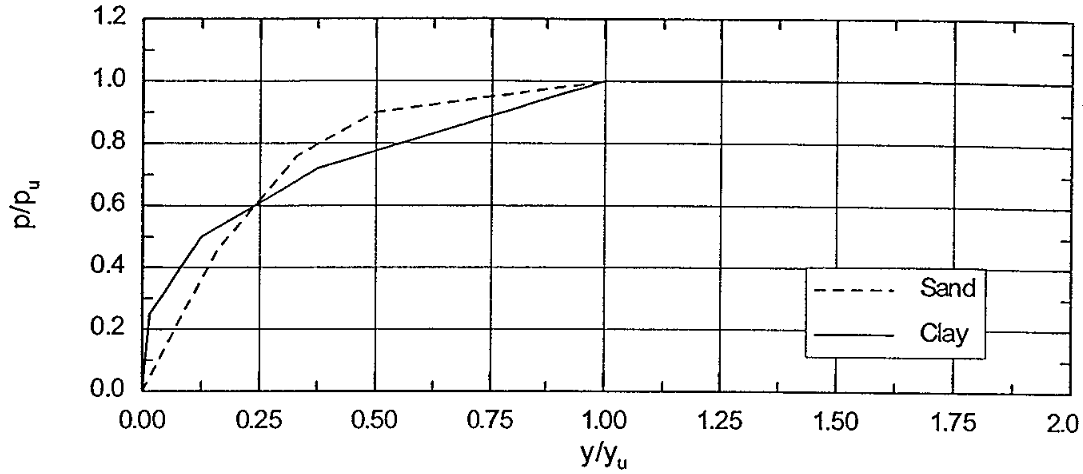
SFOBB East Span Seismic Safety Project



SUBSOIL CONDITION AND SOIL PROPERTIES

PIER E12 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	15		
3-6	Clay	0.02	20		
6-9	Clay	0.02	22		
9-12	Clay	0.005	100		
12-15	Clay	0.005	100		
15-18	Clay	0.005	100		
18-21	Clay	0.005	100		
21-24	Clay	0.005	110		
24-27	Clay	0.005	120		
27 -30	Clay	0.005	120		
30-33	Clay	0.005	120		
33-36	Clay	0.005	120		
36-39	Clay	0.005	240		
39-42	Clay	0.005	175		
42-45	Clay	0.005	140		
45-51	Clay	0.005	240		
51-57	Clay	0.005	200		
57-63	Clay	0.005	165		
63-69	Clay	0.005	170		
69-75	Clay	0.005	240		
75-81	Clay	0.005	240		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	54	100.0	Clay
3.0	117	100.0	Clay
6.0	139	100.0	Clay
9.0	169	100.0	Clay
12.0	787	25.0	Clay
15.0	891	25.0	Clay
18.0	996	25.0	Clay
21.0	1100	25.0	Clay
24.0	1232	25.0	Clay
30.0	1345	25.0	Clay
36.0	2686	25.0	Clay
42.0	1566	25.0	Clay
51.0	2686	25.0	Clay
63.0	1847	25.0	Clay
81.0	2686	25.0	Clay

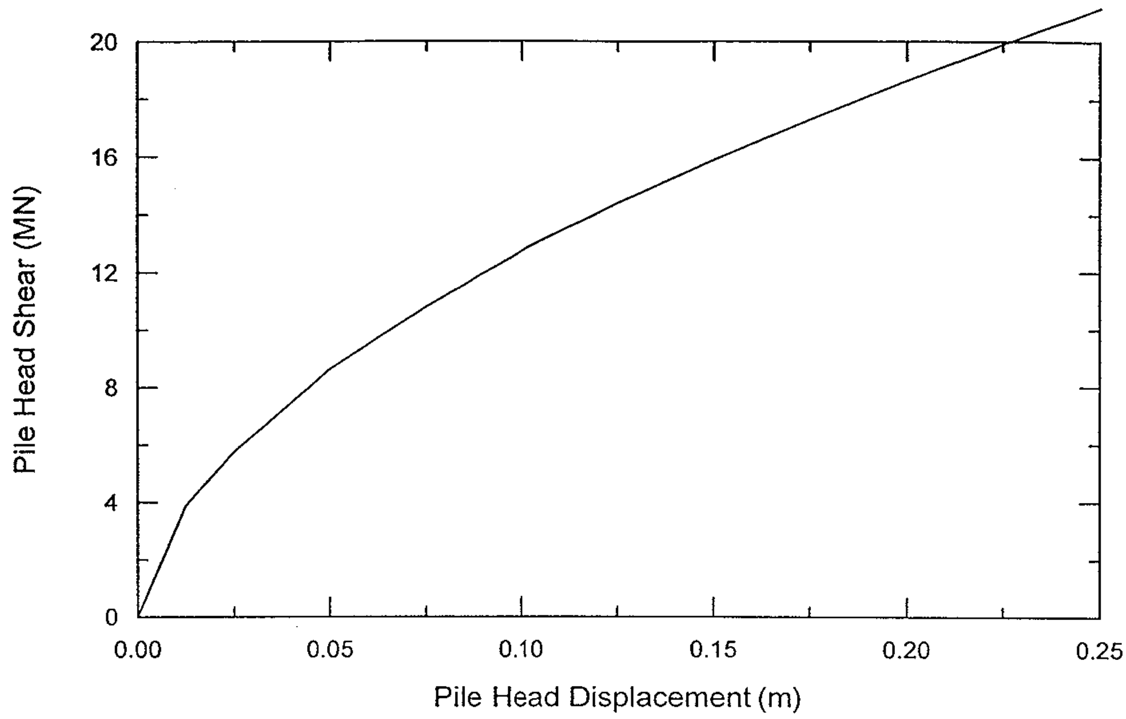
LATERAL PILE DESIGN PARAMETERS
PIER E12 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

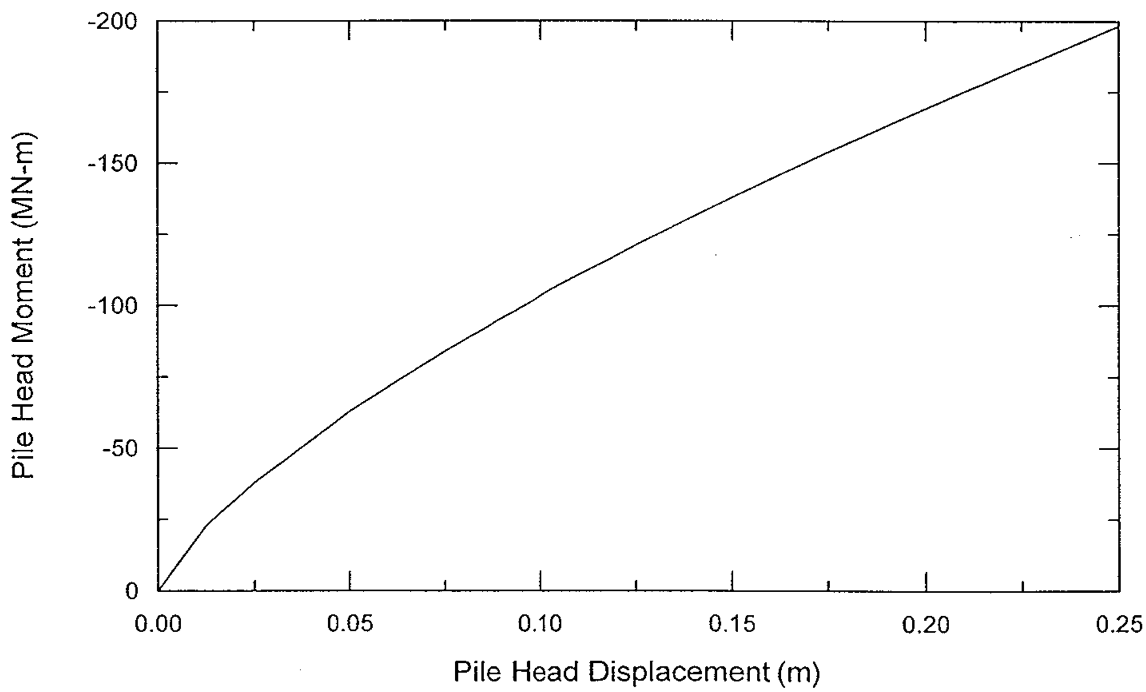
Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	13	1.6	27	12.5	39	37.5	54	100.0	54	249.9		
3.0	2	0	0	29	1.6	58	12.5	84	37.5	117	100.0	117	249.9		
6.0	3	0	0	34	1.6	69	12.5	100	37.5	139	100.0	139	249.9		
9.0	4	0	0	42	1.6	84	12.5	121	37.5	169	100.0	169	249.9		
12.0	5	0	0	196	0.4	393	3.1	566	9.4	787	25.0	787	62.5		
15.0	6	0	0	222	0.4	445	3.1	641	9.4	891	25.0	891	62.5		
18.0	7	0	0	249	0.4	498	3.1	717	9.4	996	25.0	996	62.5		
21.0	8	0	0	275	0.4	550	3.1	792	9.4	1100	25.0	1100	62.5		
24.0	9	0	0	308	0.4	616	3.1	887	9.4	1232	25.0	1232	62.5		
30.0	10	0	0	336	0.4	672	3.1	969	9.4	1345	25.0	1345	62.5		
36.0	11	0	0	671	0.4	1343	3.1	1934	9.4	2686	25.0	2686	62.5		
42.0	12	0	0	391	0.4	783	3.1	1127	9.4	1566	25.0	1566	62.5		
51.0	13	0	0	671	0.4	1343	3.1	1934	9.4	2686	25.0	2686	62.5		
63.0	14	0	0	461	0.4	923	3.1	1330	9.4	1847	25.0	1847	62.5		
81.0	15	0	0	671	0.4	1343	3.1	1934	9.4	2686	25.0	2686	62.5		

COORDINATES of p-y CURVES
PIER E12 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

