Appendix B3
Structural Engineering

Oakland Harbor Navigation Improvement
Feasibility Report

CENWP-ENC-DS

October 12, 2021

US Army Corps
of Engineers®

1. INTRODUCTION

This appendix is prepared to briefly describe the structural parameters used for the Oakland Harbor Navigation Improvement (-50 Foot Deepening) Project (Phase 1A Supplemental Documentation Report (SDR), dated March 2001) to provide a feasibility-level structural design recommendation for the proposed bulkheads of the Oakland Harbor Turning Basins Widening Navigation Feasibility Study. This appendix also evaluates and summarizes the general design parameters, assumptions, and preliminary calculations used for the existing Bulkheads. After evaluating the available data and information of the -50-ft deepening project cited above, this appendix provides a feasibility-level structural recommendation for the proposed structural features. The recommendations may include possible improvements or will suggest applying similar approaches as the -50-ft deepening project while also integrating the current structural requirements and standards.

2. DESIGN CRITERIA

The design criteria was taken from the original design parameters gleaned from previous reports and data provided. The engineering evaluation is generally based on grossly assumed geotechnical design parameters across all design locations. These assumptions and parameters will require further investigation for more detailed design.

- ACI 318-14: Building Code Requirements for Structural Concrete and Commentary (2014)
- ASCE 7-16: Minimum Design Loads for Buildings and Other Structures (2016)
- AISC 360-16: Specifications for Structural Steel Building
- EM 1110-2-2502 Retaining and Flood Walls (1989)
- ER 1110-2-1806 Earthquake Design and Evaluation for Civil Works Projects
- USGS 2014 Seismic Hazard Map
- Seed and Whitman (1970)
- UFC 3-301-01: Structural Engineering (2016)
- Soil properties for bulkhead retaining walls:
    - Soil density: 120 pcf (dry)
    - Soil density: 57.6 pcf (submerged)
    - Surcharge: 250 psf
    - Active earth pressure Coefficient: 0.35
    - Passive earth pressure Coefficient: 3.0
    - Point of Fixity: Elevation -36.00 (assumed 10 feet below sheet pile embedment elevation, i.e. “Wall Bench”)
    - Wall Bench: Elevation -26.00’
    - Water elevation is same at front and back face of the retaining wall

3. GENERAL LAYOUT OF IMPROVEMENTS

The main structures that will be constructed as a part of this improvement are in the dashed lines in Figure 1.

