HOFFMAN CONSTRUCTION COMPANY
OF CALIFORNIA
805 SW BROADWAY, SUITE 2100
PORTLAND, OR 97205
TEL: 503/221-8811 • FAX: 503/221-8934

Submittal Package

Transmittal Details

Seaside Schools
2000 Spruce Dr.
Seaside, OR 97138

Project # 5710017
Tel: Fax:

Hoffman Construction Co Of Oregon

Transmittal to remain with Submittal

Reference Number: 0003-BP13332251.05B-1 **Date Transmitted: 7/20/2018**
Retaining Wall D

Transmitted To: Chris Lawson
Hoffman Construction Co Of Oregon
805 SW Broadway Ste 2100
Portland, OR 97205-3361

Trade	Importance	Responsible Engineer
	Urgent	

Items

Submittal Item No	Description	Type	Action
00003 - 333225 - 1	Retaining Wall	Shop Drawings and Product Data	Approved as Noted

Package Notes:

Bric to submit to City of Seaside for Deferred Submittal.

Reviewer's General Comments:

Chris Lawson
Signature

7-20-18
Signed Date

Submittal Review

DATE: July 13, 2018

SUBMITTAL NO.: 0003 – BP13332251.05B-01

SUBMITTAL NAME:

PROJECT: 1600377-Seaside Schools

DATE RECEIVED: July 13, 2018

Corrections or comments made on the shop drawings or materials submittal during this review do not relieve contractor from compliance with requirements of the drawings and specifications, all of which have priority over this shop drawing or material submittal. This check is only for review of general conformance with the design concept of the project and general compliance with the information given in the contract documents.

- ☒ NO EXCEPTIONS TAKEN
- ☐ MAKE CORRECTIONS NOTED
- ☐ REVISE AND RESUBMIT
- ☐ REJECTED
- ☐ SUBMIT SPECIFIED ITEM

☐ Reviewed ☒ Furnish as Corrected
☐ Rejected ☐ Revise and Resubmit
☐ Not Required for Review ☐ Submit Specified Item

This review is only for general conformance with the design concept and the information given in the Construction Documents. Corrections or comments made on the submittal during this review do not relieve the contractor from compliance with the requirements of the plans and specifications. Review of a specific item shall not include review of an assembly of which the item is a component. The Contractor is responsible for: dimensions to be confirmed and correlated at the jobsite; information that pertains solely to the fabrication processes or to the means, methods, techniques, sequences and procedures of construction; coordination of the Work with that of all other trades and performing all Work in a safe and satisfactory manner.

KPFF Consulting Engineers
Date 07/18/2018
By JDE

REVIEWED BY:
Molly Bluhm

REMARKS:
Forward to Structural and Geotech for their review.

☑ NO EXCEPTION NOTED ☐ MAKE CORRECTIONS NOTED
☐ ACCEPTED WITH COMMENTS ☐ REVISE AND RESUBMIT

THIS REVIEW IS FOR GENERAL CONFORMANCE WITH DESIGN CONCEPT ONLY. DEVIATION FROM PLANS OR SPECIFICATIONS NOT CLEARLY NOTED BY THE CONTRACTOR HAS NOT BEEN REVIEWED. REVIEW SHALL NOT CONSTITUTE A COMPLETE CHECK OF ALL DETAILED DIMENSIONS OR COUNT OR SERVE TO RELIEVE THE CONTRACTOR OF CONTRACTURAL RESPONSIBILITY FOR ANY ERROR OR DEVIATION FROM CONTRACT REQUIREMENTS.

GEODESIGN, INC.

DATE 7/18/2018 BY Shawn Dimke

HOFFMAN CONSTRUCTION COMPANY
This submittal has been reviewed for general conformance with the contract documents. Contractor's review does not relieve the Vendor/Subcontractor of responsibility for compliance with all requirements of the contract, including completeness and accuracy of this submittal.

07/12/2018	0003-BP13332251.05B
Date	Submittal #
lawsonc	
Reviewed By	

CONDON-JOHNSON & ASSOCIATES, INC.

NO EXCEPTIONS TAKEN

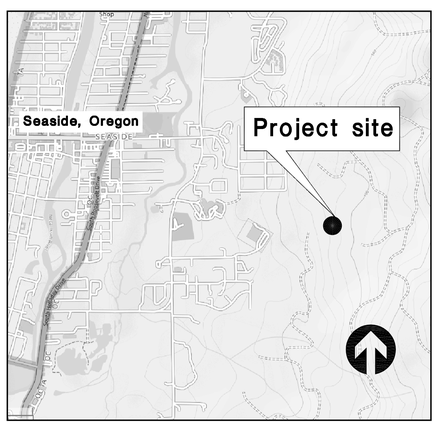
FORWARD ON TO STRUCTURAL AND GEOTECH FOR REVIEW

NEW HIGH SCHOOL WALL 'D'

1801 S. FRANKLIN ST., SEASIDE, OREGON

PERMANENT RETAINING WALL PLANS

SHEET NUMBER	SHEET TITLE
SH1.0-1.2	COVER SHEET AND NOTES
SH2.0-2.1	WALL PLAN VIEWS
SH3.0-3.1	WALL ELEVATIONS
SH4.0	CROSS-SECTIONS
SH5.0-5.2	DETAILS



VICINITY MAP

GENERAL:

THE CONTRACTOR IS RESPONSIBLE FOR FIELD VERIFYING ALL EXISTING DIMENSIONS AND SITE CONDITIONS, DETERMINING ACTUAL LOCATIONS OF ALL EXISTING UTILITIES SHOWN ON THE PLANS AND THOSE UTILITIES OR UNDERGROUND OBSTRUCTIONS NOT SHOWN ON THE PLANS, AND FOR REMOVAL OF ALL ABANDONED UTILITIES, OR OTHER UNDERGROUND OBSTRUCTIONS THAT INTERFERE WITH THE NEW CONSTRUCTION.

THE CONTRACTOR IS RESPONSIBLE FOR THE CONSTRUCTION PROCESS AND THE SAFETY OF THE WORKERS. THIS INCLUDES BUT IS NOT LIMITED TO, THE CONSTRUCTION SEQUENCE, TEMPORARY HANDRAILS, EXCAVATION ACCESS, AND BARRIERS. IT ALSO INCLUDES LIFTING OF MATERIALS AND CONSTRUCTION EQUIPMENT INTO AND OUT OF THE EXCAVATION, TEMPORARY BRACING OF FORMWORK, TEMPORARY SHORING OF EXCAVATIONS, AND STABILITY OF ALL TEMPORARY CUT SLOPES.

REFERENCE DATA:

THE EXISTING SITE, TOPOGRAPHICAL, AND UTILITY DATA; THE PROPOSED GRADES AND UTILITIES; THE DIMENSIONS AND DEPTHS OF THE PROPOSED FOUNDATIONS; AND THE PROPOSED RETAINING WALL LOCATIONS ARE BASED ON THE FOLLOWING:

- THE DRAWINGS TITLED: "C5.02, RETAINING WALL ENLARGEMENT", AND "C5.21, RETAINING WALL PROFILES", OF THE PLAN SET TITLED: "NEW MIDDLE SCHOOL / HIGH SCHOOL, SEASIDE SCHOOL DISTRICT", DATED APRIL 5, 2018, PREPARED BY KPFF.
- THE ELECTRONIC DRAWING FILES NAMED: "03TTXS5.DWG", "P3TTXSV.DWG", "03TTXNT.DWG", "63TT-E5.DWG", "63TT.F6.DWG", AND "03TTXWALL.DWG", FILES DATED MAY 17 AND MAY 24, 2018, PREPARED BY KPFF.

BUILDING CODES, DESIGN MANUALS, AND SPECIFICATIONS:

2012 INTERNATIONAL BUILDING CODE (AS AMENDED BY THE CITY OF PORTLAND)

2014 OREGON STRUCTURAL SPECIALTY CODE

PUBLICATION NO. FHWA-IF-99-015, GEOTECHNICAL ENGINEERING CIRCULAR NO. 4, GROUND ANCHORS AND ANCHORED SYSTEMS

DESIGN CALCULATIONS:

THE RETAINING WALL DESIGN CALCULATIONS ARE CONTAINED IN THE LETTER REPORT TITLED: "REVISION 1 PERMANENT RETAINING WALL DESIGN SUBMITTAL, NEW HIGH SCHOOL WALL "D", 1801 S. FRANKLIN ST., SEASIDE, OREGON", PREPARED BY GROUND SUPPORT PLLC FOR CONDON-JOHNSON & ASSOCIATES, INC., DATED JULY 12, 2018.

DESIGN SURCHARGE LOADS:

THE RETAINING WALL HAS A RELATIVELY MINOR 3H:1V FINISHED SLOPE BEHIND THE WALL AND THE ROADWAY IS OVER 30-FT FROM THE WALL.

DURING CONSTRUCTION, NO SIGNIFICANT SURCHARGE WILL BE ALLOWED BEHIND THE WALL ON THE SLOPE; AND THE GENERAL CONTRACTOR HAS CONFIRMED THIS IS ACCEPTABLE.

ONCE THE WALL IS BUILT AND THE FINAL GRADING COMPLETED, A LIVE LOAD SURCHARGE OF 250 PSF VERTICAL AND 75 PSF HORIZONTAL WAS CONSIDERED BEHIND THE WALL.

SEISMIC DESIGN CONSIDERATIONS:

THE REFERENCED GEOTECHNICAL REPORT RECOMMENDS THAT FOR SEISMIC DESIGN, AN ADDITIONAL EQUIVALENT UNIFORM LOADING OF 8.5H BE CONSIDERED. CONSIDERING THE 3H:1V BACKSLOPE AND TABLE 1 IN THE GEOTECHNICAL REPORT, THIS IS INCREASED BY 1.3 TO A VALUE OF 11H. IN ADDITION, THE ROUGHLY 12" PERMANENT FACING WAS ACCOUNTED FOR WITH A LATERAL PRESSURE OF 75 PSF. NEVERTHELESS, BECAUSE THE PERMANENT WALL HEIGHT IS 3-FT SHORTER THAN THE TEMPORARY WALL HEIGHT, NEITHER THE LIVE LOAD SURCHARGE NOR THE SEISMIC LOADING ARE CRITICAL TO THE WALL DESIGN. THE CRITICAL LOAD COMBINATION IS H + 0.75(L + 0.7E). L IS 75 PSF; AND FOR A 16-FT HIGH WALL, E IS 11(16) + 75 = 251 PSF.

SUBSURFACE DESIGN PARAMETERS:

THE SUBSURFACE DESIGN PARAMETERS AND SHORING WALL DESIGN CRITERIA ARE BASED UPON THE FOLLOWING PROJECT GEOTECHNICAL REPORT: "REPORT OF GEOTECHNICAL ENGINEERING SERVICES, SEASIDE SCHOOL DISTRICT CAMPUS, SEASIDE, OREGON", PREPARED BY GEODESIGN, INC., DATED NOVEMBER 20, 2017; AND THE FOLLOWING GEOTECHNICAL ADDENDUM: "ADDENDUM 1, ADDITIONAL RECOMMENDATIONS FOR FOUNDATIONS, TOPSOIL PLACEMENT, AND WALLS, SEASIDE NEW MIDDLE/HIGH SCHOOL, SEASIDE, OREGON", PREPARED BY GEODESIGN, INC., DATED JUNE 12, 2018. THE EARTH PRESSURE DIAGRAMS AND SHORING DESIGN CRITERIA ARE SHOWN ON THIS SET OF PLANS.

GROUNDWATER:

FOR THE PURPOSES OF DESIGN OF THE RETAINING WALL, THE WATER TABLE HAS BEEN ASSUMED TO OCCUR BENEATH THE BASE OF THE EXCAVATION, IN ACCORDANCE WITH THE FINDINGS FROM THE GEOTECHNICAL INVESTIGATION. IF LOCALIZED WET ZONES AND/OR PERCHED POCKETS AND STRINGERS OF WATER-BEARING SOILS ARE ENCOUNTERED, THEN THE WALL FACE EXCAVATION MUST PROCEED CAUTIOUSLY TO AVOID EXCESSIVE GROUND LOSS OR DISTURBANCE IN AREAS OF WATER BEARING SOILS. GAPS IN THE TIMBER LAGGING WILL PROVIDE A FREE-DRAINING FACE CONDITION.

STRUCTURAL STEEL:

ALL STRUCTURAL STEEL WIDE FLANGE AND OTHER ROLLED SHAPES SHALL CONFORM TO ASTM A572 / AASHTO M270, GRADE 50; ALL STRUCTURAL STEEL PLATES SHALL CONFORM TO ASTM A36 / AASHTO M270, GRADE 36; ALL RECTANGULAR STEEL TUBE WALERS SHALL CONFORM TO ASTM A500, GRADE B; AND ALL PIPES SHALL CONFORM TO ASTM A53 GRADE B, UNLESS SHOWN OTHERWISE ON THE PLANS, OR APPROVED OTHERWISE BY THE ENGINEER.