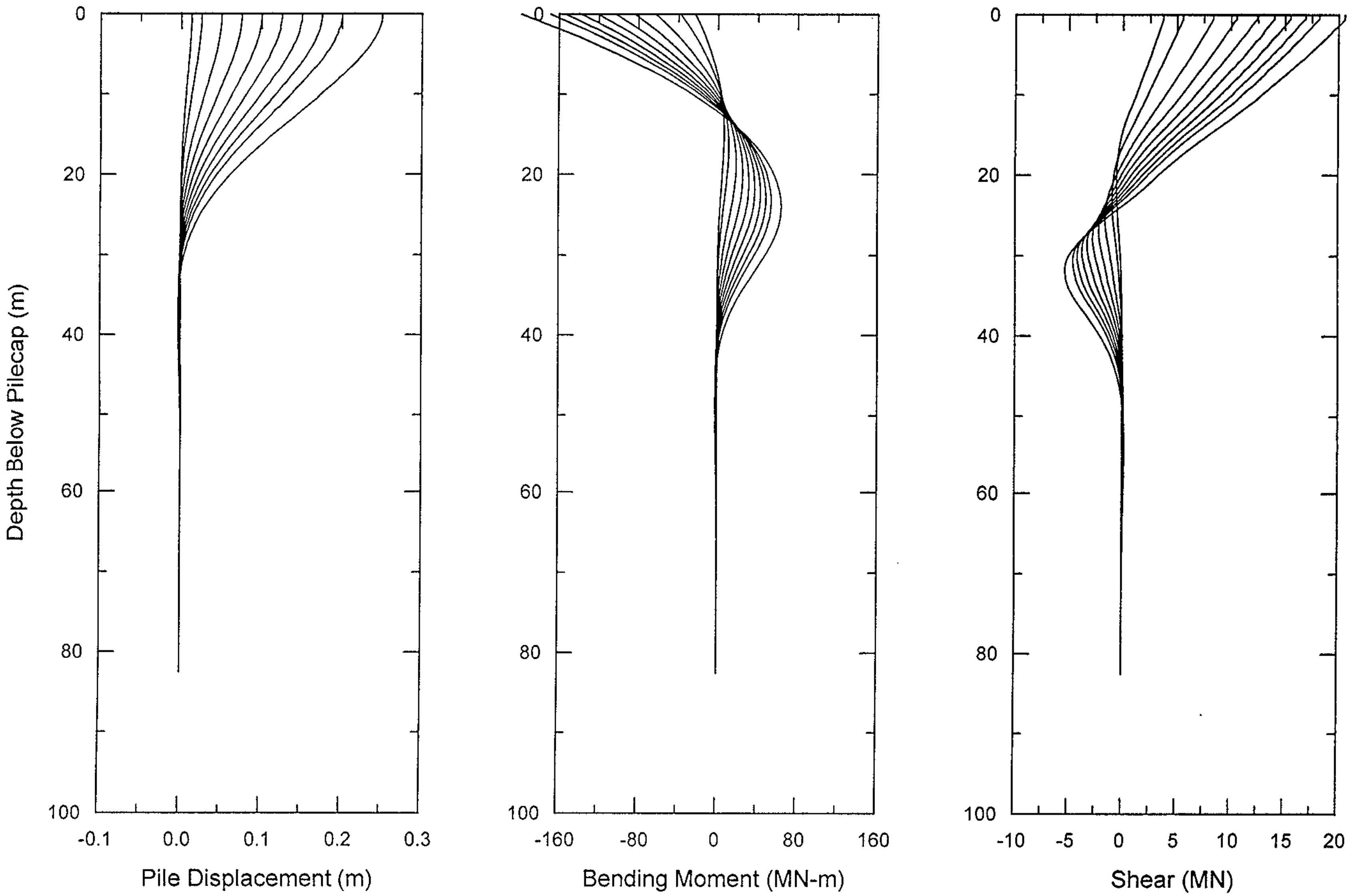




PILE HEAD SHEAR AND BENDING MOMENT
PIER E12 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E12.4

SFOBB Task Order No. 5
EMI Project No. 98-145



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E12 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
9.865E+005	0.000E+000	0.000E+000	0.000E+000	-4.131E+006	0.000E+000
0.000E+000	9.382E+005	0.000E+000	3.723E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.152E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	3.723E+006	0.000E+000	7.621E+008	0.000E+000	0.000E+000
-4.131E+006	0.000E+000	0.000E+000	0.000E+000	5.652E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	5.467E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.629E+006	0.000E+000	0.000E+000	0.000E+000	-3.449E+007	0.000E+000
0.000E+000	3.586E+006	0.000E+000	3.412E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.191E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	3.412E+007	0.000E+000	1.150E+009	0.000E+000	0.000E+000
-3.449E+007	0.000E+000	0.000E+000	0.000E+000	9.489E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.141E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -6.1 m

CONDENSED STIFFNESS MATRICES
PIER E12 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E12.6

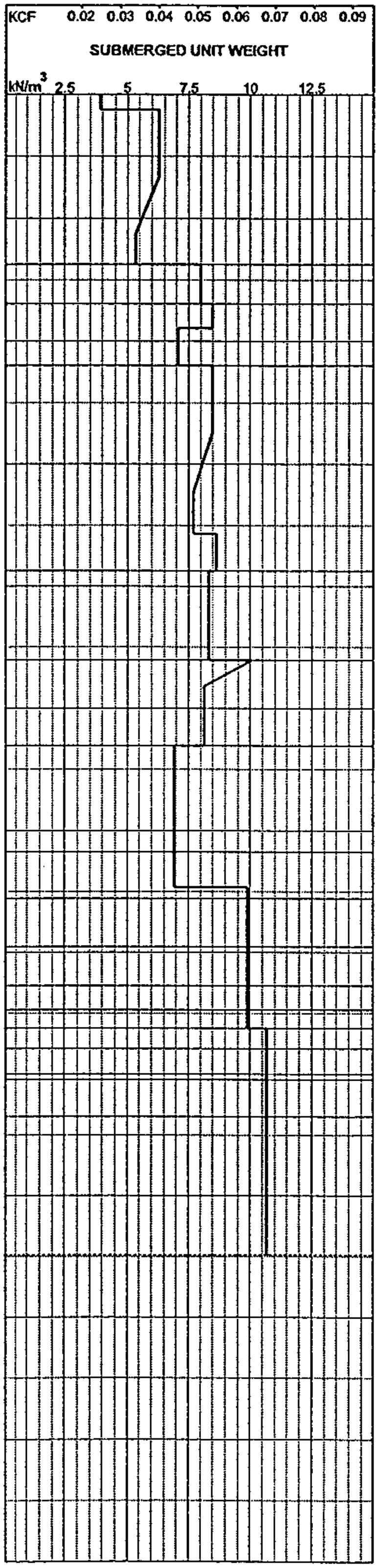
Coordinates: E1838363 N648170
CA State Plane Zone 3, NAD83, Meters

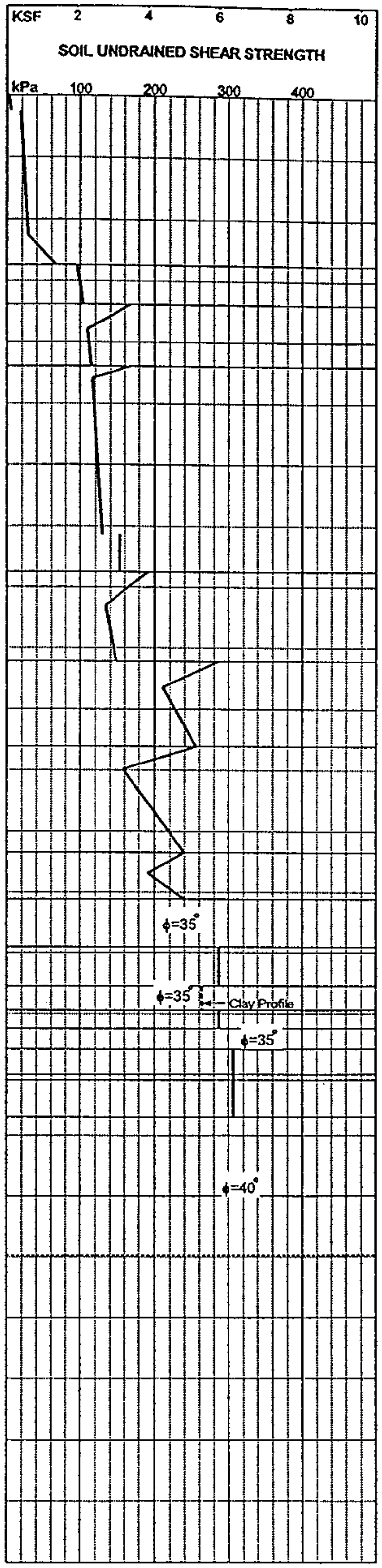
MUDLINE ELEVATION: -3.4m (MSL)

MATERIAL DESCRIPTION	STRATUM NO	UNIT
Fat CLAY (CH), soft to firm, olive gray -dark gray silty fine sand, with a few clay pockets, shells and shell fragments, 4.6m to 5.2m -sand layer, 9.6m to 10.1m (13.7m)	I	YBM
Fat CLAY (CH), stiff to very stiff, greenish gray -sand layer, 15.4m to 15.7m (16.9m) -sand layer below 16.5m	II	MPSA
Fat CLAY (CH), very stiff, greenish gray (21.9m)	III	OBM/UAM
Fat CLAY (CH), very stiff, greenish gray -interlayered silt and clay, below 35.7m (38.7m)	IV	OBM/UAM
Fat CLAY (CH), very stiff to hard, greenish gray (46.0m)	V	OBM/UAM
Fat CLAY (CH), hard, greenish gray (53.0m)	VI	OBM/UAM
Fat CLAY (CH), very stiff to hard, olive gray (61.7m)	VII	OBM/UAM
Fat CLAY (CH), very stiff to hard, olive gray -silt layer to 61.9m -silt layer, 64.6m to 65.2m (65.5m)	VIII	OBM/UAM
Silty Fine SAND (SM), medium dense to dense, dark greenish gray -clay layer, 65.8m to 66.4m (69.5m) -laminated sand and clay at 66.4m	IX	OBM/UAM
Fat CLAY (CH), hard, dark greenish gray (72.7m)	X	OBM/UAM
Interlayered SAND (SP), dense, and CLAY (CL), hard (74.7m)	XI	OBM/UAM
Sandy CLAY (CL), dense, dark greenish gray (76.2m)	XII	LAA
Fine to Coarse SAND (SW) with fine to coarse gravel, dense, gray (77.9m)	XIII	LAA
Lean CLAY (CL), hard, dark greenish gray (80.5m)	XIV	LAA
Fat CLAY (CH), hard, yellowish brown -sand layer, 80.9m to 81.2m (83.5m)	XV	LAA
Silty Fine to Coarse SAND (SM) with fine gravel, very dense, yellowish brown -with a clay layer, 87.2m to 87.9m	XVI	LAA

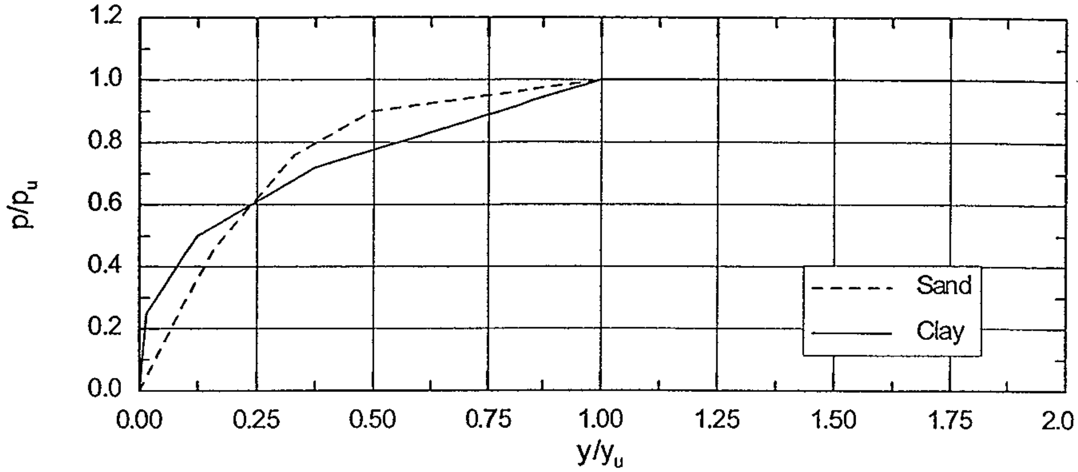
TOTAL DEPTH: 94.9m BACKFILLED WITH: Cement Grout

ELEV. (m): -10, -20, -30, -40, -50, -60, -70, -80, -90, -100, -110, -120
DEPTH (m): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110





SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E13 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.01	25		
9-12	Clay	0.01	30		
12-15	Clay	0.075	90		
15-18	Clay	0.005	110		
18-21	Clay	0.005	110		
21-24	Clay	0.005	140		
24-27	Clay	0.005	120		
27 -30	Clay	0.005	120		
30-33	Clay	0.005	125		
33-36	Clay	0.005	140		
36-39	Clay	0.005	155		
39-42	Clay	0.005	155		
42-45	Clay	0.005	140		
45-51	Clay	0.005	220		
51-57	Clay	0.005	200		
57-63	Clay	0.005	200		
63-69	Clay	0.005	220		
69-75	Clay	0.005	240		
75-81	Clay	0.005	240		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	38	100.0	Clay
3.0	113	100.0	Clay
6.0	181	50.0	Clay
9.0	221	50.0	Clay
12.0	296	50.0	Clay
15.0	799	37.5	Clay
18.0	1063	25.0	Clay
21.0	1176	25.0	Clay
24.0	1561	25.0	Clay
30.0	1399	25.0	Clay
36.0	1736	25.0	Clay
42.0	1561	25.0	Clay
51.0	2462	25.0	Clay
63.0	2239	25.0	Clay
81.0	2686	25.0	Clay