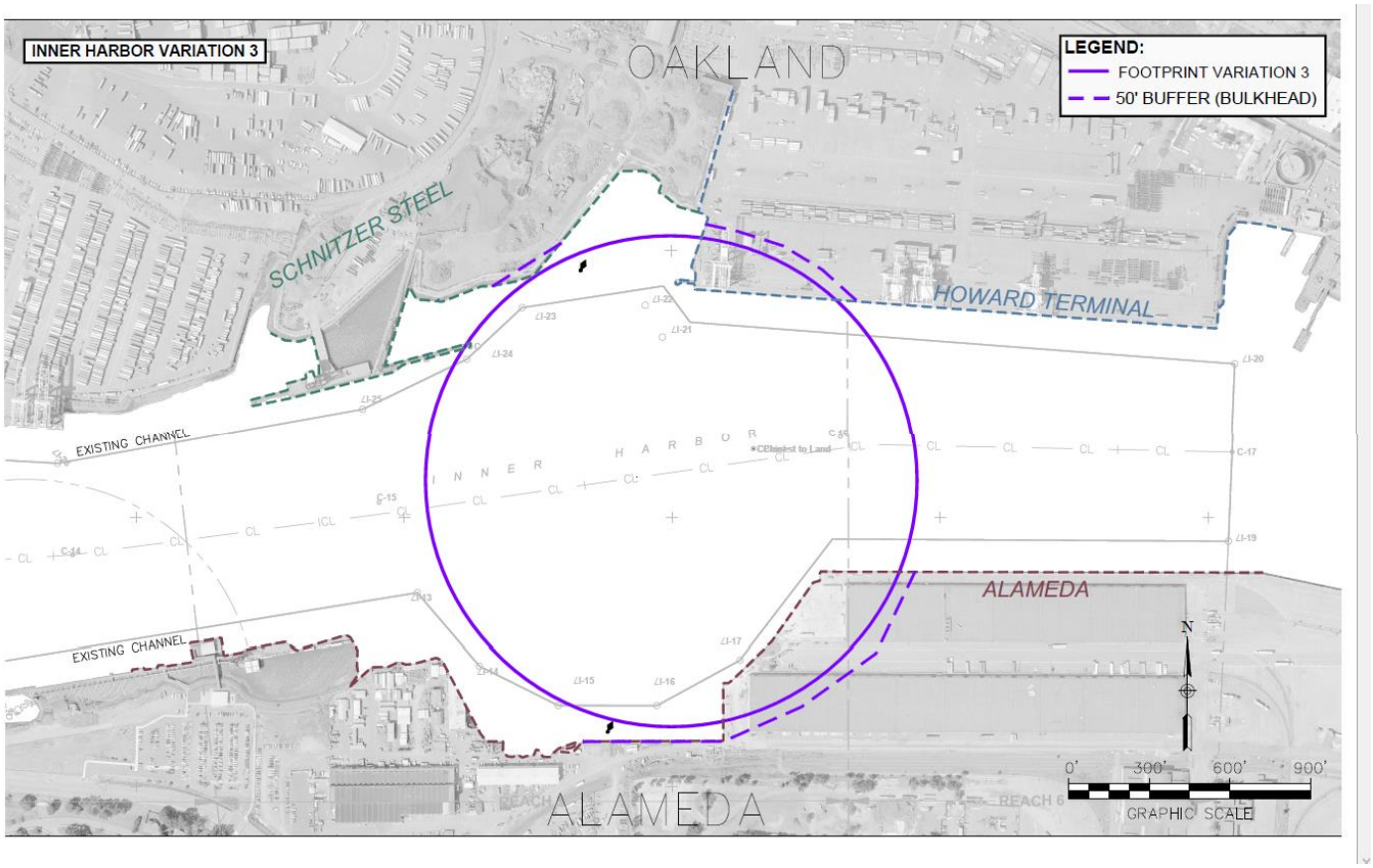

Figure 1: Proposed Inner Harbor Turning Basin Structural Features

4. BULKHEAD STRUCTURE

The bulkhead structure that was evaluated was a generalized version of the SDR and dredging plan, sheet C8, provided by SPN personnel. The new proposed design is a sheet pile wall braced with batter piles, which was the most efficient design for harbor improvements. AZ 52-700 sheet pile and 24" diameter steel concrete filled batter piles at 10-foot spacing was considered for the new bulkhead structure in this analysis. The existing bulkhead drawings show AZ-48 sheet pile with concrete and steel batter piles at 11.5-foot spacing in some locations. Although it is unclear what was installed for the existing bulkhead structure, 11.5-foot batter pile spacing for a new design did not meet strength requirements. Based on project ~~scope and~~scope and information provided by the project delivery team, this appendix was developed to only address a single new bulkhead layout design configuration.

5. DESIGN CRITERIA FOR HARBOR IMPROVEMENTS

The bench elevation for both sheet pile and batter piles was assumed to be -26 feet, as shown on the sketch below. The point of fixity of the sheet pile and the batterpiles were assumed to be at elevation-36 feet.

See figure 2 for general design feature cross section.