TIMBER LAGGING:

ALL LAGGING BOARDS SHALL BE IN GOOD CONDITION, AND SHALL BE HEM-FIR NO. 2 OR BETTER. THE CONTRACTOR SHALL EXCAVATE THE WALL FACE AND INSTALL THE LAGGING IN SUCH A MANNER AS TO MAINTAIN A SAFE WORK PLACE AND AVOID EXCESSIVE SLOUGHING AND OVERBREAK. BACKFILL BEHIND LAGGING BOARDS WITH A FREE-DRAINING GRANULAR MATERIAL OR PERMEABLE GROUT, (NATIVE SOILS ARE NOT APPROVED BY THE GEOTECHNICAL ENGINEER).

PRIOR TO PLACING THE SUBSEQUENT SET OF TIMBER LAGGING, UNLESS APPROVED OTHERWISE BY THE GEOTECHNICAL ENGINEER, DO NOT EXCAVATE MORE THAN 4 FEET BELOW THE CURRENT DEPTH OF LAGGED WALL FACE. ALONG ANCHORED WALLS, DO NOT EXCAVATE MORE THAN 2 FEET BELOW THE CURRENT LEVEL OF ANCHORS UNTIL THE THOSE ANCHORS ARE INSTALLED, CURED, TESTED, AND STRESSED. EXCAVATION MUST NOT BE LEFT OVERNIGHT WITHOUT LAGGING INSTALLED TO THE LOWEST EXCAVATED LEVEL.

STRUCTURAL WELDING:

MINIMUM WELD SIZE 1/4" CONTINUOUS FILLET. MINIMUM WELD LENGTH 2 INCHES. ALL WELDING TO BE PERFORMED BY AWS-CERTIFIED WELDERS PER AWS STANDARD SPECIFICATIONS. USE E70XX ELECTRODES.

LEAN-MIX CONCRETE:

ALL LEAN-MIX CONCRETE SHALL HAVE A MINIMUM OF 1-1/2 SACKS (141 LBS) OF CEMENT AND 100 LBS OF FLY ASH PER CUBIC YARD OF CONCRETE. PORTLAND CEMENT SHALL BE TYPE I, II, OR III CONFORMING TO ASTM C150 / AASHTO M85. FLY ASH SHALL BE TYPE F CONFORMING TO ASTM C618.

SLUMP FOR ALL LEAN-MIX CONCRETE SHALL NOT BE LESS THAN 5 INCHES AND NO GREATER THAN 9 INCHES. ADMIXTURES SHALL CONFORM TO THE REQUIREMENTS OF ASTM C494 / AASHTO M194, SHALL BE USED IN ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS, AND SHALL BE APPROVED BY THE ENGINEER.

AGGREGATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM C33 / AASHTO M6 FOR FINE AGGREGATES AND AASHTO M80, CLASS B FOR COARSE AGGREGATES.

GEOCOMPOSITE WALL DRAINAGE BOARD:

ALL GEOCOMPOSITE WALL DRAINAGE BOARD SHALL BE AMERDRAIN 500, MIRAFI G100, OR AN APPROVED EQUAL.

SPECIAL INSPECTION OF THE SHORING WALLS:

IN ACCORDANCE WITH SECTION 1704 OF IBC (2012), SPECIAL INSPECTION IS REQUIRED FOR THE FOLLOWING SHORING ITEMS OR PROCESSES: SOLDIER PILE INSTALLATION, AND GROUND ANCHOR INSTALLATION AND TESTING.

MONITORING:

SURVEY MONITORING OF THE SHORING WALLS, SHALL BE PERFORMED TO DETERMINE THE VERTICAL AND HORIZONTAL MOVEMENT OF THE MONITORING POINTS. THE MEASURING SYSTEM SHALL HAVE AN ACCURACY OF AT LEAST 0.01 FEET.

THE MONITORING PROGRAM SHALL BE DETERMINED BY THE GEOTECHNICAL SPECIAL INSPECTOR BUT, AT A MINIMUM, SHALL INCLUDE THE FOLLOWING:

- MONITORING POINTS SHALL CONSIST OF RODS OR BOLTS EMBEDDED INTO THE OBJECT OF INTEREST OR CROSS-HAIRS INSCRIBED ONTO A PLATE THAT IS ATTACHED TO THE OBJECT OF INTEREST.
- MONITORING POINTS SHALL BE ESTABLISHED: (1) ALONG EACH WALL AT THE TOP OF EVERY THIRD SOLDIER PILE, AND (2) ON ANY ADJACENT STRUCTURES THAT ARE LOCATED WITHIN A HORIZONTAL DISTANCE EQUAL TO THE WALL HEIGHT ALONG THE SHORING WALLS.
- READINGS SHALL BE TAKEN AND REPORTED AT LEAST TWICE A WEEK, ONE TIME OF WHICH MUST BE BY A LICENSED SURVEYOR.

MONITORING DATA SHALL BE DISTRIBUTED TO THE GEOTECHNICAL ENGINEER, THE SHORING DESIGN ENGINEER, AND THE GENERAL CONTRACTOR FOR REVIEW.

THE EXPECTED LATERAL SHORING WALL MOVEMENT IS ON THE ORDER OF 1/2". IF MOVEMENTS EXCEED 1/2", THE EXCAVATION SHALL BE HALTED UNTIL FURTHER REVIEW BY GROUND SUPPORT PLLC.

DESIGN	DRAWN	REV/CHK	DATE	REV	DESCRIPTION
CJA	JSS	RJB	6/4/2018	0	PERMIT ISSUE
CJA	JSS	RJB	7/12/2018	1	RESPONSE TO COMMENTS

REGISTERED PROFESSIONAL ENGINEER 93872 OREGON JULY 14, 2018 CHRIS J. VAN SCHAIK
EXPIRATION DATE: 06-30-20

Ground Support PLLC
16932 Woodinville Redmond Rd NE, #210
Woodinville, WA 98072
Ph: (425) 488-1143 Fax: (425) 605-4057

SEASIDE HIGH SCHOOL, WALL 'D'
PERMANENT RETAINING WALL
COVER SHEET AND NOTES

PROJ. NO. 18-28

SHEET NUMBER

SH1.0

D:\Jobs\2018\18-28 (Seaside-OR-CJA)\(shoring)\(permitting)\R1 (20180712)\18288h01aR1.dwg, 7/12/2018 12:15:06 PM

GROUND ANCHORS - GENERAL:

A. THE CONTRACTOR SHALL SELECT THE GROUND ANCHOR TYPE, THE INSTALLATION METHOD, THE BOND LENGTH, THE ANCHOR DIAMETER, AND THE METHOD OF GROUTING, IN ORDER TO DEVELOP THE DESIGN LOADS INDICATED ON THE PLANS, AS VERIFIED IN ACCORDANCE WITH THE ANCHOR TESTING PROGRAM.

B. THE CONTRACTOR SHALL PREPARE AND SUBMIT TO THE ENGINEER FOR REVIEW AND APPROVAL WORKING DRAWINGS AND A DESIGN SUBMISSION DESCRIBING THE GROUND ANCHOR SYSTEM OR SYSTEMS INTENDED FOR USE. THE WORKING DRAWINGS AND DESIGN SUBMISSION SHALL BE SUBMITTED 15 DAYS PRIOR TO THE COMMENCEMENT OF THE GROUND ANCHOR WORK. THE WORKING DRAWING AND DESIGN SUBMISSION SHALL INCLUDE THE FOLLOWING:

1. CERTIFIED MILL TEST RESULTS AND TYPICAL STRESS-STRAIN CURVES FOR THE PRESTRESSING STEEL. THE TYPICAL STRESS-STRAIN CURVE SHALL BE OBTAINED BY APPROVED STANDARD PRACTICES. THE GUARANTEED ULTIMATE STRENGTH, YIELD STRENGTH, ELONGATION, AND COMPOSITION SHALL BE SPECIFIED.
2. GROUT MIX DESIGN AND THE PROCEDURES FOR GROUT PLACEMENT.
3. CALIBRATION DATA FOR EACH TEST JACK, PRESSURE GAUGE AND REFERENCE PRESSURE GAUGE TO BE USED. THE CALIBRATION TESTS SHALL HAVE BEEN PERFORMED BY AN INDEPENDENT TESTING LABORATORY AND TESTS SHALL HAVE BEEN PERFORMED WITHIN 60 DAYS OF THE DATE SUBMITTED.

GROUND ANCHORS - INSTALLATION:

A. AT THE GROUND SURFACE, THE DRILLHOLE SHALL BE LOCATED WITHIN 4 INCHES OF THE LOCATION SHOWN ON THE PLANS. THE DRILLHOLE SHALL BE LOCATED SO THE LONGITUDINAL AXIS OF THE DRILLHOLE AND THE LONGITUDINAL AXIS OF THE TENDON ARE PARALLEL. THE GROUND ANCHOR SHALL NOT BE DRILLED IN A LOCATION THAT REQUIRES THE TENDON TO BE BENT IN ORDER TO CONNECT THE BEARING PLATE TO THE SUPPORTED STRUCTURE.

B. AT THE POINT OF ENTRY, THE GROUND ANCHOR SHALL BE INSTALLED WITHIN +/- 3 DEGREES OF THE INCLINATION FROM HORIZONTAL SHOWN IN THE PLANS. AT THE POINT OF ENTRY, THE HORIZONTAL ANGLE MADE BY THE GROUND ANCHOR AND THE STRUCTURE SHALL BE WITHIN +/- 3 DEGREES OF A LINE DRAWN PERPENDICULAR TO THE PLANE OF THE STRUCTURE, UNLESS SHOWN OTHERWISE ON THE PLANS.

C. WHEN CAVING CONDITIONS ARE ENCOUNTERED, NO FURTHER DRILLING WILL BE ALLOWED UNTIL THE CONTRACTOR SELECTS A METHOD TO PREVENT GROUND MOVEMENT. THE CONTRACTOR MAY USE TEMPORARY CASING. THE CONTRACTOR'S METHOD TO PREVENT GROUND MOVEMENT SHALL BE APPROVED BY THE ENGINEER.

D. THE TENDON SHALL BE INSERTED INTO THE DRILLHOLE TO THE DESIRED DEPTH WITHOUT DIFFICULTY. WHEN THE TENDON CANNOT BE COMPLETELY INSERTED, THE CONTRACTOR SHALL REMOVE THE TENDON FROM THE DRILLHOLE AND CLEAN OR REDRILL THE HOLE TO PERMIT INSERTION. PARTIALLY INSERTED TENDONS SHALL NOT BE DRIVEN OR FORCED INTO THE HOLE.

E. THE CONTRACTOR SHALL USE A NEAT-CEMENT OR A SAND-CEMENT GROUT. THE CEMENT SHALL NOT CONTAIN LUMPS OR OTHER INDICATIONS OF HYDRATION. ADMIXTURES, IF USED, SHALL BE MIXED IN ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS.

F. THE GROUT EQUIPMENT SHALL PRODUCE A GROUT FREE OF LUMPS AND UNDISPERSED CEMENT. A POSITIVE DISPLACEMENT GROUT PUMP SHALL BE USED. THE PUMP SHALL BE EQUIPPED WITH A PRESSURE GAUGE TO MONITOR GROUT PRESSURES AND A STROKE COUNTER. THE PRESSURE GAUGE SHALL BE CAPABLE OF MEASURING PRESSURES OF AT LEAST 150 PSI OR TWICE THE ACTUAL GROUT PRESSURES USED BY THE CONTRACTOR, WHICHEVER IS GREATER. THE GROUTING EQUIPMENT SHALL BE SIZED TO ENABLE THE GROUT TO BE PUMPED IN ONE CONTINUOUS OPERATION. THE MIXER SHALL BE CAPABLE OF CONTINUOUSLY AGITATING THE GROUT.

G. THE GROUT SHALL BE INJECTED FROM THE LOWEST POINT OF THE DRILLHOLE. THE GROUT MAY BE PUMPED THROUGH GROUT TUBES, CASING, OR DRILL RODS. THE GROUT CAN BE PLACED BEFORE OR AFTER INSERTION OF THE TENDON. THE QUANTITY OF THE GROUT AND THE GROUT PRESSURES SHALL BE RECORDED. THE GROUT PRESSURES AND GROUT TAKES SHALL BE CONTROLLED TO PREVENT EXCESSIVE HEAVE IN SOILS OR FRACTURING OF ROCK FORMATIONS.

H. NO GROUT SHALL BE PLACED UNDER PRESSURE ABOVE THE BOND LENGTH DURING INITIAL GROUTING OF THE ANCHOR BOND LENGTH. THE GROUT AT THE TOP OF THE DRILLHOLE SHALL NOT CONTACT THE BACK OF THE STRUCTURE OR THE BOTTOM OF THE TRUMPET.

I. AFTER GROUTING, THE TENDON SHALL NOT BE LOADED UNTIL THE GROUT HAS ATTAINED SUFFICIENT STRENGTH TO CARRY THE TEST LOAD.

J. IF THE ANCHOR IS PERMANENT, THE CORROSION PROTECTION SURROUNDING THE UNBONDED LENGTH OF THE TENDON SHALL EXTEND UP BEYOND THE BOTTOM SEAL OF THE TRUMPET OR 1 FOOT INTO THE TRUMPET IF NO TRUMPET SEAL IS PROVIDED. IF THE ANCHOR IS PERMANENT, THE CORROSION PROTECTION SURROUNDING THE NO-LOAD ZONE LENGTH SHALL NOT CONTACT THE BEARING PLATE OR ANCHOR HEAD DURING STRESSING. TRUMPET GROUT SHALL BE PLACED AFTER THE GROUND ANCHOR HAS BEEN TESTED AND LOCKED OFF.