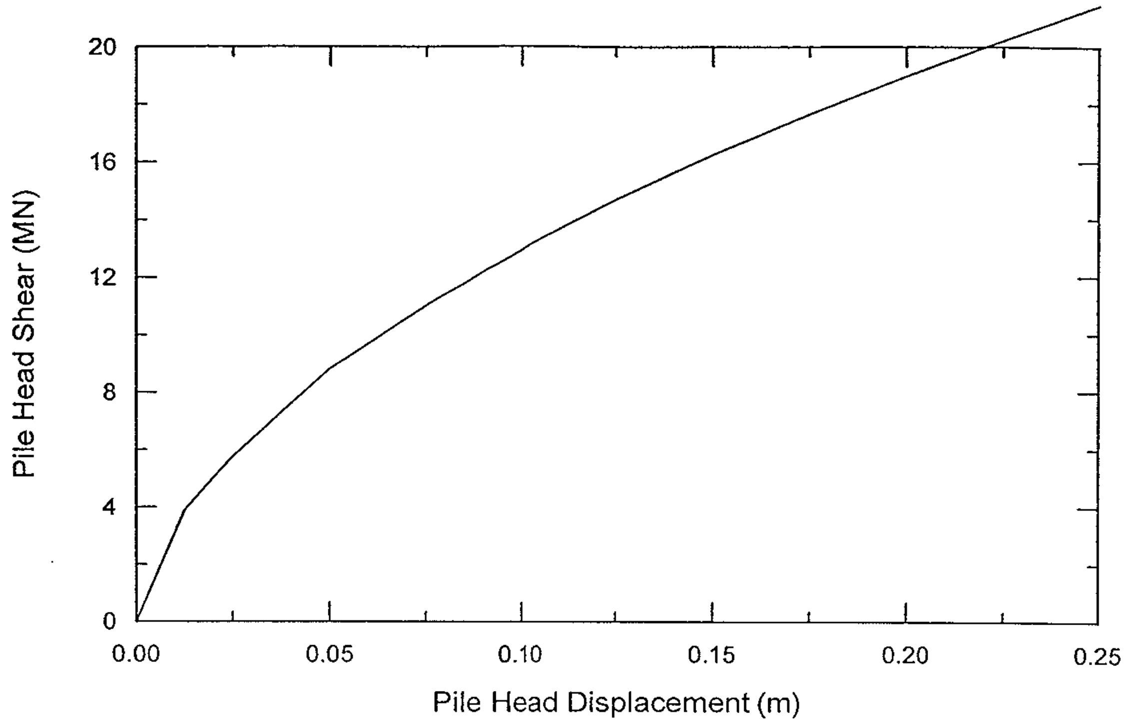
LATERAL PILE DESIGN PARAMETERS
PIER E13 EASTBOUND & WESTBOUND
SFOBB EastSpan Seismic Safety Project

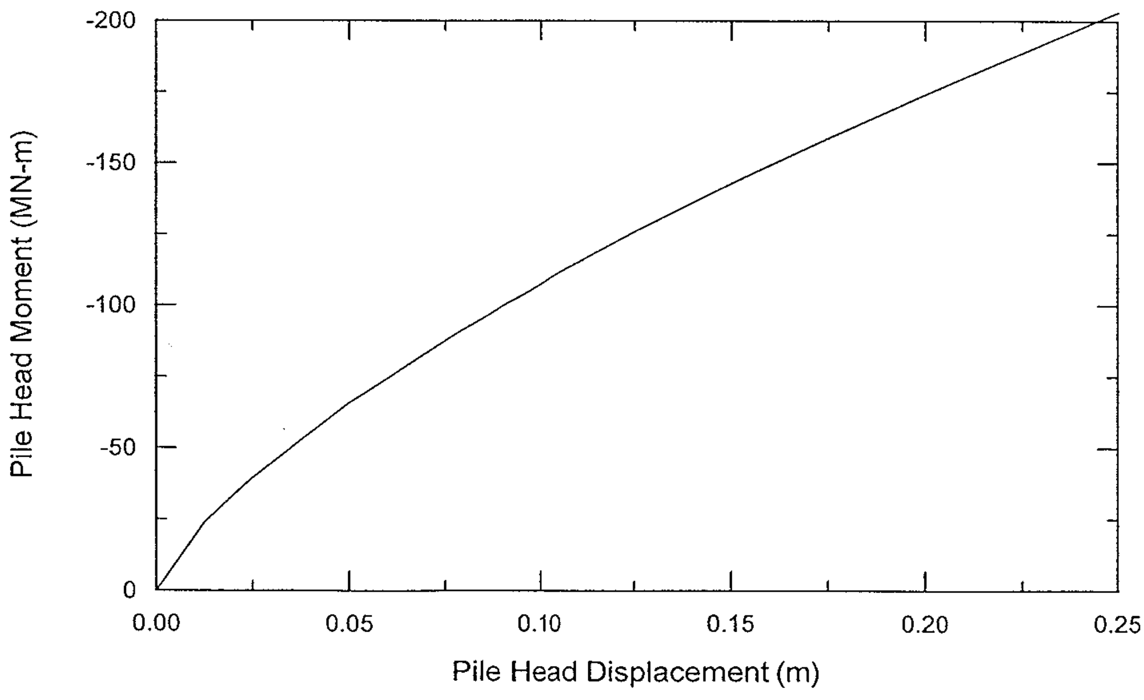
Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	28	1.6	56	12.5	81	37.5	113	100.0	113	249.9		
6.0	3	0	0	45	0.8	90	6.2	130	18.7	181	50.0	181	125.0		
9.0	4	0	0	55	0.8	110	6.2	159	18.7	221	50.0	221	125.0		
12.0	5	0	0	74	0.8	148	6.2	213	18.7	296	50.0	296	125.0		
15.0	6	0	0	199	0.6	399	4.7	575	14.1	799	37.5	799	93.7		
18.0	7	0	0	265	0.4	531	3.1	765	9.4	1063	25.0	1063	62.5		
21.0	8	0	0	294	0.4	588	3.1	847	9.4	1176	25.0	1176	62.5		
24.0	9	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
30.0	10	0	0	349	0.4	699	3.1	1007	9.4	1399	25.0	1399	62.5		
36.0	11	0	0	434	0.4	868	3.1	1250	9.4	1736	25.0	1736	62.5		
42.0	12	0	0	390	0.4	780	3.1	1124	9.4	1561	25.0	1561	62.5		
51.0	13	0	0	615	0.4	1231	3.1	1773	9.4	2462	25.0	2462	62.5		
63.0	14	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		
81.0	15	0	0	671	0.4	1343	3.1	1934	9.4	2686	25.0	2686	62.5		

COORDINATES of p-y CURVES
PIER E13 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

Earth Mechanics

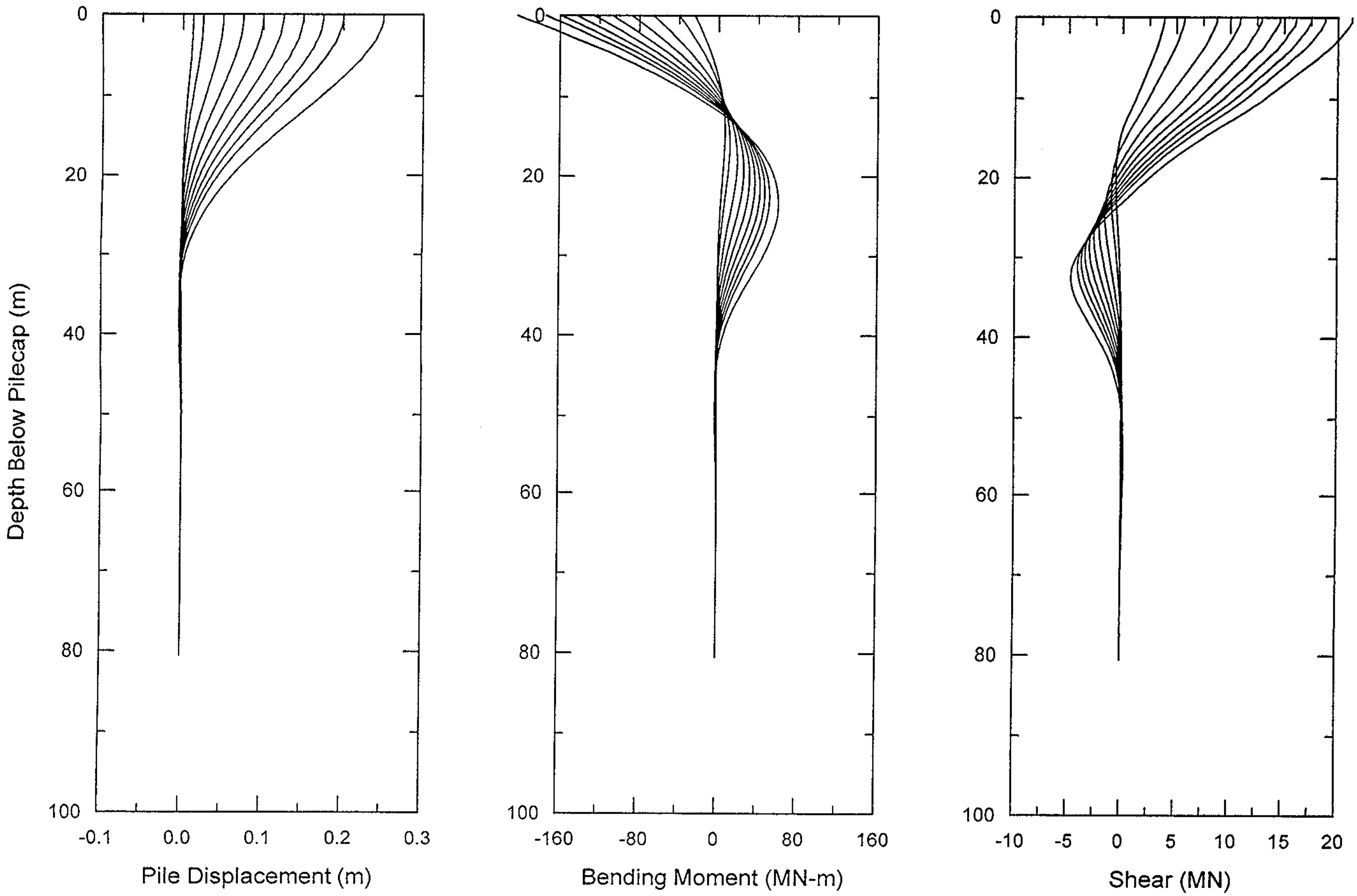
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E13 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E13.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E13 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5

EMI Project No. 98-145

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.017E+006	0.000E+000	0.000E+000	0.000E+000	-6.750E+006	0.000E+000
0.000E+000	9.816E+005	0.000E+000	6.448E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.626E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	6.448E+006	0.000E+000	6.364E+008	0.000E+000	0.000E+000
-6.750E+006	0.000E+000	0.000E+000	0.000E+000	4.879E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	5.863E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.873E+006	0.000E+000	0.000E+000	0.000E+000	-4.514E+007	0.000E+000
0.000E+000	4.833E+006	0.000E+000	4.480E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.196E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	4.480E+007	0.000E+000	1.248E+009	0.000E+000	0.000E+000
-4.514E+007	0.000E+000	0.000E+000	0.000E+000	1.046E+009	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.818E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -8.0 m

CONDENSED STIFFNESS MATRICES
PIER E13 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E13.6