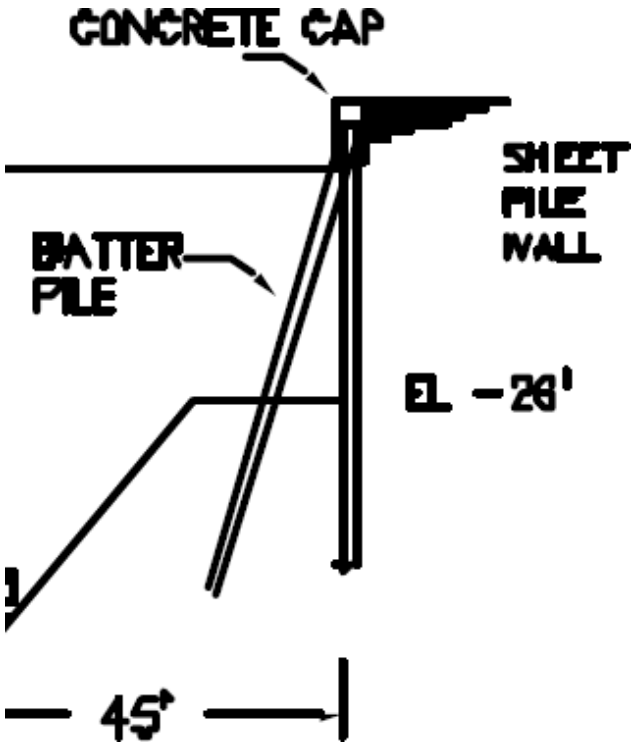

Figure 2: Cross Section of Bulkhead Used for the -50-ft Deepening Project at the Inner Harbor Basin

Seismic criteria:

The sheet pile and batter piles to be designed and constructed to resist the effects of earthquake motions, at a minimum, equivalent to the OBE per ETL 1110-2-584. For this project, a return period of 975 years was considered as the MDE. This return period differs from that recommended in the Supplemental design report, which used a return period of 475 years.

USGS 2014 Seismic Hazard Map was used to obtain the information below:Location: Latitude, 37.791297, Longitude: -122.287034

Peak Ground Acceleration (PGA): 0.619g

Spectral Acceleration Parameter at Short Period: 1.441g Spectral Acceleration Parameter at a Period of 1 second: 0.454

Design Loads:

A STAAD model was developed to perform analysis. The loads considered were as follows:

1. Dead load: D

   Gravity loads of sheet pile, battered steel piles, and 5'X7' concrete cap.

2. Active soil pressure: Fa
3. Passive soil pressure: Fp
4. Surcharge load: Fs
5. Seismic load: E

ASD Load Combination:

1.0 D + 1.0 Fa + 1.0 Fp + 1.0 Fs + .7 E , ASCE 7-16

6. SUMMARY OF ANALYSIS

Analysis for the proposed bulkhead was performed with AZ 52-700 sheet pile and 24" diameter battered steel piles, filled with concrete and at 10' spacing. Due to the increased seismic load applied to the wall, the sheet pile size had to be increased to AZ 52-700 from the original bulkhead sheet pile (AZ 48). The analysis confirms that the new design elements are adequate for the assumed loads mentioned above. The height of the sheet pile, sheet pile fixity, batter pile design, batter pile spacing, and other design details will need further design evaluation by geotechnical and structural engineers during the design phase.

7. CONSTRUCTION CONSIDERATIONS

Construction considerations were not included as part of this structural investigation. It is assumed since this design is similar to the current wall design that the new wall would be constructable. It is recommended that any lessons learned from the original bulkhead construction be used to guide best practices decisions for the development of the new wall design and for construction documentation for the new retaining wall.

8. RECOMMENDATIONS

The design as presented in this appendix is preliminary and is based on limited information and generalized assumptions available at the time of analysis. This should be considered a proof of concept,and a verification of the design currently in place at this location. As noted in the report, the new wall design will need to be updated based on project specific geotechnical and seismic considerations.

Depending on input from the project delivery team during the design phase, the sheet pile wall size may be able to be reduced should the seismic return period be reduced from that used in this analysis. Additionally, this analysis looked a single wall layout, as noted above. Additional wall sections, details, etc. will need to be investigated further during detailed design.