GROUND ANCHORS - GROUT:

A. THE GROUT SHALL BE A NEAT OR SAND/CEMENT MIXTURE WITH A MINIMUM 3-DAY COMPRESSIVE STRENGTH OF 1500 PSI AND A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 3000 PSI PER ASTM C109 / AASHTO T106.

B. TYPE II CEMENT CONFORMING TO THE REQUIREMENTS OF ASTM C150 / AASHTO M85 SHALL BE USED.

C. FINE AGGREGATES SHALL CONSIST OF CLEAN, NATURAL SAND, CONFORMING TO THE REQUIREMENTS OF ASTM C33 / AASHTO M6. MANUFACTURED SAND IS ACCEPTABLE PROVIDED IT IS SUITABLE FOR PUMPING IN ACCORDANCE WITH ACI 304, SECTION 4.2.2.

D. ADMIXTURES SHALL BE IN ACCORDANCE WITH ASTM C494 / AASHTO M194. ADMIXTURES WHICH CONTROL BLEED, IMPROVE FLOW, REDUCE WATER CONTENT, AND RETARD SET MAY BE USED IN THE GROUT SUBJECT TO THE APPROVAL OF THE ENGINEER. EXPANSIVE ADMIXTURES SHALL ONLY BE ADDED TO THE GROUT USED FOR FILLING SEALED ENCAPSULATIONS, TRUMPETS AND ANCHORAGE COVERS. ACCELERATORS WILL NOT BE PERMITTED. ADMIXTURES SHALL BE COMPATIBLE WITH PRESTRESSING STEELS AND MIXED IN ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATION.

GROUND ANCHORS - TENDONS:

A. THE GROUND ANCHORS TENDONS SHALL CONSIST OF ONE OF THE FOLLOWING:

1. BAR TENDONS WITH AN ULTIMATE TENSILE STRNGTH OF 150 KSI CONFORMING TO ASTM A722 / AASHTO M275.
2. SEVEN-WIRE, LOW-RELAXATION STRANDS WITH AN ULTIMATE TENSILE STRENGTH OF 270 KSI CONFORMING TO ASTM A416 / AASHTO M203.
3. "COMPACT", SEVEN-WIRE, LOW-RELAXATION STRANDS CONFORMING TO ASTM A779.

B. BAR TENDON COUPLERS, IF REQUIRED, SHALL BE FURNISHED BY THE MANUFACTURER OF THE BARS AND SHALL DEVELOP THE ULTIMATE TENSILE STRENGTH OF THE BARS WITHOUT EVIDENCE OF ANY FAILURE. STRAND COUPLERS SHALL NOT BE ALLOWED.

GROUND ANCHORS - CORROSION PROTECTION:

A. THIS SECTION ONLY APPLIES TO PERMANENT GROUND ANCHORS.

B. CORROSION PROTECTION OF THE UNBONDED LENGTH SHALL BE PROVIDED BY A SHEATH COMPLETELY FILLED WITH CORROSION-INHIBITING GREASE OR GROUT. IF GREASE IS USED UNDER THE SHEATH, PROVISIONS SHALL BE MADE TO PREVENT THE GREASE FROM ESCAPING AT THE ENDS OF THE SHEATH. IF THE SHEATH IS NOT FABRICATED FROM A SMOOTH TUBE, THEN A SEPARATE BONDBREAKER MUST BE PROVIDED. THE BONDBREAKER SHALL PREVENT THE TENDON FROM BONDING TO THE ANCHOR GROUT SURROUNDING THE UNBONDED LENGTH.

C. THE SHEATH SHALL BE FABRICATED FROM ONE OF THE FOLLOWING:

1. A POLYETHYLENE TUBE PULLED OR PUSHED OVER THE PRESTRESSING STEEL. THE POLYETHYLENE SHALL BE TYPE II, III, OR IV AS DEFINED BY ASTM D1248 (OR APPROVED EQUAL). THE TUBING SHALL HAVE A MINIMUM WALL THICKNESS OF 40 MILS.
2. A HOT-MELT EXTRUDED POLYPROPYLENE TUBE. THE POLYPROPYLENE SHALL BE CELL CLASSIFICATION B55542-11 AS DEFINED BY ASTM D4101 (OR APPROVED EQUAL). THE TUBING SHALL HAVE A MINIMUM WALL THICKNESS OF 40 MILS.
3. A HOT-MELT EXTRUDED POLYETHYLENE TUBE. THE POLYETHYLENE SHALL BE HIGH DENSITY TYPE III AS DEFINED BY ASTM D1248 (OR APPROVED EQUAL). THE TUBING SHALL HAVE A MINIMUM WALL THICKNESS OF 40 MILS.
4. PLASTIC PIPE OR TUBE OF PVC CONFORMING TO ASTM D1784 CLASS 13464-B, SCHEDULE 40 MINIMUM.
5. A CORRUGATED TUBE CONFORMING TO THE REQUIREMENTS OF THE TENDON BOND LENGTH ENCAPSULATION.

D. THE BONDBREAKER SHALL BE FABRICATED FROM A SMOOTH PLASTIC TUBE OR PIPE HAVING THE FOLLOWING PROPERTIES:

1. RESISTANCE TO CHEMICAL ATTACK FROM AGGRESSIVE ENVIRONMENTS, GROUT OR GREASE.
2. RESISTANCE TO AGING BY ULTRAVIOLET LIGHT.
3. FABRICATED FROM MATERIAL NON-DETRIMENTAL TO THE TENDON.
4. CAPABLE OF WITHSTANDING ABRASION, IMPACT, AND BENDING DURING HANDLING AND INSTALLATION.
5. ENABLE THE TENDON TO ELONGATE DURING TESTING AND STRESSING.
6. ALLOW THE TENDON TO REMAIN UNBONDED AFTER LOCKOFF.

E. THE BOND LENGTH PORTION OF THE TENDON SHALL BE CORROSION PROTECTED BY ENCAPSULATING THE TENDON IN A GROUT-FILLED CORRUGATED PLASTIC TUBE. THE TENDONS MAY BE GROUTED INSIDE THE ENCAPSULATION PRIOR TO INSERTING THE TENDON IN THE DRILLHOLE OR AFTER THE TENDON HAS BEEN PLACED IN THE DRILLHOLE. THE TENDON SHALL BE CENTRALIZED WITHIN THE TENDON BOND LENGTH ENCAPSULATION WITH A MINIMUM OF 0.10 INCHES OF GROUT COVER. SPACERS SHALL BE USED ALONG THE TENDON BOND LENGTH OF MULTI-ELEMENT TENDONS TO SEPARATE THE ELEMENTS OF THE TENDON SO THE PRESTRESSING STEEL WILL BOND TO THE ENCAPSULATION GROUT.

F. THE TENDON ENCAPSULATION SHALL BE FABRICATED FROM ONE OF THE FOLLOWING:

1. HIGH DENSITY CORRUGATED POLYETHYLENE TUBING CONFORMING TO THE REQUIREMENTS OF AASHTO M252 AND HAVING A MINIMUM WALL THICKNESS OF 40 MILS.
2. CORRUGATED POLYVINYL CHLORIDE TUBES MANUFACTURED FROM RIGID PVC COMPOUNDS CONFORMING TO ASTM D1784, CLASS 13464-B, AND HAVING A MINIMUM WALL THICKNESS OF 40 MILS.

G. THE TRUMPET USED TO PROVIDE A TRANSITION FROM THE ANCHORAGE TO THE UNBONDED LENGTH CORROSION PROTECTION SHALL BE FABRICATED FROM A STEEL PIPE OR TUBE CONFORMING TO ASTM A53 FOR PIPE AND ASTM A500 FOR TUBING. THE TRUMPET SHALL HAVE A MINIMUM WALL THICKNESS OF 0.125 INCHES FOR DIAMETERS UP TO 4 INCHES AND 0.20 INCHES FOR LARGER DIAMETERS.

H. THE TRUMPET SHALL BE WELDED TO THE BEARING PLATE. THE TRUMPET SHALL HAVE AN INSIDE DIAMETER EQUAL TO OR LARGER THAN THE HOLE OR PATTERN OF HOLES IN THE BEARING PLATE. THE TRUMPET SHALL BE LONG ENOUGH TO ACCOMMODATE MOVEMENTS OF THE STRUCTURE DURING STRESSING. FOR STRAND TENDONS WITH ENCAPSULATION OVER THE UNBONDED LENGTH, THE TRUMPET SHALL BE LONG ENOUGH TO ENABLE THE TENDON TO MAKE A TRANSITION FROM THE DIAMETER OF THE TENDON IN THE UNBONDED LENGTH TO THE DIAMETER OF THE TENDON AT THE ANCHOR HEAD WITHOUT DAMAGING THE ENCAPSULATION. TRUMPETS SHALL BE FILLED WITH GROUT OR OTHER APPROVED MATERIAL AND SHALL HAVE A TEMPORARY SEAL TO ENABLE FILLING.

I. ANCHORAGE COVERS SHALL BE FABRICATED FROM STEEL OR DUCTILE CAST IRON WITH A MINIMUM THICKNESS OF 0.1 INCHES. THE COVER SHALL BE SECURELY ATTACHED TO THE ANCHORAGE DEVICE OR BEARING PLATE.

GROUND ANCHORS - SPACERS AND CENTRALIZERS:

A. SPACERS SHALL BE USED ALONG THE TENDON BOND LENGTH OF MULTI-ELEMENT TENDONS TO SEPARATE EACH OF THE INDIVIDUAL ELEMENTS OF THE TENDON SO THE PRESTRESSING STEEL WILL BOND TO THE GROUT. SPACERS SHALL BE POSITIONED SO THEIR CENTER-TO-CENTER SPACING DOES NOT EXCEED 10 FEET. IN ADDITION, THE UPPER SPACER SHALL BE LOCATED A MAXIMUM OF 5 FEET FROM THE TOP OF THE TENDON BOND LENGTH AND THE LOWER SPACER SHALL BE LOCATED A MAXIMUM OF 5 FEET FROM THE BOTTOM OF THE TENDON BOND LENGTH. SPACERS SHALL PERMIT GROUT TO FREELY FLOW UP THE DRILLHOLE OR BOND LENGTH ENCAPSULATION. SPACERS SHALL BE FABRICATED FROM PLASTIC.

B. CENTRALIZERS SHALL PERMIT FREE GROUT FLOW AND SHALL PROVIDE A MINIMUM OF 0.5 INCHES OF COVER OVER THE TENDON BOND LENGTH ENCAPSULATION. CENTRALIZERS SHALL BE SECURELY ATTACHED TO THE ENCAPSULATION AND THE CENTER TO CENTER SPACING SHALL NOT EXCEED 10 FEET. THE UPPER CENTRALIZER SHALL BE LOCATED A MAXIMUM OF 5 FEET FROM THE TOP OF THE TENDON BOND LENGTH AND THE LOWER CENTRALIZER SHALL BE LOCATED A MAXIMUM OF 1 FOOT FROM THE BOTTOM OF THE TENDON BOND LENGTH. CENTRALIZERS SHALL BE FABRICATED FROM PLASTIC.

GROUND ANCHORS - ANCHORAGE DEVICES:

A. ANCHORAGE DEVICES SHALL BE CAPABLE OF DEVELOPING 95% OF THE MINIMUM SPECIFIED ULTIMATE TENSILE STRENGTH OF THE PRESTRESSING STEEL TENDON. THE ANCHORAGE DEVICES SHALL CONFORM TO THE STATIC STRENGTH REQUIREMENTS OF SECTION 3.1.6(1) AND SECTION 3.1.8(1) OF THE PTI "GUIDE SPECIFICATION FOR POST TENSIONING MATERIALS".

B. THE BEARING PLATES SHALL BE STRUCTURAL STEEL CONFORMING TO ASTM A36/AASHTO M183. THE BEARING PLATES SHALL BE SIZED SO THE ALLOWABLE BENDING STRESSES IN THE PLATE PER AISC-ASD ARE NOT EXCEEDED WHEN THE DESIGN LOAD OF THE GROUND ANCHOR IS APPLIED.

GROUND ANCHORS - TESTING:

A. EACH GROUND ANCHOR SHALL BE TESTED. THE MAXIMUM TEST LOAD SHALL NOT EXCEED 80% OF THE MINIMUM GUARANTEED ULTIMATE TENSILE STRENGTH (GUTS) OF THE TENDON. THE TEST LOAD SHALL BE SIMULTANEOUSLY APPLIED TO THE ENTIRE TENDON. STRESSING OF SINGLE ELEMENTS OF MULTI-ELEMENT TENDONS WILL NOT BE PERMITTED.