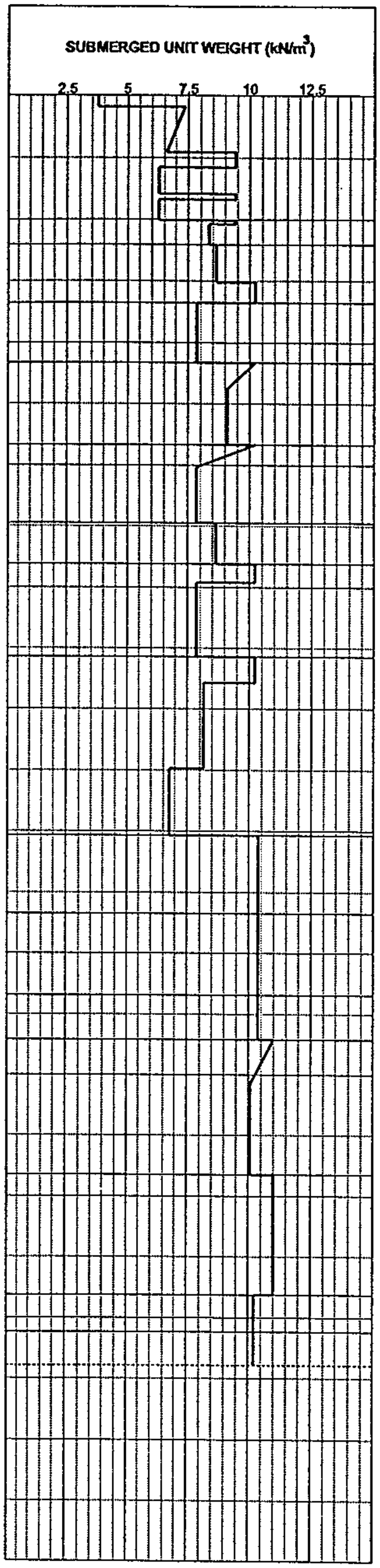
Earth Mechanics FUGRO

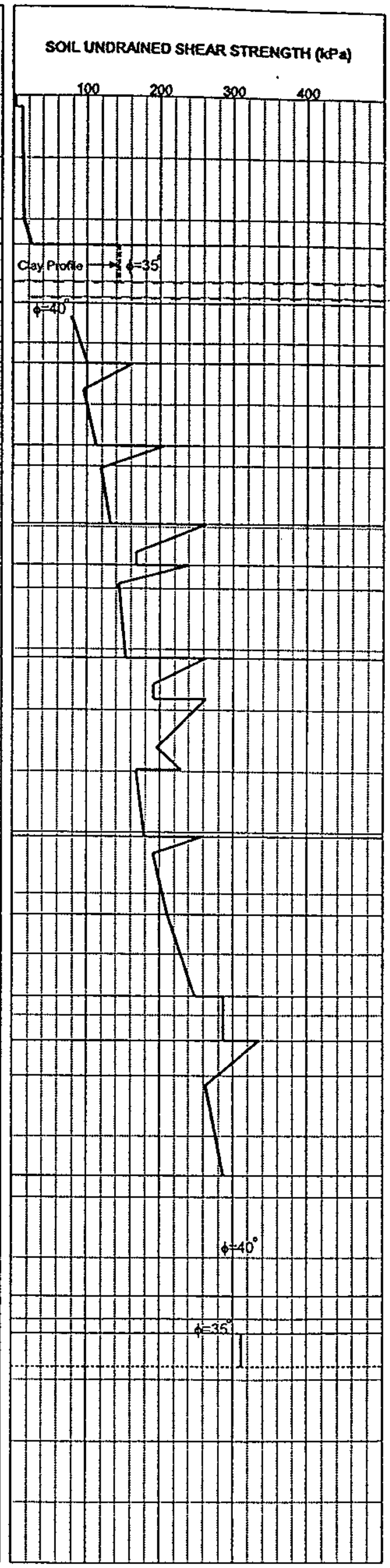
Coordinates: E1838475 N648229
CA State Plane Zone 3, NAD83, Meters

MUDLINE ELEVATION: -3.0m (MSL)

MATERIAL DESCRIPTION	STRATUM NO	UNIT
Fat CLAY (CH), very soft to firm, dark gray to olive gray -gray silty fine to fine sand with clay pockets and seams, 4.6m to 5.8m -sand layer, 7.9m to 8.4m -sand layer, 10.1m to 10.4m (12.0m)	I	YBM
Interlayered Silty Fine SAND (SM), dense, gray, and Fat CLAY (CH), very stiff, gray -clay with sand seams, 13.4m to 13.7m -clay with sand seams and pockets, 14.3m to 14.8m (16.8m)	II	MPSA
-sand with clay pockets at 14.8m -very dense fine sand below 15.1m	III	OBM/UAM
Fat CLAY (CH), stiff to very stiff, gray (21.6m) -very dense gray sand, 18.4m to 18.7m -very dense sand with clay seams, 18.9m to 19.5m Fat CLAY (CH), very stiff, gray (28.3m)	IV	OBM/UAM
Fat CLAY (CH), hard to very stiff, gray -silt layer, 30.0m to 30.5m (34.7m)	V	OBM/UAM
Fat CLAY (CH), hard to very stiff, greenish gray (38.1m)	VI	OBM/UAM
Fat CLAY (CH), hard to very stiff, greenish gray to olive gray (45.7m)	VII	OBM/UAM
Fat CLAY (CH), hard to very stiff, greenish gray -with silt layers at 49.1m and 49.4m (60.4m)	VIII	OBM/UAM
Lean to Fat CLAY (CL/CH), hard, greenish gray (66.8m)	IX	OBM/UAM
Fat CLAY (CH), hard, yellowish brown (73.5m)	X	OBM/UAM
Lean CLAY (CL), hard, greenish gray -sand with clay layers, 74.2m to 75.6m (77.1m)	XI	OBM/UAM
Lean CLAY (CL), hard, yellowish brown with light gray mottling (88.2m)	XII	LAA
Fine to Coarse SAND (SW-SM) with silt and fine gravel, dense to very dense, yellowish red -hard lean clay, with iron oxide staining, silty fine sand partings and fine gravel pockets, 95.7m to 96.3m (98.1m)	XIII	LAA
Silty Fine SAND (SM), dense to very dense, yellowish red (101.2m)	XIV	LAA
Fat CLAY (CH), hard, brown -sand below 103.8m	XV	LAA

TOTAL DEPTH: 103.9m BACKFILLED WITH: Cement Grout

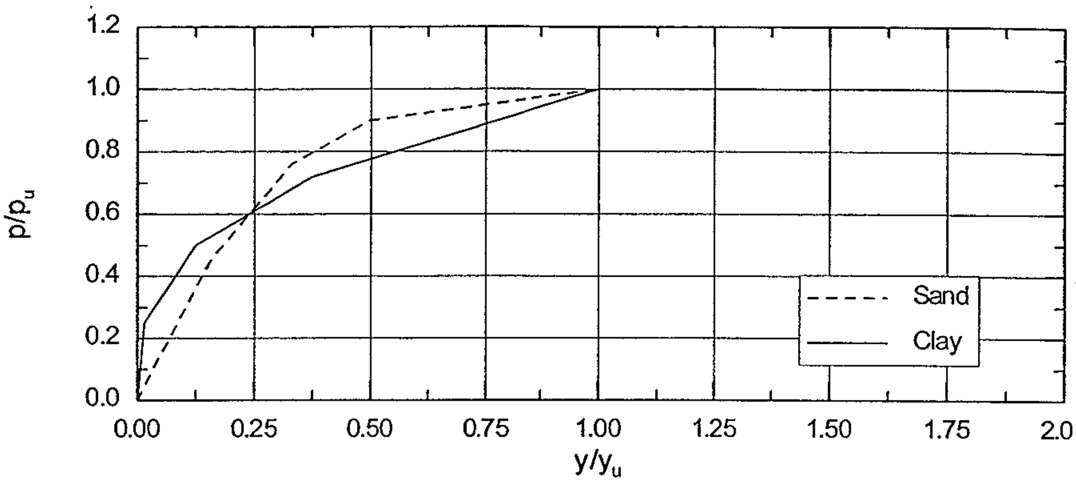




SUBSOIL CONDITION AND SOIL PROPERTIES

PIER E14 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	18		
3-6	Clay	0.02	18		
6-9	Clay	0.02	20		
9-12	Sand			35	5440
12-15	Sand			40	5440
15-18	Clay	0.0075	90		
18-21	Clay	0.0075	90		
21-24	Clay	0.005	115		
24-27	Clay	0.005	105		
27 -30	Clay	0.005	140		
30-33	Clay	0.005	130		
33-36	Clay	0.005	200		
36-39	Clay	0.005	200		
39-42	Clay	0.005	150		
42-45	Clay	0.005	150		
45-51	Clay	0.005	220		
51-57	Clay	0.005	180		
57-63	Clay	0.005	180		
63-69	Clay	0.005	210		
69-75	Clay	0.005	260		
75-81	Clay	0.005	280		

p-y DATA

Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	67	100	Clay
3.0	103	100	Clay
6.0	151	100	Clay
8.9	193	100	Clay
9.1	960	12	Sand
12.0	1688	16	Sand
14.9	4078	30	Sand
15.1	819	37	Clay
18.0	914	37	Clay
21.0	1009	37	Clay
24.0	1286	25	Clay
30.0	1453	25	Clay
36.0	2239	25	Clay
42.0	1679	25	Clay
51.0	2462	25	Clay
63.0	2016	25	Clay
81.0	2907	25	Clay

LATERAL PILE DESIGN PARAMETERS
PIER E14 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

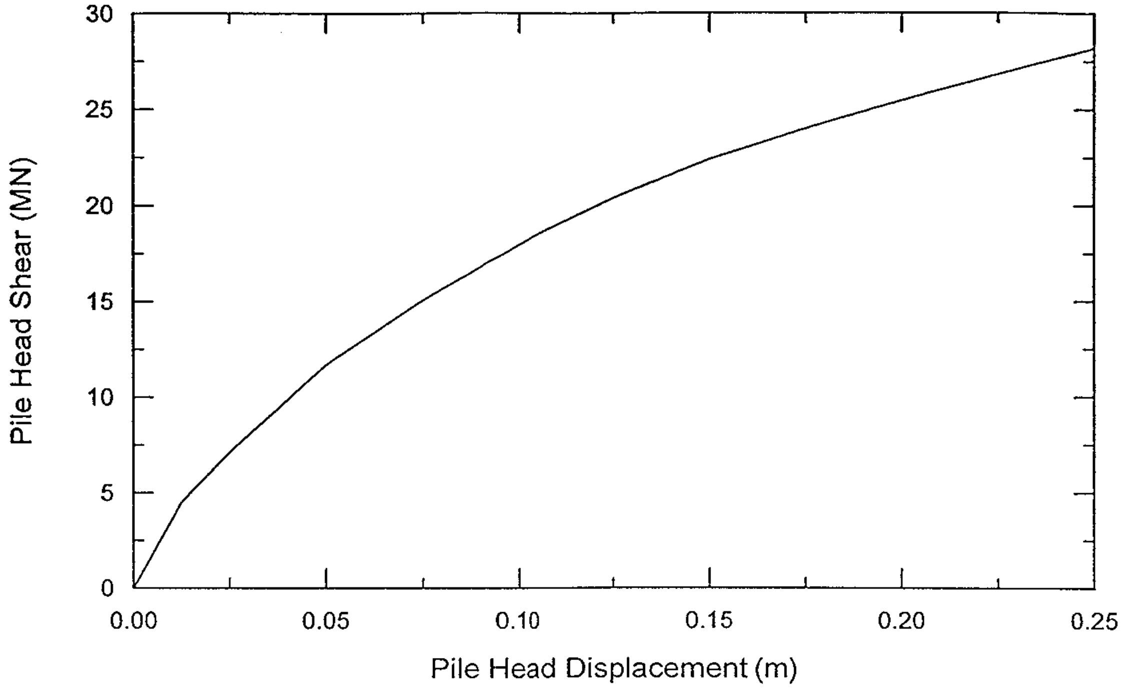
Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	17	1.6	34	12.5	48	37.5	67	100.0	67	249.9		
3.0	2	0	0	25	1.6	51	12.5	74	37.5	103	100.0	103	249.9		
6.0	3	0	0	37	1.6	75	12.5	109	37.5	151	100.0	151	249.9		
8.9	4	0	0	48	1.6	96	12.5	139	37.5	193	100.0	193	249.9		
9.1	5	0	0	96	0.4	441	1.9	729	3.9	873	5.8	960	11.7	960	19.5
12.0	6	0	0	168	0.5	776	2.6	1283	5.2	1536	7.8	1688	15.5	1688	25.9
14.9	7	0	0	407	1.0	1876	5.1	3099	10.1	3711	15.2	4078	30.3	4078	50.5
15.1	8	0	0	204	0.6	409	4.7	590	14.1	819	37.5	819	93.7		
18.0	9	0	0	228	0.6	457	4.7	658	14.1	914	37.5	914	93.7		
21.0	10	0	0	252	0.6	504	4.7	726	14.1	1009	37.5	1009	93.7		
24.0	11	0	0	321	0.4	643	3.1	926	9.4	1286	25.0	1286	62.5		
30.0	12	0	0	363	0.4	726	3.1	1046	9.4	1453	25.0	1453	62.5		
36.0	13	0	0	559	0.4	1119	3.1	1612	9.4	2239	25.0	2239	62.5		
42.0	14	0	0	419	0.4	839	3.1	1209	9.4	1679	25.0	1679	62.5		
51.0	15	0	0	615	0.4	1231	3.1	1773	9.4	2462	25.0	2462	62.5		
63.0	16	0	0	504	0.4	1008	3.1	1451	9.4	2016	25.0	2016	62.5		
81.0	17	0	0	726	0.4	1453	3.1	2093	9.4	2907	25.0	2907	62.5		