9. ATTACHMENTS

a. Design Calculations

b. STAAD Model

10. CONTACT

If there are questions or comments on the design or analysis please contact Mike Carl or Mehdi Roshani, Portland District Corps of Engineers.

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Mehdi Roshani

CENWP-ENC-DS

Civil Engineer

Matthew Hanson

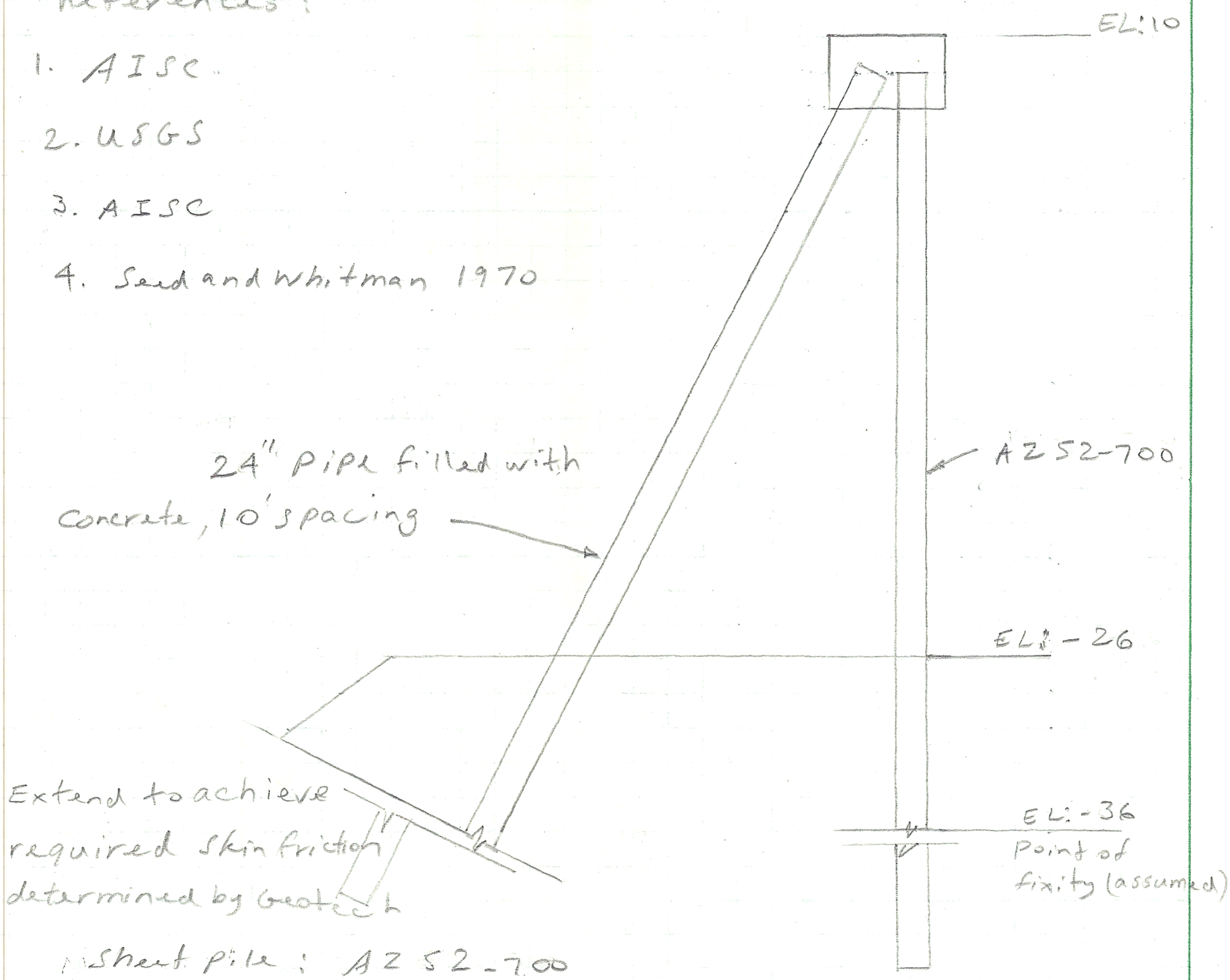
CENWP-ENC-DS

Chief, Structural Design Section

Sheet pile with batter pile Design

References:

1. AISC
2. USGS
3. AISC
4. Seed and Whitman 1970



Sheet pile: AZ52-700

weight: 50.93 lbs/ft^2

$S = 95.9$ in^3/ft Section Modulus

$I = 953$ in^4/ft Moment of Inertia

Depth: 19.88 in

Batter Pile: 24" ϕ with 10' spacing, filled with concrete

Assumptions: Water ballanced on both side of sheet pile
No water pressure

$K_a = .35$ active pressure coefficient

$K_p = 3.0$ passive Pressure Coefficient

$\gamma_s = 120$ lbs/ft^3 Soil Unit weight

$\gamma_{sub} = 57.6$ lbs/ft^3 submerged soil unit weight

Point of Pile fixity = EL: -36

Surcharge: 250 PSF.

F_a, Active Pressure: $w_a = K_a \gamma_{sub} H = .35 \times 57.6 \times 46 = 927.36$ lbs/ft^2

F_p, Passive Pressure: $w_p = K_p \gamma_{sub} H = 3 \times 57.6 \times 10' = 1728$ lbs/ft^2

F_s, Surcharge charge: $w_{surcharge} = K_a \times 250 = 87.50$ lbs/ft^2

Concrete cap weight: $5' \times 7' \times 10' \times 150 = 52,500$ lbs

Seismic:

Latitude: 37.791297, Longitude: -122.287034

USGS 2014:

Return period of 975 years: ER1110-2-1806

PGA = .6188g, $S_s = 1.441g$, $S_1 = .4535$

$w_s = \frac{3}{4} K_h \gamma H$ Seed and Whitman 1970

$K_h = \frac{S_{DS}}{2.5} = \frac{\frac{2}{3} \times S_1}{2.5} = \frac{\frac{2}{3} \times 1.441}{2.5} = .384$

E, $w_s = \frac{3}{4} \times .384 \times 120 \times 46 = 1590$ lbs/ft^2

STAAD output:

Load combination: $1.0D + 1.0F_a + 1.0F_p + 1.0F_s + 0.7E$
A

Max. Moment @ point of fixity = 2,855 Kip-ft

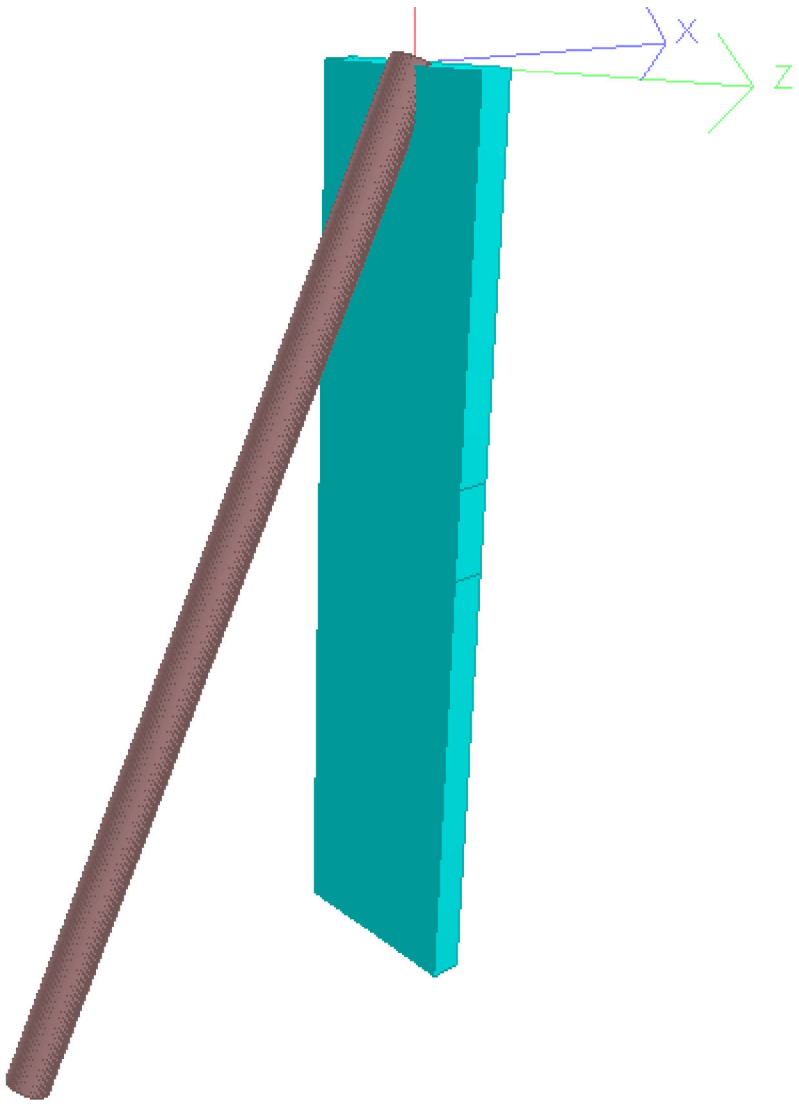
Sheet pile Moment Capacity:

$F_y = 60,000$ PSI $S = 95.9$ in^3/ft

$M_n = F_y \times S = 60,000 \times 95.9 \times 10' = 57,540$ K-in

$= 4,795$ K-ft

$\frac{M_n}{\Omega_b} = \frac{4,795}{1.67} = 2,871$ K-ft $> 2,855$ K-ft : okay


X
Z

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**************************************************
*                                                *
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*           Version  21.00.02.30                 *
*           Proprietary Program of               *
*           Bentley Systems, Inc.                *
*           Date=    OCT 12, 2021                *
*           Time=    14:44:19                    *
*                                                *
*  Licensed to: USACE HQ                         *
**************************************************
```

```
     1. STAAD SPACE
INPUT FILE: C:\Users\g2ecdmr9\Desktop\Oakland Basin Bulkhead\STAAD\Oakland Basin Sheet Pile 10-12-21-3.STD
     2. START JOB INFORMATION
     3. ENGINEER DATE 05-OCT-21
     4. END JOB INFORMATION
     5. INPUT WIDTH 79
     6. UNIT FEET KIP
     7. JOINT COORDINATES
     8. 1 0 0 0; 2 0 -46 0; 3 -23 -45 0; 4 0 -36 0
     9. MEMBER INCIDENCES
    10. 2 1 3; 3 1 4; 4 4 2
    11. START USER TABLE
    12. TABLE 1
    13. UNIT FEET KIP
    14. PRISMATIC
    15. SHEETPILE
    16. 1.04 0.422 4 4 1.04 1.04 1.65 10
    17. TABLE 2
    18. UNIT FEET KIP
    19. PRISMATIC
    20. SHEETPILE2
    21. 1.04 0.46 4 4 1.04 1.04 1.66 10
    22. TABLE 3
    23. UNIT FEET KIP
    24. PRISMATIC
    25. SHEETPILE2
    26. 1.04 0.46 4 4 1.04 1.04 1.66 10
    27. END
    28. DEFINE MATERIAL START
    29. ISOTROPIC STEEL
    30. E 4.176E+06
    31. POISSON 0.3
    32. DENSITY 0.489024
    33. ALPHA 6.5E-06
    34. DAMP 0.03
    35. TYPE STEEL
    36. STRENGTH FY 5184 FU 8352 RY 1.5 RT 1.2
    37. END DEFINE MATERIAL
    38. MEMBER PROPERTY AMERICAN
```