B. THE TESTING EQUIPMENT SHALL CONSIST OF:

1. A DIAL GAUGE OR VERNIER SCALE CAPABLE OF MEASURING TO 0.001 INCHES SHALL BE USED TO MEASURE THE GROUND ANCHOR MOVEMENT. THE MOVEMENT-MEASURING DEVICE SHALL HAVE A MINIMUM TRAVEL EQUAL TO THE THEORETICAL ELASTIC ELONGATION OF THE TOTAL ANCHOR LENGTH AT THE MAXIMUM TEST LOAD PLUS 1 INCH. THE DIAL GAUGE OR VERNIER SCALE SHALL BE SUPPORTED INDEPENDENT OF THE JACKING SYSTEM AND RETAINED STRUCTURE AND SHALL BE ALIGNED SO THAT ITS AXIS IS WITHIN 5 DEGREES FROM THE AXIS OF THE GROUND ANCHOR.

2. A HYDRAULIC JACK AND PUMP SHALL BE USED TO APPLY THE TEST LOAD. THE JACK AND PRESSURE GAUGE SHALL BE CALIBRATED BY AN INDEPENDENT TESTING LABORATORY AS A UNIT. THE PRESSURE GAUGE SHALL BE GRADUATED IN 100 PSI INCREMENTS OR LESS. THE PRESSURE GAUGE WILL BE USED TO MEASURE THE APPLIED LOAD. THE RAM TRAVEL OF THE JACK SHALL NOT BE LESS THAN THE THEORETICAL ELASTIC ELONGATION OF THE TOTAL ANCHOR LENGTH AT THE MAXIMUM TEST LOAD PLUS ONE INCH. THE JACK SHALL BE INDEPENDENTLY SUPPORTED AND CENTERED OVER THE TENDON SO THAT THE TENDON DOES NOT CARRY THE WEIGHT OF THE JACK.

C. PERFORMANCE TESTING SHALL BE PERFORMED ON 5 PERCENT OF THE GROUND ANCHORS OR A MINIMUM OF 3 ANCHORS, WHICHEVER IS GREATER. THE PERFORMANCE TEST SHALL BE MADE BY LOADING AND UNLOADING THE GROUND ANCHOR IN ACCORDANCE WITH THE FOLLOWING SCHEDULE. AT LOAD INCREMENTS OTHER THAN THE MAXIMUM TEST LOAD, THE LOAD SHALL BE HELD LONG ENOUGH TO OBTAIN A STABLE READING.

AL	AL
0.25 DL	0.25 DL
AL	0.50 DL
0.25 DL	0.75 DL
0.50 DL	1.00 DL
AL	1.25 DL
0.25 DL	AL
0.50 DL	0.25 DL
0.75 DL	0.50 DL
AL	0.75 DL
0.25 DL	1.00 DL
0.50 DL	1.25 DL
0.75 DL	1.50 DL
1.00 DL	AL

THE ALIGNMENT LOAD (AL) SHOULD BE THE MINIMUM LOAD REQUIRED TO ALIGN THE TESTING APPARATUS AND SHOULD NOT EXCEED 0.05DL. DIAL GAUGES SHOULD BE SET AT "ZERO" AFTER THE ALIGNMENT LOAD HAS BEEN APPLIED.

THE MAXIMUM TEST LOAD SHALL BE HELD FOR 10 MINUTES. THE LOAD-HOLD PERIOD SHALL START AS SOON AS THE MAXIMUM TEST LOAD IS APPLIED AND THE ANCHOR MOVEMENT SHALL BE MEASURED AND RECORDED AT 1, 2, 3, 5, 6, AND 10 MINUTES. IF THE ANCHOR MOVEMENT BETWEEN 1 AND 10 MINUTES EXCEEDS 0.04 INCHES, THE MAXIMUM TEST LOAD SHALL BE HELD AN ADDITIONAL 50 MINUTES. IF THE LOAD HOLD IS EXTENDED, THE ANCHOR MOVEMENTS SHALL BE RECORDED AT 20, 30, 50, AND 60 MINUTES. IF AN ANCHOR FAILS IN CREEP, RETESTING WILL NOT BE ALLOWED.

D. PROOF TESTS SHALL BE PERFORMED ON ALL PRODUCTION ANCHORS BY INCREMENTALLY LOADING THE GROUND ANCHOR IN ACCORDANCE WITH THE FOLLOWING SCHEDULE. AT LOAD INCREMENTS OTHER THAN MAXIMUM TEST LOAD, THE LOAD SHALL BE HELD LONG ENOUGH TO OBTAIN A STABLE READING.

AL	1.00 DL
0.25 DL	1.33 DL
0.50 DL	
0.75 DL	

THE ALIGNMENT LOAD (AL) SHOULD BE THE MINIMUM LOAD REQUIRED TO ALIGN THE TESTING APPARATUS AND SHOULD NOT EXCEED 0.05DL. DIAL GAUGES SHOULD BE SET AT "ZERO" AFTER THE ALIGNMENT LOAD HAS BEEN APPLIED.

THE MAXIMUM TEST LOAD SHALL BE HELD FOR 10 MINUTES. THE LOAD-HOLD PERIOD SHALL START AS SOON AS THE MAXIMUM TEST LOAD IS APPLIED AND THE ANCHOR MOVEMENT SHALL BE MEASURED AND RECORDED AT 1, 2, 3, 5, 6, AND 10 MINUTES. IF THE ANCHOR MOVEMENT BETWEEN 1 AND 10 MINUTES EXCEEDS 0.04 INCHES, THE MAXIMUM TEST LOAD SHALL BE HELD OF AN ADDITIONAL 50 MINUTES. IF THE LOAD HOLD IS EXTENDED, THE ANCHOR MOVEMENTS SHALL BE RECORDED AT 20, 30, 50, AND 60 MINUTES. IF AN ANCHOR FAILS IN CREEP, RETESTING WILL NOT BE ALLOWED.

E. A PERFORMANCE OR PROOF TESTED GROUND ANCHOR WITH A 10 MINUTE LOAD HOLD CREEP TEST IS CONSIDERED ACCEPTABLE WHEN:

1. THE GROUND ANCHOR CARRIES THE MAXIMUM TEST LOAD WITH LESS THAN 0.04 INCHES OF MOVEMENT BETWEEN THE 1 AND 10 MINUTE READINGS.
2. THE TOTAL MOVEMENT AT THE MAXIMUM TEST LOAD EXCEEDS 80% OF THE THEORETICAL ELASTIC ELONGATION OF THE UNBONDED LENGTH.

F. A PERFORMANCE OR PROOF TESTED GROUND ANCHOR WITH A 60 MINUTE LOAD HOLD CREEP TEST IS CONSIDERED ACCEPTABLE WHEN:

1. THE GROUND ANCHOR CARRIES THE MAXIMUM TEST LOAD WITH LESS THAN 0.08 INCHES OF MOVEMENT PER LOG CYCLE OF TIME AND THE CREEP RATE IS LINEAR OR DECREASING.
2. THE TOTAL MOVEMENT AT THE MAXIMUM TEST LOAD EXCEEDS 80% OF THE THEORETICAL ELASTIC ELONGATION OF THE UNBONDED LENGTH.

G. UPON SUCCESSFUL COMPLETION OF THE TEST, THE LOAD SHALL BE ADJUSTED TO THE SPECIFIED LOCK-OFF LOAD. AFTER TRANSFERRING THE LOAD TO THE ANCHORAGE DEVICE AND PRIOR TO REMOVING THE JACK, A LIFT-OFF READING SHALL BE MADE. THE LIFT-OFF READING SHALL BE WITHIN 10 PERCENT OF THE SPECIFIED LOCK-OFF LOAD.

H. GROUND ANCHORS THAT HAVE A CREEP RATE GREATER THAN SPECIFIED CAN BE INCORPORATED IN THE FINISHED WORK AT A LOAD EQUAL TO ONE-HALF OF THE FAILURE LOAD. THE FAILURE LOAD IS THE MAXIMUM LOAD CARRIED BY THE ANCHOR AFTER THE LOAD HAS BEEN ALLOWED TO STABILIZE FOR TEN MINUTES.

I. WHEN A GROUND ANCHOR FAILS, THE CONTRACTOR SHALL MODIFY THE ANCHOR DESIGN, THE CONSTRUCTION PROCEDURES, OR BOTH. THESE MODIFICATIONS MAY INCLUDE, BUT ARE NOT LIMITED TO: INSTALLING REPLACEMENT GROUND ANCHORS, MODIFYING THE INSTALLATION METHODS, INCREASING THE BOND LENGTH, OR CHANGING THE GROUND ANCHOR TYPE. ANY MODIFICATION WHICH REQUIRES CHANGES TO THE STRUCTURE SHALL HAVE PRIOR APPROVAL OF THE ENGINEER.

DRILLED SOLDIER PILES:

THE MINIMUM REQUIRED STRUCTURAL STEEL W-SHAPES FOR THE SOLDIER PILES ARE INDICATED ON THE PLANS. ALTERNATIVE STEEL SECTIONS MAY BE USED PROVIDED THAT THE SECTION MODULUS OF EACH ALTERNATIVE STEEL SECTION ARE EQUAL TO OR GREATER THAN THE CROSS-SECTIONAL AREA AND SECTION MODULUS OF THE CORRESPONDING STEEL SECTION SHOWN ON THE PLANS, AND IS APPROVED BY THE SHORING DESIGNER.

SHAFTS SHALL BE CONSTRUCTED SO THAT THE CENTER AT THE TOP OF THE SHAFT IS WITHIN +/- 3 INCHES OF THE PLAN LOCATION. SHAFTS SHALL BE PLUMB. THE ELEVATION AT THE TOP OF SHAFT SHALL BE +/- 3 INCHES FROM THE PLAN LOCATION. DURING CONSTRUCTION FOR THE SHAFTS, THE CONTRACTOR SHALL MAKE FREQUENT CHECKS ON THE PLUMBNESS, ALIGNMENT, AND DIMENSIONS OF THE SHAFTS. ANY DEVIATION EXCEEDING THE ALLOWABLE TOLERANCES SHALL BE CORRECTED IMMEDIATELY.

THE STEEL SOLDIER PILES SHALL BE PLACED SO THAT THE CENTER OF THE PILE IS WITHIN +/- 1 INCH OF THE PLAN LOCATION AT THE TOP OF THE PILE, AND WITHIN 0.5% OF VERTICAL WITH DEPTH.

SHAFTS SHALL BE EXCAVATED TO THE REQUIRED DEPTH AS SHOWN ON THE PLANS. THE EXCAVATION SHALL BE COMPLETED IN A CONTINUOUS OPERATION USING EQUIPMENT CAPABLE OF EXCAVATING THROUGH THE TYPE OF MATERIAL EXPECTED TO BE ENCOUNTERED.

IF THE SHAFT EXCAVATION IS STOPPED WITH THE APPROVAL OF THE ENGINEER, THE SHAFT SHALL BE SECURED BY INSTALLATION OF A SAFETY COVER. IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO ENSURE THE SAFETY OF THE SHAFT AND SURROUNDING SOIL AND THE STABILITY OF THE SIDE WALLS. A TEMPORARY CASING SHOULD BE USED IF NECESSARY TO ENSURE SUCH SAFETY AND STABILITY.

WHERE CAVING CONDITIONS ARE ENCOUNTERED, FURTHER EXCAVATION WILL NOT BE ALLOWED UNTIL THE CONTRACTOR SELECTS A METHOD TO PREVENT GROUND MOVEMENT. THE CONTRACTOR MAY ELECT TO PLACE A TEMPORARY CASING OR USE OTHER METHODS APPROVED BY THE ENGINEER.

THE CONTRACTOR SHALL USE APPROPRIATE MEANS (SUCH AS A CLEANOUT BUCKET), TO CLEAN THE BOTTOM OF THE EXCAVATION SUCH THAT NO MORE THAN 2 INCHES OF LOOSE OR DISTURBED MATERIAL IS PRESENT.

WHEN UNEXPECTED OBSTRUCTIONS, WHICH REQUIRE SPECIALIZED EQUIPMENT AND/OR LABOR ARE ENCOUNTERED, THE CONTRACTOR SHALL NOTIFY THE ENGINEER PROMPTLY AND THE OBSTRUCTIONS SHALL BE REMOVED AND THE EXCAVATION CONTINUED IN A MANNER APPROVED BY THE ENGINEER.

TEMPORARY CASINGS FOR THE SHAFTS SHALL BE REMOVED. A MINIMUM 5 FOOT HEAD OF CONCRETE MUST BE MAINTAINED TO BALANCE THE SOIL AND WATER PRESSURE AT THE BOTTOM OF THE CASING DURING REMOVAL. THE CASING SHALL BE SMOOTH.

SHAFT CONCRETE SHALL BE PLACED AS SHOWN ON THE PLANS AND SHALL COMMENCE WITHIN 2 HOURS AFTER COMPLETION OF THE EXCAVATION. SHAFT CONCRETE SHALL BE PLACED IN ONE CONTINUOUS OPERATION TO THE TOP OF THE SHAFT.

IF WATER IS NOT PRESENT, THE CONCRETE SHALL BE DEPOSITED BY A METHOD WHICH PREVENTS AGGREGATE SEGREGATION. THE CONTRACTOR'S METHOD FOR DEPOSITING CONCRETE SHALL HAVE APPROVAL OF THE ENGINEER PRIOR TO CONCRETE PLACEMENT.