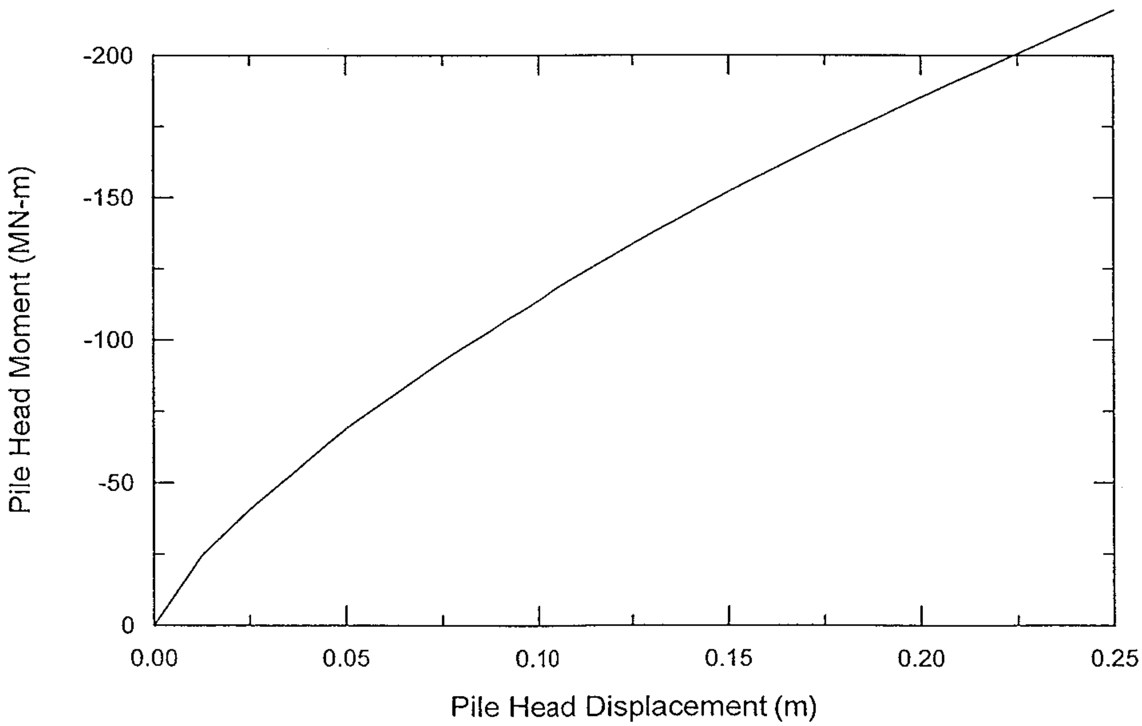
COORDINATES of p-y CURVES
PIER E14 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E14.3

SFOBB Task Order No. 5
EMI Project No. 98-145

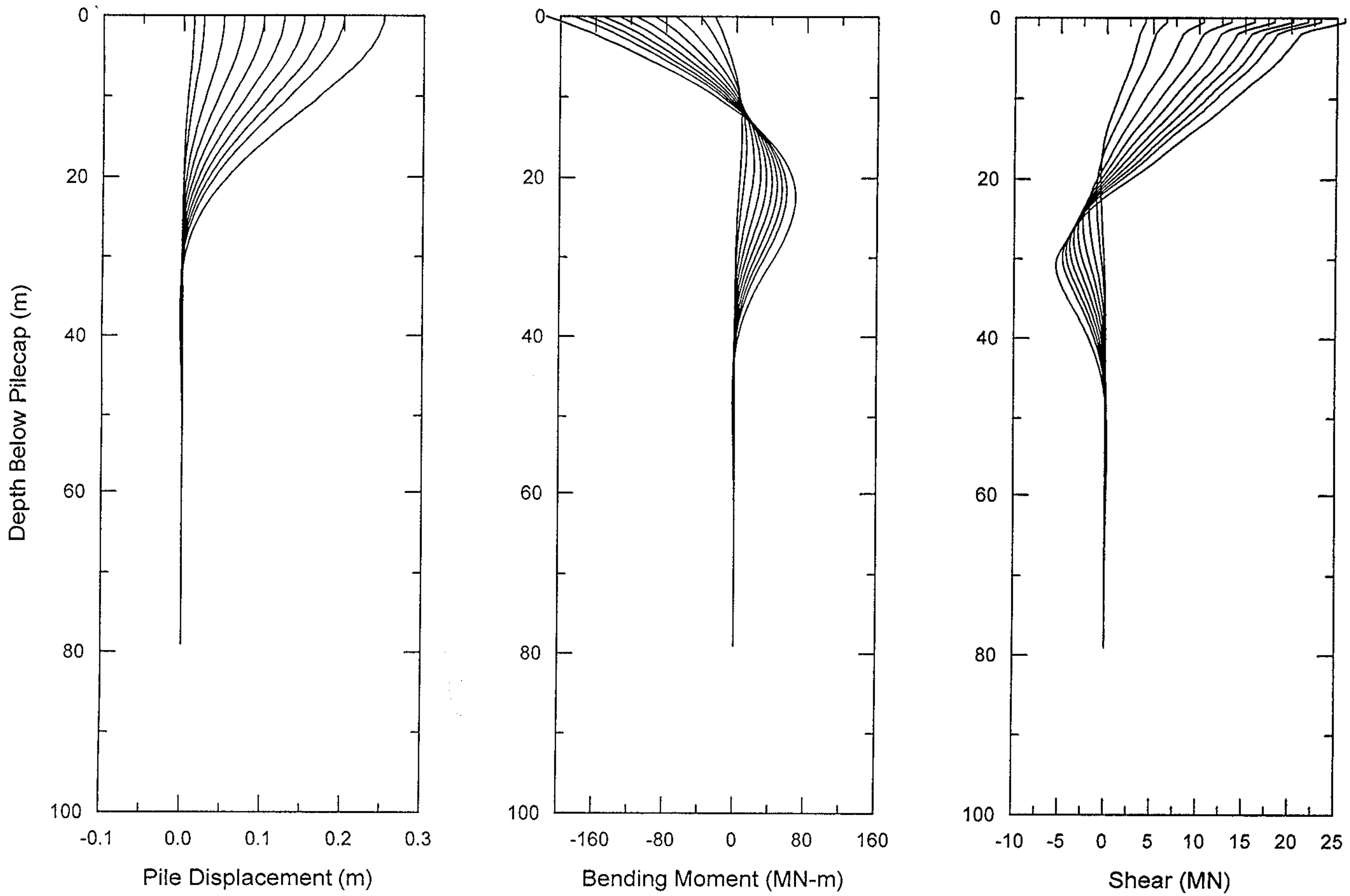
Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E14 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E14.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E14 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5

EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E14.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.077E+006	0.000E+000	0.000E+000	0.000E+000	-1.304E+007	0.000E+000
0.000E+000	2.030E+006	0.000E+000	1.265E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.194E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.265E+007	0.000E+000	8.548E+008	0.000E+000	0.000E+000
-1.304E+007	0.000E+000	0.000E+000	0.000E+000	6.544E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.145E+008

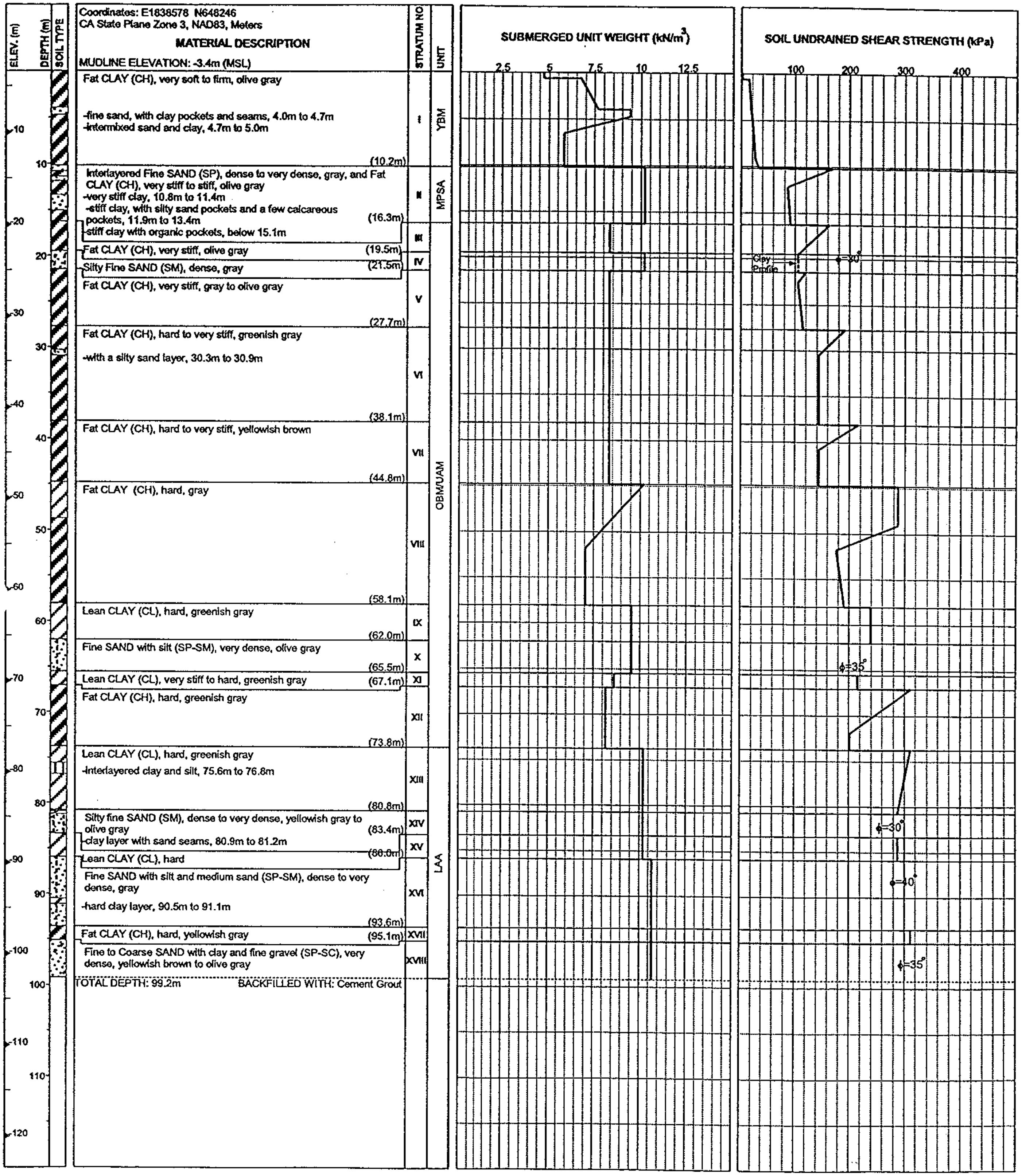
PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.821E+006	0.000E+000	0.000E+000	0.000E+000	-4.827E+007	0.000E+000
0.000E+000	5.783E+006	0.000E+000	4.794E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	2.195E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	4.794E+007	0.000E+000	1.248E+009	0.000E+000	0.000E+000
-4.827E+007	0.000E+000	0.000E+000	0.000E+000	1.045E+009	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	3.257E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -9.5 m