```
 39. 2 TABLE ST PIPS240
 40. MEMBER PROPERTY
 41. 3 4 UPTABLE 2 SHEETPILE2
 42. CONSTANTS
 43. MATERIAL STEEL ALL
 44. SUPPORTS
 45. 2 3 FIXED
 46. MEMBER RELEASE
 47. 2 START MZ
 48. LOAD 1 LOADTYPE NONE  TITLE SELF WEIGHT
 49. SELFWEIGHT Y -1 LIST 2 3
 50. LOAD 2 LOADTYPE NONE  TITLE ACTIVE SOIL PRESSURE
 51. MEMBER LOAD
 52. 4 TRAP GX -7.25478 -9.27 0 10
 53. 3 TRAP GX 0 -7.25478 0 36
 54. LOAD 3 LOADTYPE NONE  TITLE SESIMIC PRESSURE
 55. MEMBER LOAD
 56. 4 TRAP GX -3.45652 0 0 10
 57. 3 TRAP GX -15.9 -3.45652 0 36
 58. LOAD 4 LOADTYPE NONE  TITLE CONCRETE CAP
 59. JOINT LOAD
 60. 1 FY -52.5
 61. LOAD 5 LOADTYPE NONE  TITLE PASSIVE PRESSURE
 62. MEMBER LOAD
 63. 4 TRAP GX 0 17.28 0 10
 64. LOAD 6 LOADTYPE NONE  TITLE SURCHARGE
 65. MEMBER LOAD
 66. 4 UNI GX -0.88 0 10
 67. 3 UNI GX -0.88 0 36
 68. LOAD COMB 7 DEAD + SOIL + SURCHARGE
 69. 1 1.0 2 1.0 4 1.0 5 1.0 6 1.0
 70. LOAD COMB 8 DEAD  + SOIL + SURCHARGE + .7 SEISMIC
 71. 1 1.0 2 1.0 3 0.7 4 1.0 5 1.0 6 1.0
 72. PERFORM ANALYSIS


        P R O B L E M   S T A T I S T I C S
        -----------------------------------

  NUMBER OF JOINTS          4  NUMBER OF MEMBERS       3
  NUMBER OF PLATES          0  NUMBER OF SOLIDS        0
  NUMBER OF SURFACES        0  NUMBER OF SUPPORTS      2

       Using 64-bit analysis engine.