IF WATER IS PRESENT, THE CONCRETE SHALL BE DEPOSITED BY TREMIE PLACEMENT METHODS.

HEADED STUDS:

ALL HEADED STUDS SHALL CONFORM TO ASTM A108 UNO. HEADED STUDS SHALL BE "NELSON STUDS" BY NELSON DIVISION OF TRW, INC. OR AN APPROVED EQUAL, AUTOMATICALLY END WELDED.

REINFORCING STEEL:

ALL REINFORCING STEEL SHALL CONFORM TO ASTM A615 / AASHTO M31, GRADE 60 FOR DEFORMED BARS, AND ASTM A185 / AASHTO M55 FOR WELDED WIRE FABRIC. ALL REINFORCING STEEL DETAILS IN ACCORDANCE WITH ACI 315 MANUAL OF STANDARD PRACTICE.

ALL DEFORMED REINFORCING BAR LAPS SHALL BE CLASS B, IN ACCORDANCE WITH THE 2012 INTERNATIONAL BUILDING CODE, OR AS SUMMARIZED IN THE FOLLOWING TABLE:

BAR SIZE	TENSILE DEVELOP LENGTH (IN)	LAP SPLICE LENGTH (IN)
#4	12	16
#5	15	20
#6	22	28

WELDED WIRE FABRIC (WWF) LAPS SHALL BE 2 SQUARES. SEE THE PLANS FOR SPECIFIC STRUCTURAL DETAILS.

DESIGN	DRAWN	REVIEW	DATE	REV	DESCRIPTION
CJW	JSS	RJB	6/4/2018	0	PERMIT ISSUE
CJW	JSS	RJB	7/12/2018	1	RESPONSE TO COMMENTS

REGISTERED PROFESSIONAL ENGINEER 58784 OREGON JULY 14, 1998 CHRIS J. WOLSCHLAG 7/12/18
EXPIRATION DATE: 06-30-20

Ground Support PLLC
16932 Woodinville Redmond Rd NE, #210
Woodinville, WA 98072
Ph: (425) 488-1143 Fax: (425) 605-4057

SEASIDE HIGH SCHOOL, WALL 'D'
PERMANENT RETAINING WALL
RETAINING WALL NOTES

PROJ. NO. 18-28
SHEET NUMBER
SH1.1

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SHOTCRETE

1. GENERAL

A. ALL SHOTCRETE SHALL HAVE A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 4000 PSI, AND A MINIMUM 3-DAY COMPRESSIVE STRENGTH OF 2000 PSI.

B. ALL SHOTCRETE SHALL COMPLY WITH THE REQUIREMENTS OF ACI 506.2-95 EXCEPT AS SPECIFIED OTHERWISE HEREIN. THE OWNER SHALL CONTRACT AN INDEPENDENT TESTING LABORATORY TO CORE AND TEST SHOTCRETE PANELS AND INSPECT ALL SHOTCRETE AND STEEL REINFORCEMENT PLACEMENT IN ACCORDANCE WITH ACI 506.4R-94.

C. ALL WORKERS, INCLUDING FOREMAN, NOZZLEMEN, FINISHERS AND DELIVERY EQUIPMENT OPERATORS, SHALL BE FULLY QUALIFIED TO PERFORM THE WORK. QUALIFICATION OF THE NOZZLEMEN SHALL BE BASED ON THE RESULTS OF TEST PANELS AS REQUIRED HEREIN, UNLESS APPROVED OTHERWISE BY THE ENGINEER.

D. AT LEAST 15 DAYS PRIOR TO INITIATING THE WORK, THE CONTRACTOR SHALL SUBMIT THE FOLLOWING TO THE ENGINEER FOR REVIEW AND APPROVAL:

1. WRITTEN DOCUMENTATION OF THE NOZZLEMENS QUALIFICATIONS AND PROPOSED METHOD OF SHOTCRETE PLACEMENT.
2. SHOTCRETE MIX DESIGN INCLUDING: BRAND AND TYPE OF PORTLAND CEMENT; SOURCE, GRADATION, AND QUALITY OF AGGREGATES; MIX PROPORTIONS BY WEIGHT; PROPOSED ADMIXTURES AND THEIR MANUFACTURER, DOSAGE, AND TECHNICAL LITERATURE; AND COMPRESSIVE STRENGTH TEST RESULTS FROM THE SUPPLIER NO OLDER THAN 6 MONTHS VERIFYING THE 28-DAY COMPRESSIVE STRENGTH.
3. ONCE AVAILABLE, CERTIFIED MILL TESTS FOR ALL REINFORCING STEEL FROM EACH HEAT SPECIFYING THE MINIMUM ULTIMATE STRENGTH, YIELD STRENGTH, ELONGATION, AND COMPOSITION.
4. METHODS OF CONTROLLING THE LOCATION OF THE FINISH FACE AND DETERMINING SHOTCRETE THICKNESS.

2. MATERIALS

A. ALL MATERIALS FOR SHOTCRETE SHALL CONFORM TO THE FOLLOWING REQUIREMENTS.

1. CEMENT SHALL CONFORM TO ASTM C150 / AASHTO M85, TYPE I, II, OR III.
2. FINE AGGREGATE SHALL CONFORM TO ASTM C33 / AASHTO M6.
3. COARSE AGGREGATE SHALL CONFORM TO AASHTO M-80, CLASS B.
4. WATER SHALL BE POTABLE, CLEAN, AND FREE FROM SUBSTANCES DELETERIOUS TO CONCRETE AND STEEL, OR THAT WOULD CAUSE STAINING.
5. ACCELERATOR SHALL BE THE FLUID TYPE, APPLIED AT NOZZLE, AND MEET THE REQUIREMENTS HEREIN.
6. WATER-REDUCER AND SUPER-PLASTICIZER SHALL CONFORM TO ASTM C494 / AASHTO M194, TYPE A, D, F, G.
7. AIR-ENTRAINING AGENT SHALL CONFORM TO ASTM C260 / AASHTO M154.
8. FLY ASH SHALL CONFORM TO ASTM C618 / AASHTO M295, TYPE F OR G, CEMENT REPLACEMENT UP TO 35% BY WEIGHT OF CEMENT.
9. SILICA FUME SHALL CONFORM TO ASTM C1240, 90% MINIMUM SILICON DIOXIDE SOLIDS CONTENT, NOT TO EXCEED 12% BY WEIGHT OF CEMENT.
10. WELDED WIRE FABRIC SHALL CONFORM TO ASTM A185 / AASHTO M55.
11. ALL REINFORCING STEEL SHALL CONFORM TO ASTM A615 / AASHTO M31, GRADE 60. ALL REINFORCING STEEL DETAILS SHALL CONFORM TO ACI 315.
12. CURING COMPOUNDS SHALL CONFORM TO AASHTO M148, TYPE 1D OR TYPE 2.
13. FILM PROTECTION FOR CURING SHALL CONFORM TO AASHTO M171 OR POLYETHYLENE FILM.

B. SHOTCRETE ADMIXTURES SHALL NOT BE USED UNLESS APPROVED BY THE ENGINEER. ADMIXTURES USED TO ENTRAIN AIR, TO REDUCE WATER-CEMENT RATIO, TO RETARD OR ACCELERATE SETTING TIME, OR TO ACCELERATE THE DEVELOPMENT OF STRENGTH, SHALL BE THOROUGHLY MIXED INTO THE SHOTCRETE AT THE RATE SPECIFIED BY THE MANUFACTURER UNLESS SPECIFIED OTHERWISE. ACCELERATING ADDITIVES SHALL BE COMPATIBLE WITH THE CEMENT USED, BE NON-CORROSIVE TO STEEL AND SHALL NOT PROMOTE OTHER DETRIMENTAL EFFECTS SUCH AS CRACKING OR EXCESSIVE SHRINKAGE. THE MAXIMUM ALLOWABLE CHLORIDE ION CONTENT OF ALL INGREDIENTS SHALL NOT EXCEED 0.10 PERCENT WHEN TESTED PER AASHTO T260.

C. MATERIALS SHALL BE DELIVERED, STORED AND HANDLED TO PREVENT CONTAMINATION, SEGREGATION, CORROSION OR DAMAGE. LIQUID ADMIXTURES SHALL BE STORED TO PREVENT EVAPORATION AND FREEZING.

D. AGGREGATES FOR SHOTCRETE SHALL MEET THE STRENGTH AND DURABILITY REQUIREMENT OF AASHTO M80 AND SHALL MEET THE FOLLOWING GRADATION REQUIREMENTS:

SIEVE SIZE	PERCENT PASSING BY WEIGHT	SIEVE SIZE	PERCENT PASSING BY WEIGHT
1/2 INCH	100	NO. 16	35-55
3/8 INCH	90-100	NO. 30	20-35
NO. 4	70-85	NO. 50	8-20
NO. 8	50-70	NO. 100	2-10

E. CEMENT CONTENT SHALL BE AT LEAST 600 POUNDS PER CUBIC YARD. THE WATER/CEMENT RATIO SHALL NOT BE GREATER THAN 0.45. FOR WET-MIX SHOTCRETE EXPOSED TO FREEZING AND THAWING, THE AIR CONTENT AT THE TRUCK SHALL BE BETWEEN 7 TO 10 PERCENT WHEN TESTED IN ACCORDANCE WITH ASTM C231 / AASHTO T152.

F. SHOTCRETE SHALL BE PROPORTIONED TO ATTAIN A COMPRESSIVE STRENGTH OF 2000 PSI IN 3 DAYS AND 4500 PSI IN 28 DAYS. THE AVERAGE COMPRESSIVE STRENGTH OF EACH SET OF THREE CORES EXTRACTED FROM TEST PANELS OR WALL FACE MUST BE EQUAL TO OR EXCEED 85%, WITH NO INDIVIDUAL CORE LESS THAN 75% OF THE SPECIFIED COMPRESSIVE STRENGTH IN ACCORDANCE WITH ACI 506.2.

G. AGGREGATE AND CEMENT MAY BE BATCHED BY WEIGHT OR BY VOLUME IN ACCORDANCE WITH THE REQUIREMENTS OF ASTM C94 / AASHTO M157. MIXING EQUIPMENT SHALL BE CAPABLE OF THOROUGHLY MIXING THE MATERIALS IN SUFFICIENT QUANTITY TO MAINTAIN PLACING CONTINUITY. READY-MIX SHOTCRETE SHALL BE DELIVERED AND PLACED WITHIN 1-1/2 HOURS OF THE BATCH TIME UNLESS APPROVED OTHERWISE BY THE ENGINEER.

3. TEST PANELS

A. IN GENERAL, PRECONSTRUCTION AND PRODUCTION SHOTCRETE TEST PANELS SHALL BE REQUIRED. HOWEVER, DEPENDING ON THE AMOUNT OF SHOTCRETE WALL REINFORCEMENT, THE ENGINEER MAY WAIVE THE REQUIREMENTS FOR A REINFORCED PRECONSTRUCTION TEST PANEL. PRECONSTRUCTION AND PRODUCTION TEST PANELS SHALL NOT BE DISTURBED OR MOVED WITHIN THE FIRST 24 HOURS AFTER SHOOTING. TEST PANELS SHALL BE FIELD CURED UNDER CONDITIONS SIMILAR TO THOSE ANTICIPATED FOR THE WORK. SHOTCRETING AND CORING OF TEST PANELS SHALL BE PERFORMED BY QUALIFIED PERSONNEL IN THE PRESENCE OF THE OWNER'S REPRESENTATIVE. THE CONTRACTOR SHALL NOTIFY THE OWNER'S REPRESENTATIVE NOT LESS THAN 2 DAYS PRIOR TO THE SHOOTING OF THE PRECONSTRUCTION TEST PANELS.

B. EACH NOZZLEMAN SHALL FURNISH AT LEAST TWO PRECONSTRUCTION TEST PANELS FOR EACH PROPOSED MIXTURE BEING CONSIDERED AND FOR EACH SHOOTING POSITION ENCOUNTERED ON THE JOB. PRECONSTRUCTION TEST PANELS SHALL BE MADE BY EACH APPLICATION CREW USING THE EQUIPMENT, MATERIALS, MIXTURE PROPORTIONS, AND PROCEDURES PROPOSED FOR THE JOB PRIOR TO THE COMMENCEMENT OF WORK.

C. PRECONSTRUCTION TEST PANELS SHALL BE 30 INCHES X 30 INCHES (MINIMUM), IN ACCORDANCE WITH ACI 506.2-95 AND THE FOLLOWING:

1. ONE TEST PANEL SHALL BE THE MAXIMUM SHOTCRETE THICKNESS SHOWN ON THE PLANS AND SHALL INCLUDE THE MAXIMUM ANTICIPATED REINFORCING CONGESTION. CORES EXTRACTED FROM THE REINFORCED TEST PANEL SHALL DEMONSTRATE ENCAPSULATION OF THE REINFORCEMENT IN ACCORDANCE WITH ACI 506.2 EQUAL TO CORE GRADE 2 OR BETTER.
2. ONE TEST PANEL SHALL BE UNREINFORCED, AT LEAST 6 INCHES THICK, AND USED FOR COMPRESSIVE STRENGTH TESTING.
3. THE SIDES OF THE TEST PANELS SHALL BE CHAMFERED OUTWARD AT 45 DEGREES OVER THE FULL THICKNESS OF THE PANEL.