CONDENSED STIFFNESS MATRICES
PIER E14 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

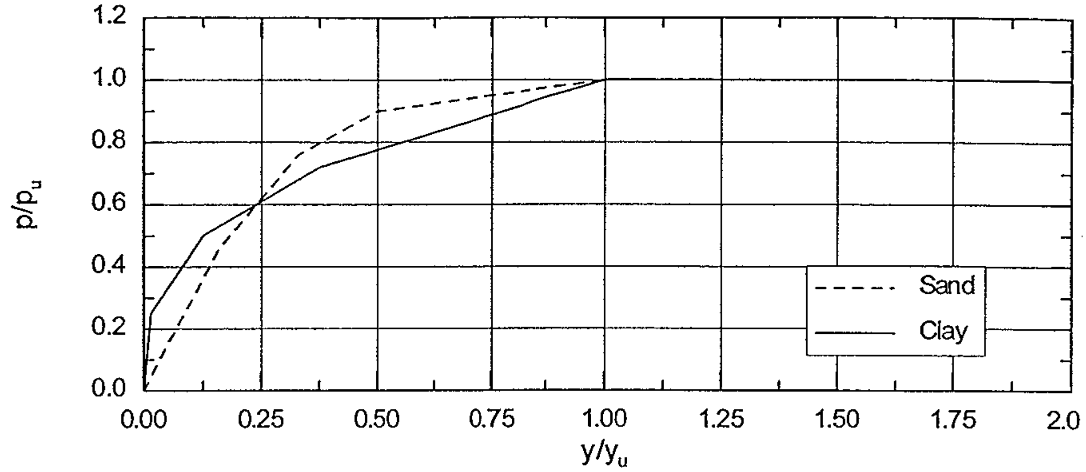
PLATE E14.6



SUBSOIL CONDITION AND SOIL PROPERTIES

PIER E15 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m²)	ϕ	k (kN/m³)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.02	22		
9-12	Clay	0.005	120		
12-15	Clay	0.0075	90		
15-18	Clay	0.005	120		
18-21	Clay	0.005	100		
21-24	Clay	0.005	110		
24-27	Clay	0.005	110		
27 -30	Clay	0.005	160		
30-33	Clay	0.005	140		
33-36	Clay	0.005	140		
36-39	Clay	0.005	160		
39-42	Clay	0.005	140		
42-45	Clay	0.005	140		
45-51	Clay	0.005	240		
51-57	Clay	0.005	180		
57-63	Clay	0.005	220		
63-69	Clay	0.005	220		
69-75	Clay	0.005	220		
75-81	Clay	0.005	300		

p-y DATA

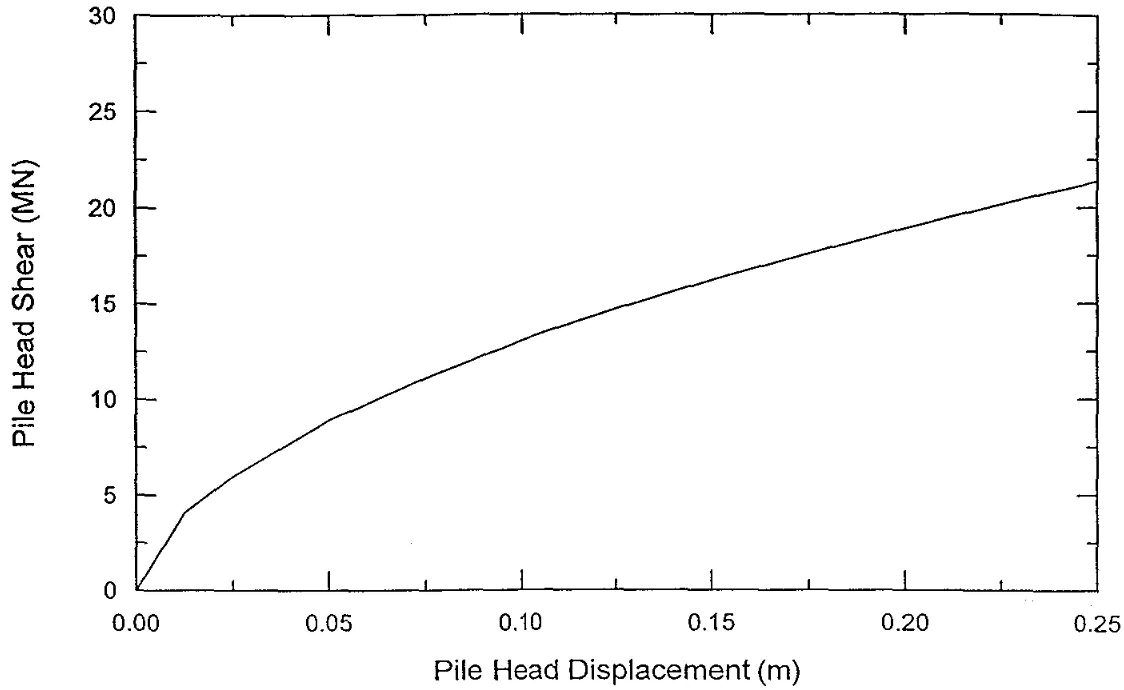
Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	38	100.0	Clay
3.0	113	100.0	Clay
6.0	167	100.0	Clay
9.0	794	25.0	Clay
12.0	921	25.0	Clay
15.0	1049	25.0	Clay
18.0	1004	25.0	Clay
21.0	1200	25.0	Clay
24.0	1232	25.0	Clay
30.0	1566	25.0	Clay
36.0	1792	25.0	Clay
42.0	1566	25.0	Clay
51.0	2686	25.0	Clay
63.0	2462	25.0	Clay
81.0	3337	25.0	Clay

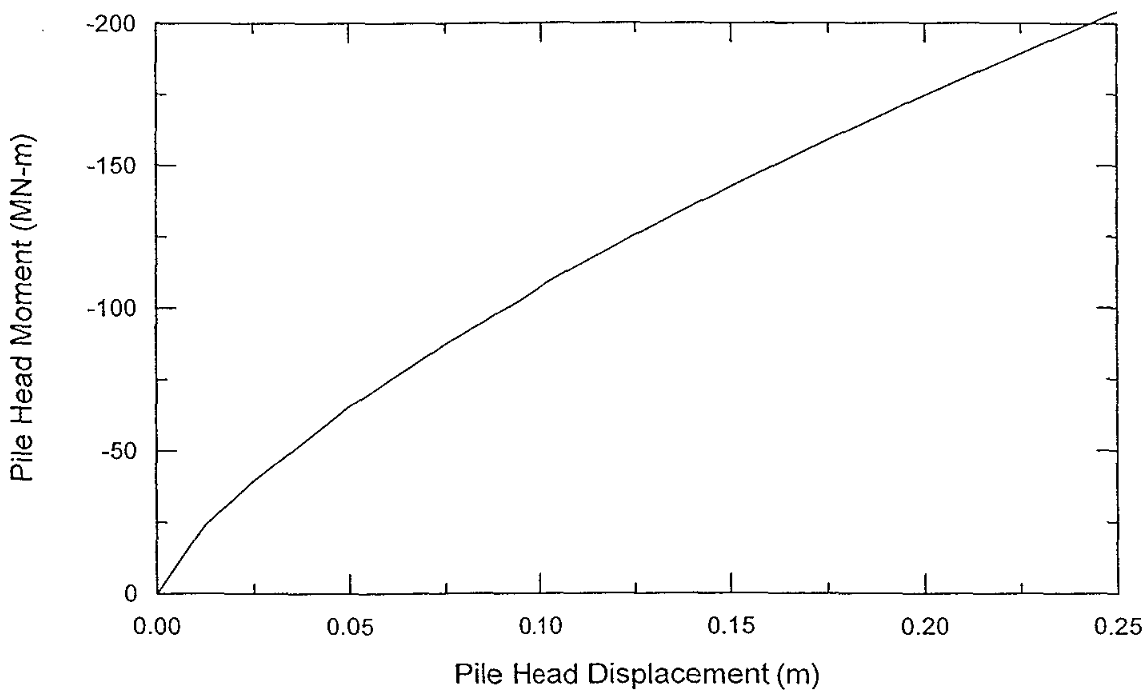
LATERAL PILE DESIGN PARAMETERS
PIER E15 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	28	1.6	56	12.5	81	37.5	113	100.0	113	249.9		
6.0	3	0	0	41	1.6	83	12.5	120	37.5	167	100.0	167	249.9		
9.0	4	0	0	198	0.4	397	3.1	571	9.4	794	25.0	794	62.5		
12.0	5	0	0	230	0.4	460	3.1	663	9.4	921	25.0	921	62.5		
15.0	6	0	0	262	0.4	524	3.1	755	9.4	1049	25.0	1049	62.5		
18.0	7	0	0	251	0.4	502	3.1	723	9.4	1004	25.0	1004	62.5		
21.0	8	0	0	300	0.4	600	3.1	864	9.4	1200	25.0	1200	62.5		
24.0	9	0	0	308	0.4	616	3.1	887	9.4	1232	25.0	1232	62.5		
30.0	10	0	0	391	0.4	783	3.1	1127	9.4	1566	25.0	1566	62.5		
36.0	11	0	0	448	0.4	896	3.1	1290	9.4	1792	25.0	1792	62.5		
42.0	12	0	0	391	0.4	783	3.1	1127	9.4	1566	25.0	1566	62.5		
51.0	13	0	0	671	0.4	1343	3.1	1934	9.4	2686	25.0	2686	62.5		
63.0	14	0	0	615	0.4	1231	3.1	1773	9.4	2462	25.0	2462	62.5		
81.0	15	0	0	834	0.4	1668	3.1	2403	9.4	3337	25.0	3337	62.5		

COORDINATES of p-y CURVES
PIER E15 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