       SOLVER USED IS THE OUT-OF-CORE BASIC SOLVER

  ORIGINAL/FINAL BAND-WIDTH=     3/     3/     12 DOF
TOTAL      PRIMARY LOAD CASES =     6, TOTAL DEGREES OF FREEDOM =      12
TOTAL LOAD COMBINATION  CASES =     2  SO FAR.
  SIZE OF STIFFNESS MATRIX =        1 DOUBLE  KILO-WORDS
  REQRD/AVAIL. DISK SPACE  =     12.0/ 769126.4 MB
```

*WARNING- APPLIED SELFWEIGHT IS LESS THAN TOTAL WEIGHT OF ALL
STRUCTURAL ELEMENTS IN LOAD CASE 1 ALONG Y.
THIS COULD BE DUE TO SELFWEIGHT APPLIED TO SPECIFIC
LIST OF MEMBERS/PLATES/SOLIDS/SURFACES.
TOTAL UNFACTORED WEIGHT OF THE STRUCTURE = 27.857 KIP
TOTAL UNFACTORED WEIGHT OF THE STRUCTURE APPLIED = 22.771 KIP

73. PARAMETER 1
74. CODE LRFD
75. LOAD LIST 7 8
76. CHECK CODE ALL
STEEL DESIGN

STAAD SPACE -- PAGE NO. 4

STAAD.Pro CODE CHECKING - (LRFD 3RD EDITION) v1.0
****

ALL UNITS ARE - KIP FEET (UNLESS OTHERWISE Noted)

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
2	ST PIPS240	(AISC SECTIONS)			
		PASS	LRFD-H1-1A-C	0.741	8
		425.62 C	0.00	-20.90	33.69

**WARNING-THIS VERSION DOES NOT DESIGN PRISMATIC SECTIONS (MEMBER 3).
PLEASE DEFINE THE PROPERTIES THROUGH A USER TABLE GENERAL SECTION.

**WARNING-THIS VERSION DOES NOT DESIGN PRISMATIC SECTIONS (MEMBER 4).
PLEASE DEFINE THE PROPERTIES THROUGH A USER TABLE GENERAL SECTION.

********** END OF TABULATED RESULT OF DESIGN **********

77. PRINT MEMBER FORCES
MEMBER FORCES

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET (LOCAL)

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
2	7	1	120.75	0.91	0.00	0.00	0.00	0.00
		3	-124.73	1.12	0.00	0.00	0.00	-5.45
	8	1	422.97	1.30	0.00	0.00	0.00	0.00
		3	-426.95	0.73	0.00	0.00	0.00	14.25
3	7	1	-54.61	55.77	0.00	0.00	0.00	0.00
		4	36.30	106.50	0.00	0.00	0.00	-129.73
	8	1	-323.54	193.65	0.00	0.00	0.00	0.00
		4	305.23	212.50	0.00	0.00	0.00	-496.49
4	7	4	-36.30	-106.50	0.00	0.00	0.00	129.73
		2	36.30	111.52	0.00	0.00	0.00	-1347.06
	8	4	-305.23	-212.50	0.00	0.00	0.00	496.49
		2	305.23	229.63	0.00	0.00	0.00	-2854.50

********** END OF LATEST ANALYSIS RESULT **********

78. PRINT SUPPORT REACTION

SUPPORT REACTION

SUPPORT REACTIONS -UNIT KIP FEET STRUCTURE TYPE = SPACE

JOINT	LOAD	FORCE-X	FORCE-Y	FORCE-Z	MOM-X	MOM-Y	MOM Z
2	7	111.52	-36.30	0.00	0.00	0.00	-1347.06
	8	229.63	-305.23	0.00	0.00	0.00	-2854.50
3	7	55.77	111.57	0.00	0.00	0.00	5.45
	8	193.65	380.50	0.00	0.00	0.00	-14.25

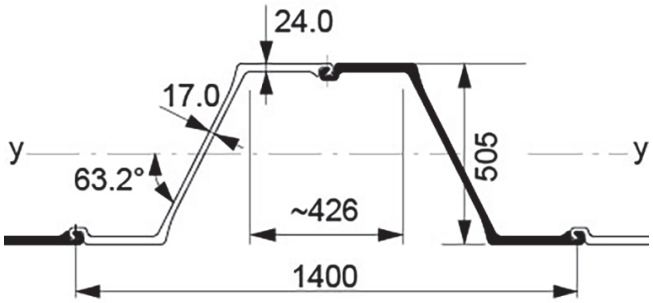
********** END OF LATEST ANALYSIS RESULT **********

79. FINISH

********** END OF THE STAAD.Pro RUN **********

**** DATE= OCT 12,2021 TIME= 14:44:19 ****

AZ 52-700 (Hot rolled sheet piles)



Section description	Product group	Shape	Section Modulus	Moment of Inertia	Width	Height	Thickness flange	Thickness web	Weight single	Weight	Coating 2 sides	Coating area
			in^3/ft cm^3/m	in^4/ft cm^4/m	inch mm	inch mm	inch mm	inch mm	lbs/ft kg/m	lbs/ft^2 kg/m^2	ft^2/ft m^2/m	ft^2/ft m^2/m
AZ 52-700	Hot rolled sheet piles	Z	95.9 5,156	953.0 130,140	27.56 700	19.88 505	0.945 24.0	0.669 17.0	117.0 174.05	50.93 248.66	6.70 2.05	1.46 1.46

Production acc. EN10248 1&2 in various steel grades
Origin: Luxembourg
Datasheet for estimation and comparison purposes