D. THE CONTRACTOR SHALL FURNISH AT LEAST ONE PRODUCTION TEST PANEL OR, IN LIEU OF PRODUCTION TEST PANELS, SIX 3-INCH DIAMETER CORES FROM THE SHOTCRETE FACE DURING THE FIRST APPLICATION OF SHOTCRETE AND HENCEFORTH FOR EVERY FIFTH APPLICATION OF SHOTCRETE, OR EVERY 5000 SQUARE FEET, OR 50 CUBIC YARDS OF SHOTCRETE PLACED, WHICHEVER IS LESS. THE PRODUCTION TEST PANELS SHALL BE CONSTRUCTED SIMULTANEOUSLY WITH THE SHOTCRETE FACING INSTALLATION AT TIMES DESIGNATED BY THE OWNER'S REPRESENTATIVE. THE PRODUCTION TEST PANELS SHALL HAVE MINIMUM DIMENSIONS OF 18 INCHES X 18 INCHES X 6 INCHES.

E. SHOTCRETE WILL BE ACCEPTED BASED ON THE 28-DAY STRENGTH OF CORES TAKEN FROM THE PRODUCTION TEST PANELS. THE FREQUENCY SPECIFIED FOR THE PRODUCTION TEST PANELS IS APPROXIMATE. A GREATER NUMBER OF PANELS MAY BE REQUIRED BY THE ENGINEER.

F. AT LEAST SIX CORES WILL BE CUT FROM EACH PRECONSTRUCTION AND PRODUCTION TEST PANEL FOR COMPRESSIVE STRENGTH TESTING. CORES SHALL BE SOAKED IN WATER FOR AT LEAST 40 HOURS IN ACCORDANCE WITH AASHTO T24 OR ACI 506.2. CORES SHALL BE AT LEAST 3 INCHES IN DIAMETER AND SHALL HAVE A MINIMUM LENGTH TO DIAMETER RATIO OF ONE. WHEN THE LENGTH OF A CORE IS LESS THAN TWICE THE DIAMETER, APPLY THE CORRECTION FACTORS GIVEN IN ASTM C42 TO OBTAIN THE COMPRESSIVE STRENGTH OF INDIVIDUAL CORES. THREE CORES SHALL BE TESTED AT 3-DAYS, AND THREE CORES SHALL BE TESTED AT 28-DAYS FOR COMPRESSIVE STRENGTH. CORE HOLES IN THE WALL SHALL BE FILLED WITH PATCHING MORTAR AFTER CLEANING AND THOROUGH DAMPENING.

4. EXECUTION OF PRODUCTION SHOTCRETE WORK

4.1 ALIGNMENT CONTROL

A. ALIGNMENT WIRES AND/OR THICKNESS CONTROL PINS SHALL BE PROVIDED AS NECESSARY TO ESTABLISH AND MAINTAIN THE MINIMUM SHOTCRETE THICKNESS SHOWN ON THE PLANS. THE MAXIMUM DISTANCE BETWEEN THE WIRES AND/OR THICKNESS CONTROL PINS ON ANY SURFACE SHALL BE EQUAL TO THE VERTICAL NAIL SPACING. THE CONTRACTOR SHALL ENSURE THAT ALIGNMENT WIRES ARE TIGHT, TRUE TO LINE, AND PLACED TO ALLOW FURTHER TIGHTENING.

4.2 SURFACE PREPARATION

A. PRIOR TO SHOTCRETING THE UNGROUTED ZONE ABOVE THE NAIL GROUT AT THE EXCAVATION CUT FACE (BIRDS BEAK), THE CONTRACTOR SHALL REMOVE ALL LOOSE MATERIALS FROM THE SURFACE OF THE GROUT.

B. THE CONTRACTOR SHALL REMOVE ALL LOOSE MATERIALS AND LOOSE DRIED SHOTCRETE FROM PREVIOUS PLACEMENT OPERATIONS AND FROM ALL RECEIVING SURFACES BY METHODS ACCEPTABLE TO THE OWNER'S REPRESENTATIVE. THE REMOVAL SHALL BE ACCOMPLISHED IN SUCH A MANNER AS NOT TO LOOSEN, CRACK, OR SHATTER THE SURFACES TO RECEIVE THE SHOTCRETE. ANY SURFACE MATERIAL THAT, IN THE OPINION OF THE OWNER'S REPRESENTATIVE, IS SO LOOSENED OR DAMAGED SHALL BE REMOVED TO SUFFICIENT DEPTH TO PROVIDE A BASE THAT IS SUITABLE TO RECEIVE THE SHOTCRETE. MATERIAL THAT LOOSENS AS THE SHOTCRETE IS APPLIED SHALL BE REMOVED. SHOTCRETE SHALL NOT BE PLACED ON FROZEN SURFACES.

4.3 DELIVERY AND APPLICATION

A. A CLEAN, DRY, OIL-FREE SUPPLY OF COMPRESSED AIR SUFFICIENT FOR MAINTAINING ADEQUATE NOZZLE VELOCITY FOR ALL PARTS OF THE WORK AND FOR SIMULTANEOUS OPERATION OF A BLOW PIPE FOR CLEANING AWAY REBOUND SHALL BE MAINTAINED AT ALL TIMES. THE EQUIPMENT SHALL BE CAPABLE OF DELIVERING THE PREMIXED MATERIAL ACCURATELY, UNIFORMLY, AND CONTINUOUSLY THROUGH THE DELIVERY HOSE.

B. THE SHOTCRETE SHALL BE APPLIED FROM THE LOWER PART OF THE WORK AREA UPWARDS TO PREVENT ACCUMULATION OF REBOUND ON UNCOVERED SURFACES. THICKNESS, METHODS OF SUPPORT, AIR PRESSURE, AND RATE OF PLACEMENT OF SHOTCRETE SHALL BE CONTROLLED TO PREVENT SAGGING OR SLOUGHING OF FRESHLY APPLIED SHOTCRETE. WHERE SHOTCRETE IS USED TO FILL THE BIRD'S BEAK, THE NOZZLE SHALL BE POSITIONED INTO THE MOUTH OF THE DRILLHOLE TO COMPLETELY FILL THE VOID. REBOUND SHALL NOT BE WORKED BACK INTO THE PLACEMENT NOR SHALL THE REBOUND BE SALVAGED. REBOUND THAT DOES NOT FALL CLEAR OF THE WORKING AREA SHALL BE REMOVED. THE NOZZLE SHALL BE HELD AT A DISTANCE AND AT AN ANGLE APPROXIMATELY PERPENDICULAR TO THE WORKING FACE SO THAT REBOUND WILL BE MINIMAL AND COMPACTION WILL BE MAXIMIZED. THE NOZZLE SHOULD BE ROTATED STEADILY IN A SMALL CIRCULAR PATTERN.

C. SHOTCRETE PLACEMENT SHALL BE BY THE BENCH GUNNING METHOD WHEN THE THICKNESS OF THE SHOTCRETE LAYER IS 6 INCHES OR GREATER. THE GUNNING METHOD SHALL CONSIST OF BUILDING UP A THICK LAYER OF SHOTCRETE FROM THE BOTTOM OF THE LIFT AND MAINTAINING THE TOP SURFACE AT APPROXIMATELY A 45-DEGREE SLOPE.

4.4 VISUAL OBSERVATION

A. A CLEARLY DEFINED PATTERN OF CONTINUOUS HORIZONTAL OR VERTICAL RIDGES OR DEPRESSIONS AT THE REINFORCING ELEMENTS AFTER THEY ARE COVERED WILL BE CONSIDERED INDICATION OF INSUFFICIENT COVER OF REINFORCEMENT OR POOR APPLICATION AND PROBABLE VOID. IN THIS CASE, THE WORK SHALL BE IMMEDIATELY SUSPENDED AND THE WORK CAREFULLY INSPECTED BY THE OWNER'S REPRESENTATIVE. THE CONTRACTOR SHALL IMPLEMENT AND COMPLETE CORRECTIVE MEASURES PRIOR TO RESUMING THE SHOTCRETE OPERATIONS.

B. THE SHOTCRETING PROCEDURE MAY BE CORRECTED BY ADJUSTING THE NOZZLE DISTANCE AND ORIENTATION PERPENDICULAR TO THE SURFACE, ADJUSTING THE WATER CONTENT OF THE SHOTCRETE MIX, OR OTHER MEANS ACCEPTABLE TO THE OWNER'S REPRESENTATIVE. ALL OVERSPRAY AND REBOUND SHALL BE REMOVED FROM THE SURFACE.

C. SURFACE DEFECTS SHALL BE REPAIRED AS SOON AS POSSIBLE AFTER INITIAL PLACEMENT OF SHOTCRETE. ALL SHOTCRETE THAT LACKS UNIFORMITY, EXHIBITS SEGREGATION, SAGGING, HONEYCOMBING, OR LAMINATION, OR CONTAINS ANY VOIDS OR SAND POCKETS SHALL BE REMOVED AND REPLACED WITH FRESH SHOTCRETE BY THE CONTRACTOR TO THE SATISFACTION OF THE OWNER'S REPRESENTATIVE.

4.6 CONSTRUCTION JOINTS

A. CONSTRUCTION JOINTS SHALL BE TAPERED TOWARD THE EXCAVATION FACE OVER A MINIMUM DISTANCE EQUAL TO THE THICKNESS OF THE SHOTCRETE LAYER. THE SURFACE OF THE JOINTS SHALL BE ROUGH AND CLEANED OF ALL LAITANCE AND FOREIGN SUBSTANCES PRIOR TO SHOTCRETE PLACEMENT.

4.7 FINISHING AND CURING REQUIREMENTS

A. SHOTCRETE SHALL BE LEFT WITH A BROOM FINISH.

B. THE SHOTCRETE SHALL BE PROTECTED FROM LOSS OF MOISTURE FOR AT LEAST 7 DAYS AFTER PLACEMENT. WHEN SHOTCRETE IS BEING PROTECTED FROM LOW TEMPERATURES, CURING SHALL BE TERMINATED NO SOONER THAN ONE DAY AFTER THE REMOVAL OF LOW TEMPERATURE PROTECTION. CURING OF SHOTCRETE SHALL BE BY METHODS THAT WILL KEEP SHOTCRETE SURFACES ADEQUATELY WET AND PROTECTED DURING THE SPECIFIED PERIOD. CURING SHALL COMMENCE WITHIN ONE HOUR OF SHOTCRETE APPLICATION. WHEN THE AMBIENT TEMPERATURE EXCEEDS 80 DEGREES FAHRENHEIT, THE CONTRACTOR SHALL PLAN THE WORK SUCH THAT CURING CAN COMMENCE IMMEDIATELY AFTER FINISHING. THE CURING SHALL BE COMPLETED USING WATER, MEMBRANE, OR FILM CURING METHODS IN ACCORDANCE WITH THE FOLLOWING REQUIREMENTS.

C. FOR WATER CURING, THE RATE OF WATER APPLICATION SHALL BE REGULATED TO PROVIDE COMPLETE SURFACE COVERAGE WITH A MINIMUM OF RUNOFF.

D. FOR MEMBRANE CURING, CURING COMPOUNDS SHALL NOT BE USED ON ANY SURFACES AGAINST WHICH ADDITIONAL SHOTCRETE OR OTHER FINISHING MATERIALS ARE TO BE BONDED UNLESS THE SURFACE IS SANDBLASTED IN A MANNER ACCEPTABLE TO THE OWNER'S REPRESENTATIVE. MEMBRANE CURING COMPOUNDS SHALL BE SPRAY APPLIED AS QUICKLY AS PRACTICAL AFTER INITIAL SHOTCRETE SET AT A COVERAGE OF NOT LESS THAN 40 SQUARE FEET PER GALLON.

E. FOR FILM CURING, POLYETHYLENE SHEETING MAY BE USED TO SUPPLEMENT WATER CURING ON SHOTCRETE THAT WILL BE COVERED LATER WITH ADDITIONAL SHOTCRETE OR CONCRETE. THE SHEETING SHALL COMPLETELY COVER ALL SURFACES, AND HAVE EDGES OVERLAPPED FOR PROPER SEALING AND ANCHORAGES.

4.8 WEATHER LIMITATIONS

A. SHOTCRETE SHALL NOT BE PLACED IN COLD WEATHER UNLESS ADEQUATELY PROTECTED WHEN THE AMBIENT TEMPERATURE IS BELOW 40Â° F AND FALLING AND/OR WHEN THE SHOTCRETE IS LIKELY TO BE SUBJECTED TO FREEZING TEMPERATURES BEFORE REACHING A MINIMUM STRENGTH OF 750 PSI. COLD WEATHER PROTECTION SHALL BE MAINTAINED UNTIL THE STRENGTH OF THE SHOTCRETE IS GREATER THAN 750 PSI. COLD WEATHER PROTECTION SHALL INCLUDE HEATING UNDER TENTS, BLANKETS OR OTHER MEANS ACCEPTABLE TO THE OWNER'S REPRESENTATIVE. THE TEMPERATURE OF THE SHOTCRETE, WHEN DEPOSITED, SHALL BE NOT LESS THAN 50Â° F NOR MORE THAN 80Â° F. THE AIR IN CONTACT WITH SHOTCRETE SURFACES SHALL BE MAINTAINED AT TEMPERATURES ABOVE 32Â° F FOR A MINIMUM OF 7 DAYS.