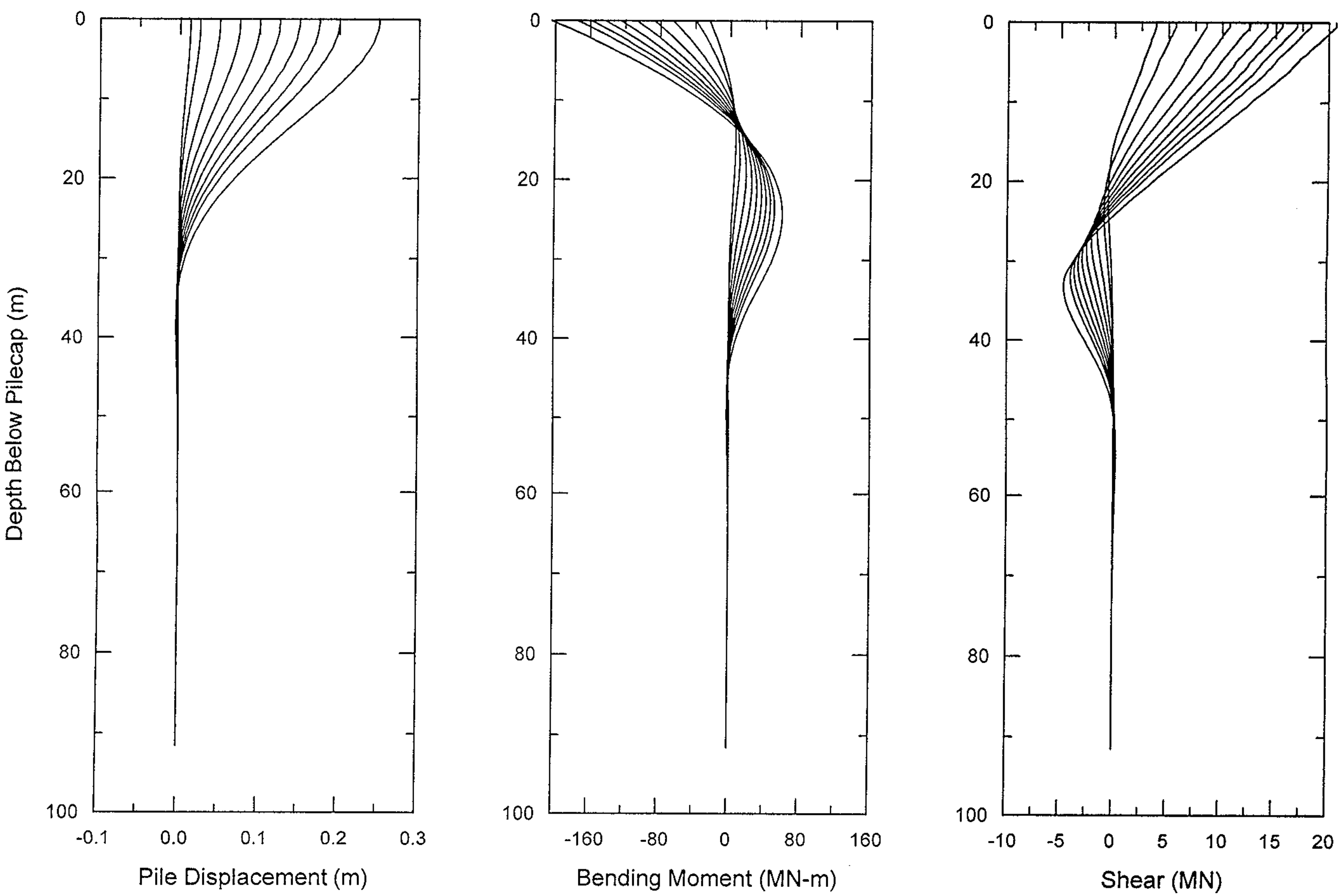
Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E15 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E15.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E15 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5
EMI Project No. 98-145

Earth Mechanics

FUGRO

PLATE E15.5

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.577E+005	0.000E+000	0.000E+000	0.000E+000	-2.636E+006	0.000E+000
0.000E+000	5.577E+005	0.000E+000	-1.440E+006	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.464E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-1.440E+006	0.000E+000	6.935E+008	0.000E+000	0.000E+000
-2.636E+006	0.000E+000	0.000E+000	0.000E+000	2.517E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	3.469E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

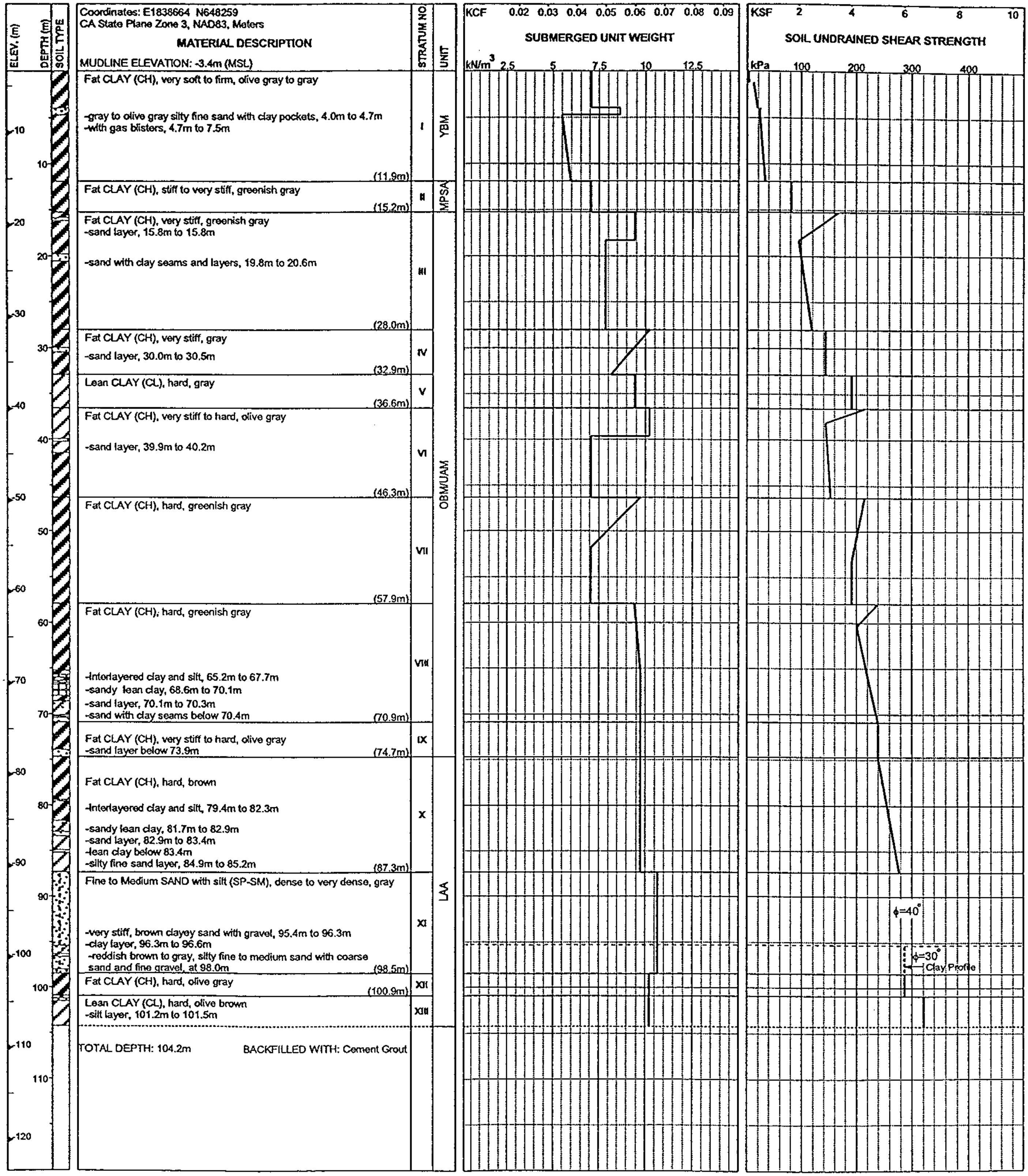
DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.030E+006	0.000E+000	0.000E+000	0.000E+000	-2.924E+007	0.000E+000
0.000E+000	3.030E+006	0.000E+000	2.590E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.457E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	2.590E+007	0.000E+000	1.018E+009	0.000E+000	0.000E+000
-2.924E+007	0.000E+000	0.000E+000	0.000E+000	5.634E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	2.002E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -4.0 m

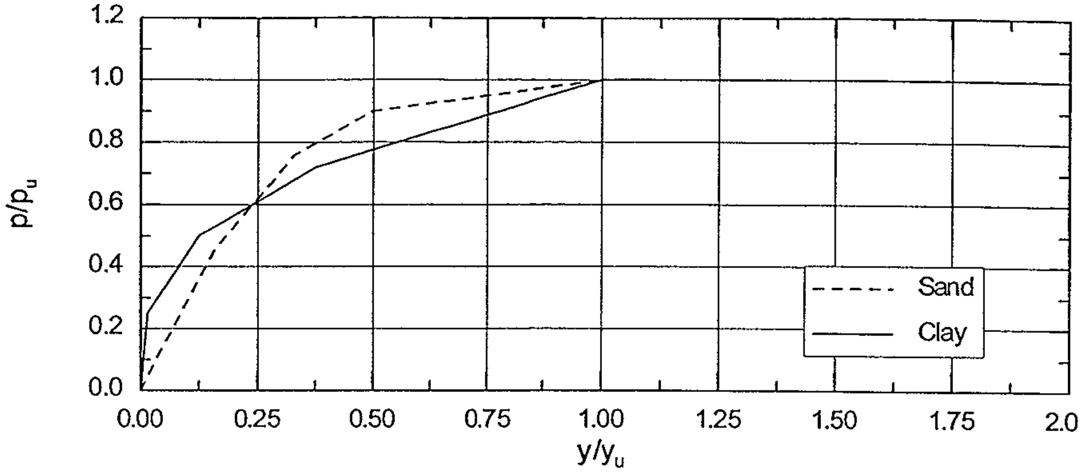
CONDENSED STIFFNESS MATRICES
PIER E15 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E15.6

Earth Mechanics FUGRO



SUBSOIL CONDITION AND SOIL PROPERTIES
PIER E16 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project



NORMALIZED p-y CURVE

SOIL STRATIGRAPHY AND PROPERTIES

Depth (m)	Soil Type	ε_{50}	S_u (kN/m^2)	ϕ	k (kN/m^3)
0-3	Clay	0.02	10		
3-6	Clay	0.02	20		
6-9	Clay	0.02	22		
9-12	Clay	0.02	30		
12-15	Clay	0.075	80		
15-18	Clay	0.005	130		
18-21	Clay	0.005	100		
21-24	Clay	0.005	110		
24-27	Clay	0.005	115		
27 -30	Clay	0.005	140		
30-33	Clay	0.005	190		
33-36	Clay	0.005	180		
36-39	Clay	0.005	145		
39-42	Clay	0.005	150		
42-45	Clay	0.005	155		
45-51	Clay	0.005	190		
51-57	Clay	0.005	190		
57-63	Clay	0.005	210		
63-69	Clay	0.005	220		
69-75	Clay	0.005	240		
75-81	Clay	0.005	250		

p-y DATA

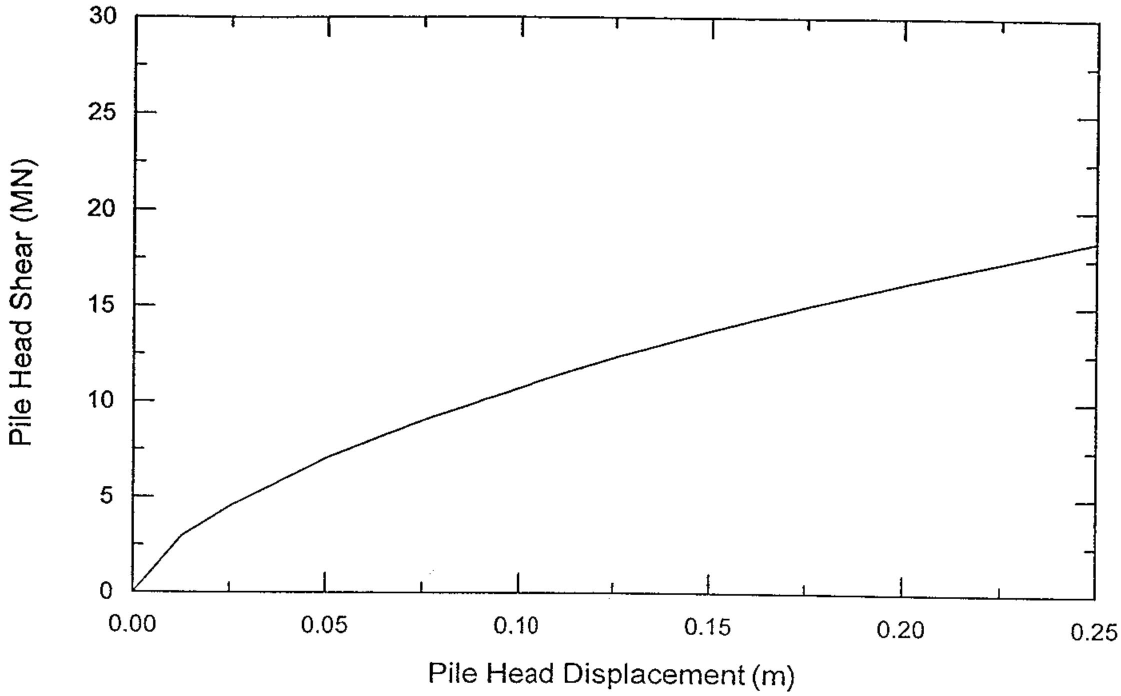
Depth (m)	p_u (kN/m)	y_u (cm)	p-y Criteria
0.0	38	100.0	Clay
3.0	113	100.0	Clay
6.0	167	100.0	Clay
9.0	255	100.0	Clay
12.0	652	37.5	Clay
15.0	1121	25.0	Clay
18.0	1004	25.0	Clay
21.0	1200	25.0	Clay
24.0	1232	25.0	Clay
30.0	2126	25.0	Clay
36.0	1623	25.0	Clay
42.0	1735	25.0	Clay
51.0	2126	25.0	Clay
63.0	2352	25.0	Clay
81.0	2799	25.0	Clay