B. SHOTCRETE APPLICATION SHALL ALSO BE SUSPENDED DURING HIGH WINDS AND HEAVY RAINS WHEN IN THE OPINION OF THE OWNER'S REPRESENTATIVE THE QUALITY OF THE APPLICATION IS NOT ACCEPTABLE. NEWLY-PLACED SHOTCRETE EXPOSED TO RAIN THAT WASHES OUT CEMENT OR OTHERWISE MAKES THE SHOTCRETE UNACCEPTABLE TO THE OWNER'S REPRESENTATIVE SHALL BE REMOVED AND REPLACED. THE CONTRACTOR SHALL PROVIDE ADEQUATELY SECURED POLYETHYLENE SHEETING OR EQUIVALENT WHEN ADVERSE EXPOSURE TO WEATHER IS ANTICIPATED.

4.9 TOLERANCES

A. THE TOLERANCES FOR SHOTCRETE FACINGS SHALL BE AS FOLLOWS:

1. THE VERTICAL LOCATION OF A HORIZONTAL SHOTCRETE JOINT SHALL BE WITHIN 1 FOOT OF THE ELEVATION SHOWN ON THE PLANS.
2. THE SHOTCRETE WALL THICKNESS SHALL BE NO LESS THAN THAT SHOWN ON THE PLANS.
3. THE HORIZONTAL AND VERTICAL LOCATIONS OF REINFORCING BARS SHALL BE WITHIN 1 INCH OF THE LOCATIONS SHOWN ON THE PLANS.
4. REINFORCING BAR LAP LENGTHS SHALL BE NO LESS THAN THAT SHOWN ON THE PLANS MINUS 1 INCH.
5. REINFORCING BAR SPACING SHALL NOT EXCEED THAT SHOWN ON THE PLANS PLUS 1 INCH.

DESCRIPTION	REV	DATE	REVIEW	DRAWN	DESIGN
PERMIT ISSUE	0	6/4/2018	RJB	JSS	CJW
RESPONSE TO COMMENTS	1	7/12/2018	RJB	JSS	CJW

REGISTERED PROFESSIONAL ENGINEER 58784PE OREGON JULY 14, 1998 CHRIS J. WOLSCHLAG 7/12/18
EXPIRATION DATE: 06-30-20

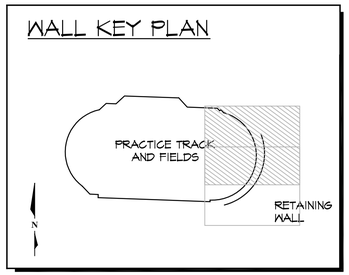
Ground Support PLLC
16932 Woodinville Redmond Rd NE, #210
Woodinville, WA 98072
Ph: (425) 488-1143 Fax: (425) 605-4057

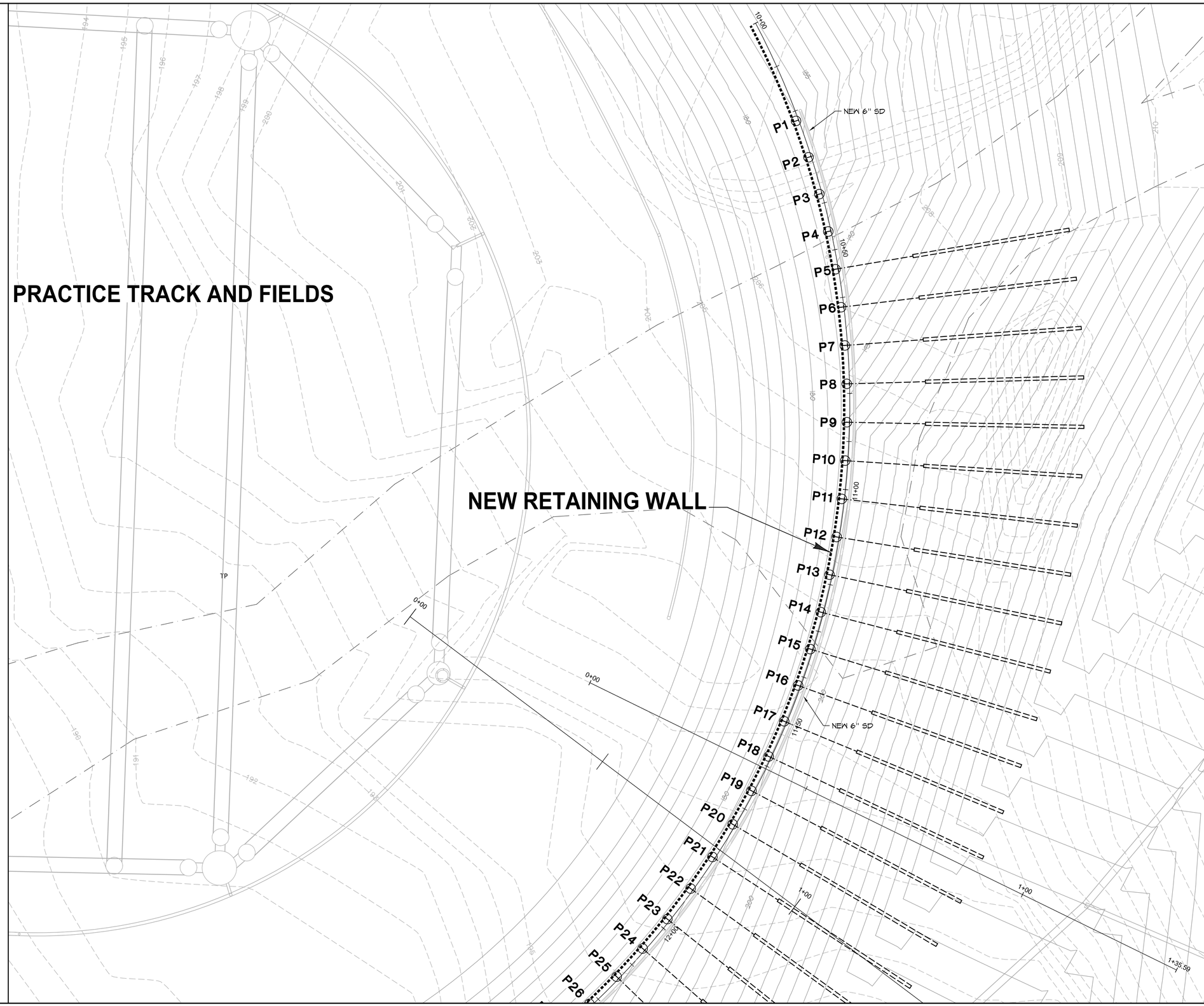
SEASIDE HIGH SCHOOL, WALL 'D'
PERMANENT RETAINING WALL
RETAINING WALL NOTES

PROJ. NO. 18-28
SHEET NUMBER
SH1.2

D:\Jobs\2018\18-28 (Seaside-OR-CJA)\(shoring)\(permitting)\R1 (20180712)\1828sh01cR1.dwg, 7/12/2018 12:15:13 PM

WALL KEY PLAN





N

0 10 20
FEET

LEGEND

P1	SOLDIER PILE
	SOIL ANCHOR
B	BUILDING GRID LOCATION
	FACE OF SOLDIER PILE WALL
100	EXISTING GRADE CONTOUR

DESIGN	DRAWN	REVIEW	DATE	REV	DESCRIPTION
CJA	JSS	RJB	6/4/2018	0	PERMIT ISSUE
CJA	JSS	RJB	7/12/2018	1	RESPONSE TO COMMENTS

REGISTERED PROFESSIONAL ENGINEER
OREGON
CHRIS J. ADAMS
JULY 14, 2018
LICENSE NO. 86784
EXPIRATION DATE: 06-30-20

Ground Support PLLC
16932 Woodinville Redmond Rd NE, #210
Woodinville, WA 98072
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SEASIDE HIGH SCHOOL, WALL 'D'

PERMANENT RETAINING WALL WALL PLAN

PROJ. NO. 18-28

SHEET NUMBER

SH2.0

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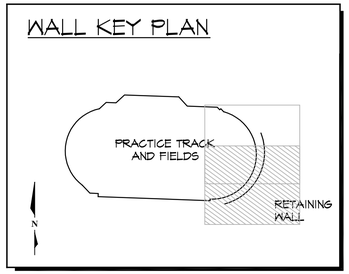

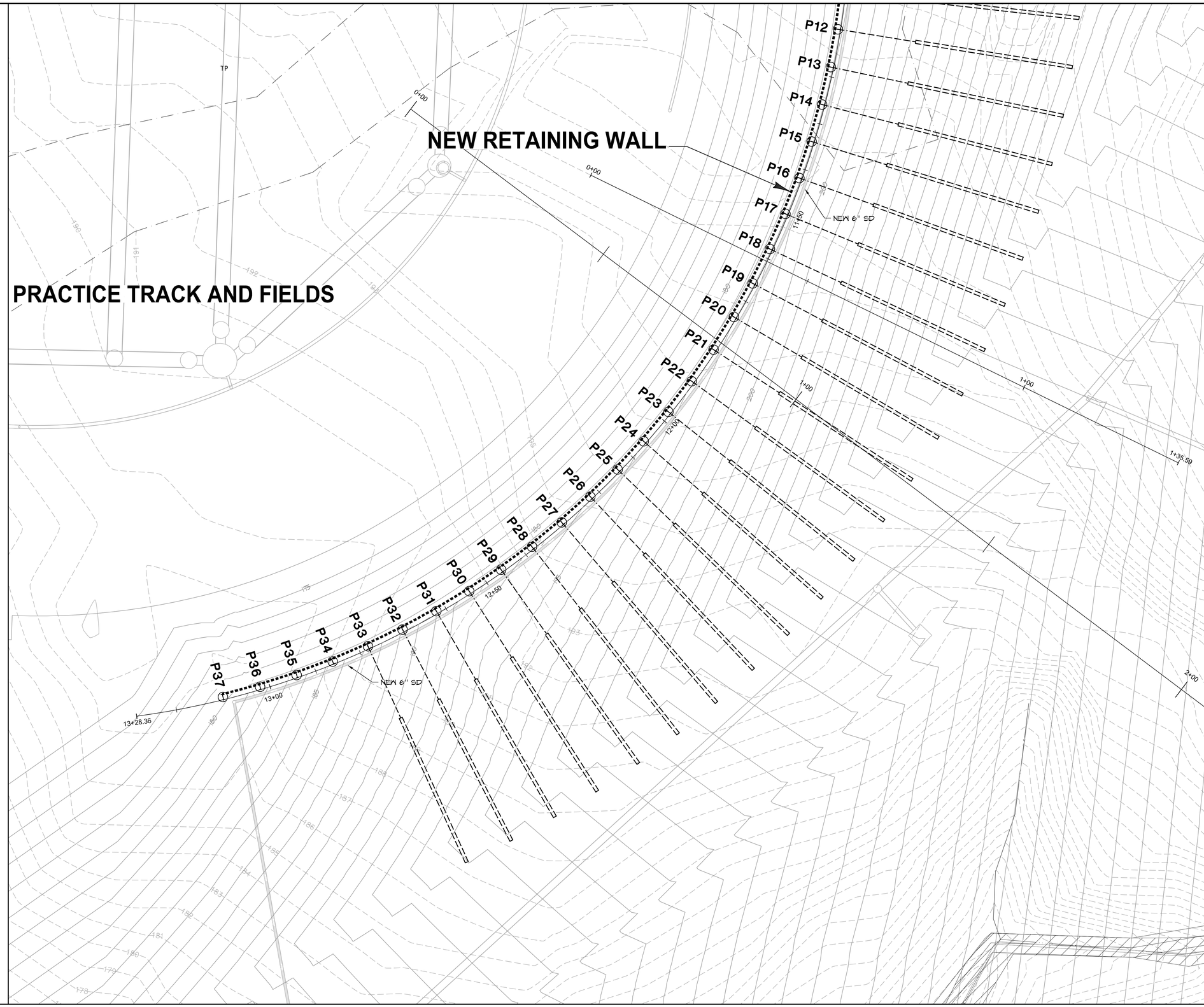

LEGEND

P1	SOLDIER PILE
	SOIL ANCHOR
B	BUILDING GRID LOCATION
	FACE OF SOLDIER PILE WALL
100	EXISTING GRADE CONTOUR

DESIGN	DRAWN	REV/CHK	DATE	REV	DESCRIPTION
CJK	JSS	RLB	6/4/2018	0	PERMIT ISSUE
CJK	JSS	RLB	7/12/2018	1	RESPONSE TO COMMENTS

REGISTERED PROFESSIONAL ENGINEER 16932 OREGON CHRIS J. KOLTAS JULY 14, 2018

EXPIRATION DATE: 06-30-20

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SEASIDE HIGH SCHOOL, WALL 'D'