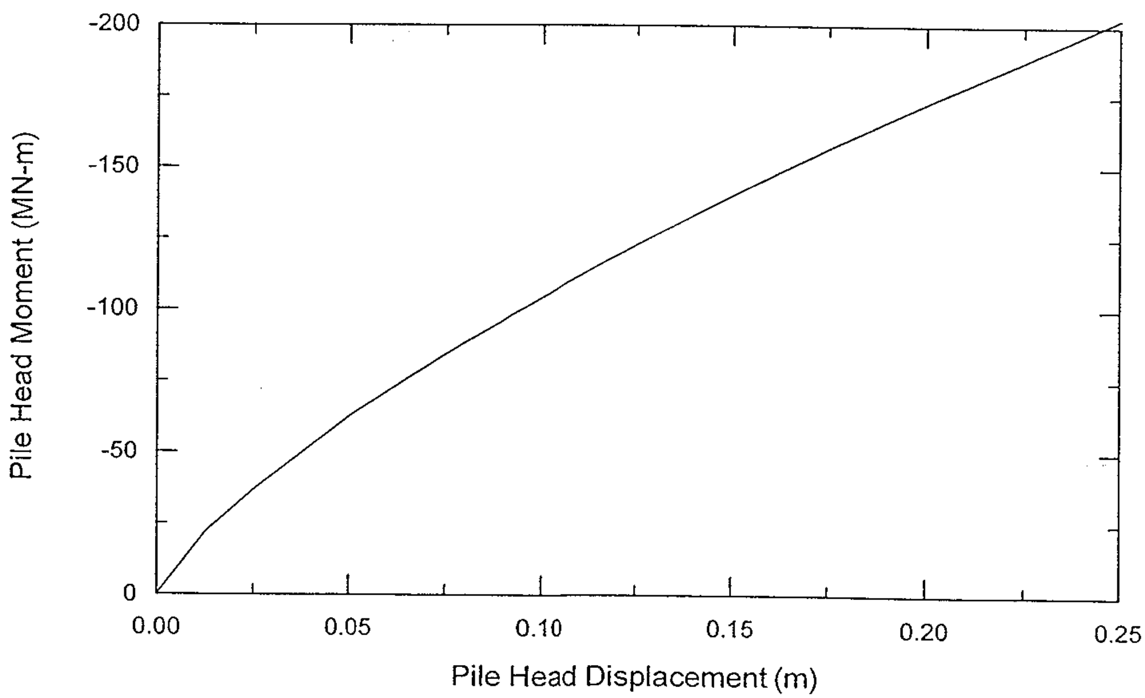
LATERAL PILE DESIGN PARAMETERS
PIER E16 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

Depth (m)	Curve No.	Coordinates of p-y Curve Points (p in kN/m, y in cm)													
		p1	y1	p2	y2	p3	y3	p4	y4	p5	y5	p6	y6	p7	y7
0.0	1	0	0	9	1.6	19	12.5	27	37.5	38	100.0	38	249.9		
3.0	2	0	0	28	1.6	56	12.5	81	37.5	113	100.0	113	249.9		
6.0	3	0	0	41	1.6	83	12.5	120	37.5	167	100.0	167	249.9		
9.0	4	0	0	63	1.6	127	12.5	183	37.5	255	100.0	255	249.9		
12.0	5	0	0	163	0.6	326	4.7	469	14.1	652	37.5	652	93.7		
15.0	6	0	0	280	0.4	560	3.1	807	9.4	1121	25.0	1121	62.5		
18.0	7	0	0	251	0.4	502	3.1	723	9.4	1004	25.0	1004	62.5		
21.0	8	0	0	300	0.4	600	3.1	864	9.4	1200	25.0	1200	62.5		
24.0	9	0	0	308	0.4	616	3.1	887	9.4	1232	25.0	1232	62.5		
30.0	10	0	0	531	0.4	1063	3.1	1531	9.4	2126	25.0	2126	62.5		
36.0	11	0	0	405	0.4	811	3.1	1168	9.4	1623	25.0	1623	62.5		
42.0	12	0	0	433	0.4	867	3.1	1249	9.4	1735	25.0	1735	62.5		
51.0	13	0	0	531	0.4	1063	3.1	1531	9.4	2126	25.0	2126	62.5		
63.0	14	0	0	588	0.4	1176	3.1	1693	9.4	2352	25.0	2352	62.5		
81.0	15	0	0	699	0.4	1399	3.1	2015	9.4	2799	25.0	2799	62.5		

COORDINATES of p-y CURVES
PIER E16 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

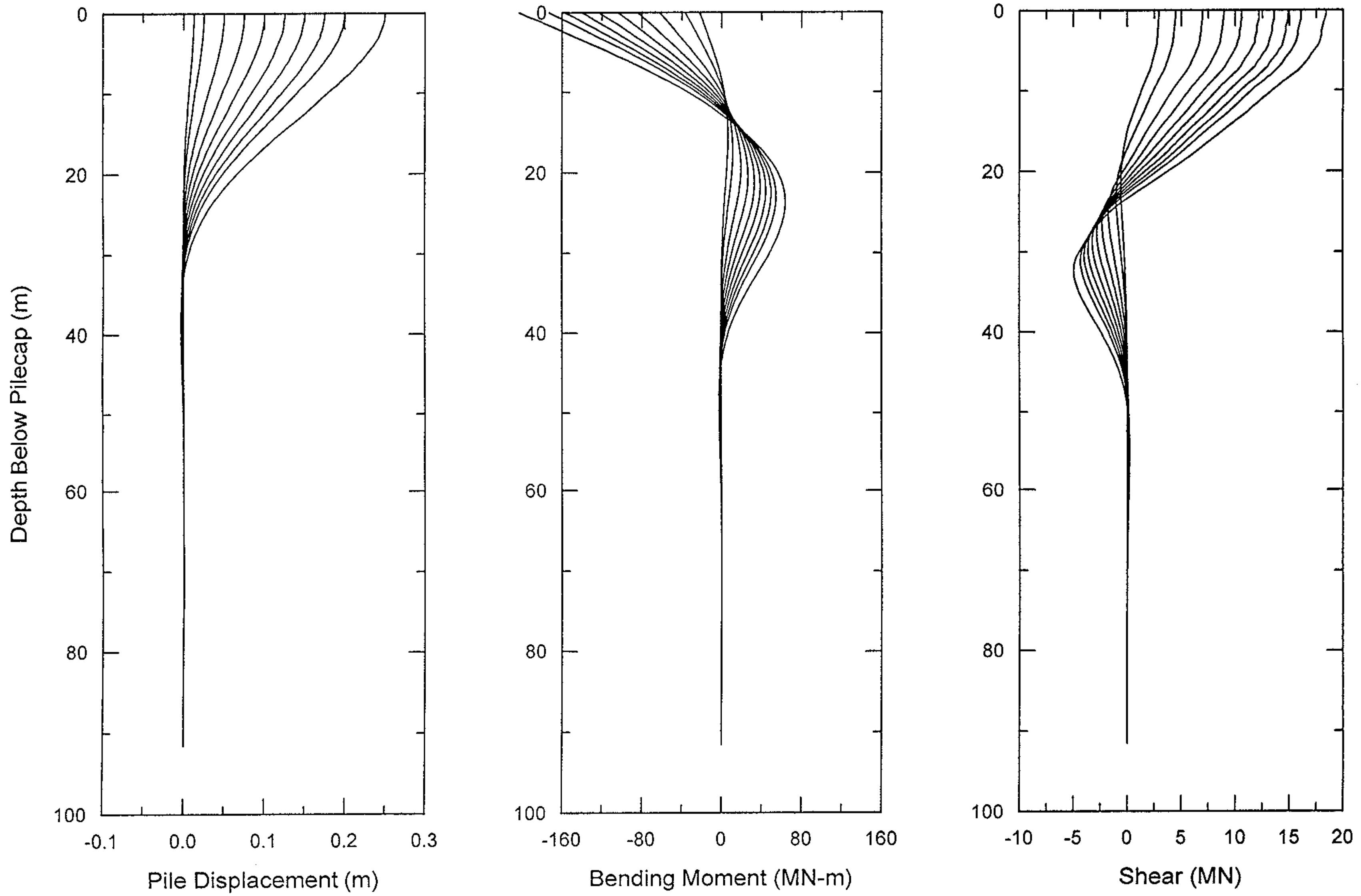
Earth Mechanics
FUGRO





PILE HEAD SHEAR AND BENDING MOMENT
PIER E16 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

PLATE E16.4



PILE DISPLACEMENT, BENDING MOMENT AND SHEAR WITH DEPTH

PIER E16 EASTBOUND & WESTBOUND

SFOBB East Span Seismic Safety Project

Earth Mechanics

FUGRO

PILE-GROUP STIFFNESS MATRIX (SEISMIC CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.065E+005	0.000E+000	0.000E+000	0.000E+000	-2.881E+006	0.000E+000
0.000E+000	5.065E+005	0.000E+000	-6.771E+005	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.281E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	-6.771E+005	0.000E+000	6.208E+008	0.000E+000	0.000E+000
-2.881E+006	0.000E+000	0.000E+000	0.000E+000	2.338E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	3.236E+007

PILE-GROUP STIFFNESS (SERVICE CONDITION)

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.115E+006	0.000E+000	0.000E+000	0.000E+000	-2.110E+007	0.000E+000
0.000E+000	2.115E+006	0.000E+000	1.750E+007	0.000E+000	0.000E+000
0.000E+000	0.000E+000	1.456E+007	0.000E+000	0.000E+000	0.000E+000
0.000E+000	1.750E+007	0.000E+000	9.406E+008	0.000E+000	0.000E+000
-2.110E+007	0.000E+000	0.000E+000	0.000E+000	4.908E+008	0.000E+000
0.000E+000	0.000E+000	0.000E+000	0.000E+000	0.000E+000	1.423E+008

Note : All units are in kN & m.
x direction is longitudinal along the bridge
y direction is transverse
z direction is vertical
Group stiffness condensed at pilecap top El. -4.5 m

CONDENSED STIFFNESS MATRICES
PIER E16 EASTBOUND & WESTBOUND
SFOBB East Span Seismic Safety Project

SECTION 5.0

SECTION 5.0
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5.0 REFERENCES

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