PERMANENT RETAINING WALL WALL PLAN

PROJ. NO. 18-28

SHEET NUMBER

SH2.1

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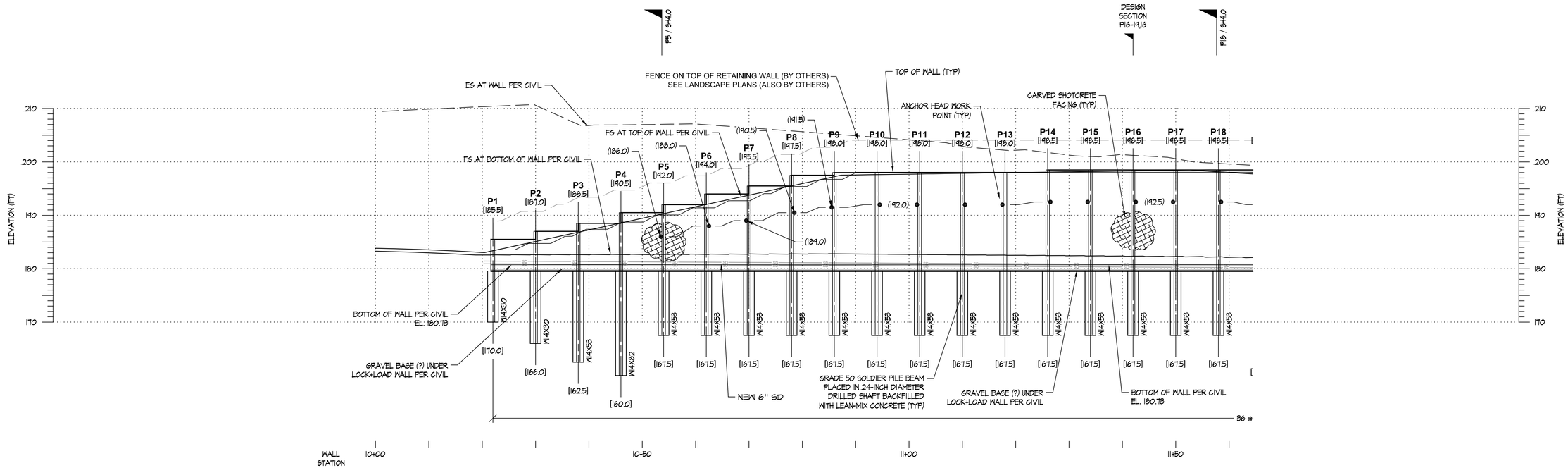


PERMANENT RETAINING WALL

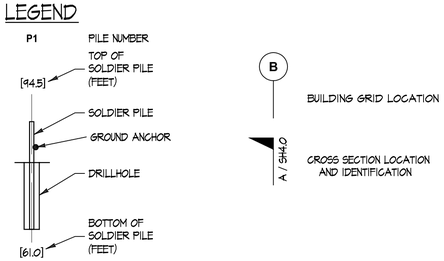
ANCHOR SCHEDULE

PILE(S)	ROW NUMBER	DECLI-NATION (DEG)	TOTAL LENGTH (FT)	UNBOND LENGTH (FT)	BOND LENGTH (FT)	NUMBER OF STRANDS	DESIGN LOAD (K)	LOCKOFF LOAD (K)
P5-P33	1	20	53	15	38	4	116	116

WALL LAGGING AREA = 4,370 SQ. FT.

NOTE: INFORMATION SUPPLIED TO GROUND SUPPORT PLLC AT TIME OF SHORING DESIGN INSUFFICIENT TO CHECK FOR ALL POTENTIAL CONFLICTS BETWEEN SHORING ELEMENTS AND UTILITIES. GENERAL CONTRACTOR IS RESPONSIBLE FOR LOCATION OF ALL UTILITIES WITHIN ZONE OF SHORING ELEMENTS AND FOR CHECKING THAT NO SUCH CONFLICTS EXIST.

LEGEND



WALL KEY PLAN

0 10 20
FEET

REV	DESCRIPTION
0	PERMIT ISSUE
1	RESPONSE TO COMMENTS

DESIGN	DRAWN	REVIEW	DATE
CJK	JSS	RJB	6/4/2018
CJK	JSS	RJB	7/12/2018

REGISTERED PROFESSIONAL ENGINEER
OREGON
CHRIS J. KAY
JULY 14, 2018
EXPIRATION DATE: 06-30-20

Ground Support PLLC
16932 Woodinville Redmond Rd NE, #210
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SEASIDE HIGH SCHOOL, WALL 'D'
PERMANENT RETAINING WALL ELEVATION

PROJ. NO. 18-28

SHEET NUMBER

SH3.0

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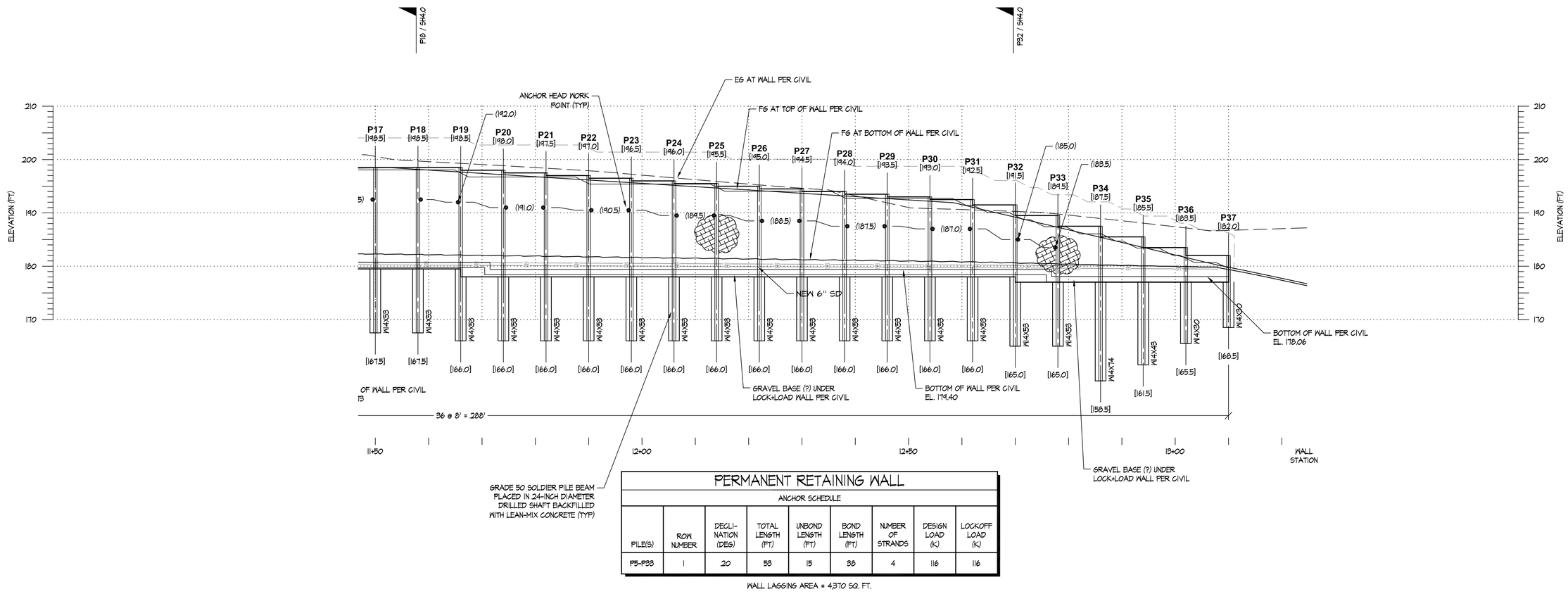


PERMANENT RETAINING WALL

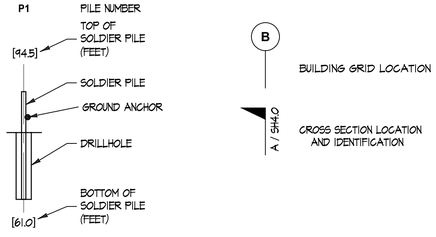
ANCHOR SCHEDULE

PILE(S)	ROW NUMBER	DECLI-NATION (DEG)	TOTAL LENGTH (FT)	UNBOND LENGTH (FT)	BOND LENGTH (FT)	NUMBER OF STRANDS	DESIGN LOAD (K)	LOCKOFF LOAD (K)
P5-P33	1	20	53	15	38	4	116	116

WALL LAGGING AREA = 4,370 SQ. FT.

NOTE: INFORMATION SUPPLIED TO GROUND SUPPORT PLLC AT TIME OF SHORING DESIGN INSUFFICIENT TO CHECK FOR ALL POTENTIAL CONFLICTS BETWEEN SHORING ELEMENTS AND UTILITIES. GENERAL CONTRACTOR IS RESPONSIBLE FOR LOCATION OF ALL UTILITIES WITHIN ZONE OF SHORING ELEMENTS AND FOR CHECKING THAT NO SUCH CONFLICTS EXIST.

LEGEND



WALL KEY PLAN

0 10 20
FEET

REV	DESCRIPTION	DATE	REVIEW	DRAWN	DESIGN
0	PERMIT ISSUE	6/4/2018	RJB	JSS	CJA
1	RESPONSE TO COMMENTS	7/12/2018	RJB	JSS	CJA

REGISTERED PROFESSIONAL ENGINEER
OREGON
JULY 14, 2018
CHRIS J. MA
SIGNATURE DATE: 08-30-20

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16932 Woodinville Redmond Rd NE, #210
Woodinville, WA 98072
Ph: (425) 488-1143 Fax: (425) 605-4057

SEASIDE HIGH SCHOOL, WALL 'D'
PERMANENT RETAINING WALL ELEVATION

PROJ. NO. 18-28

SHEET NUMBER

SH3.1

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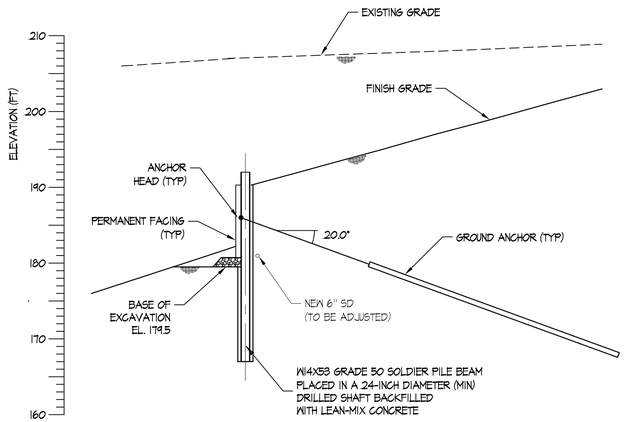
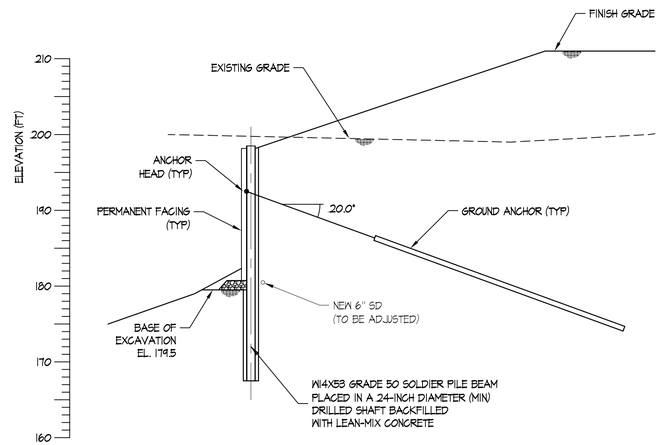


P5
SH4.0

CROSS-SECTION AT PILE P5

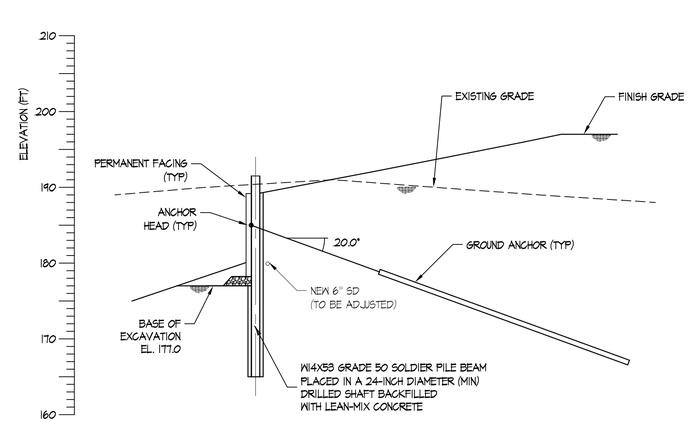
0 10
FEET



P18
SH4.0

CROSS-SECTION AT PILE P18

0 10
FEET



P32
SH4.0

CROSS-SECTION AT PILE P32

0 10
FEET

DESIGN	DRAWN	REVIEW	DATE	REV	DESCRIPTION
CJA	JSS	RJB	6/4/2018	0	PERMIT ISSUE
CJA	JSS	RJB	7/12/2018	1	RESPONSE TO COMMENTS

REGISTERED PROFESSIONAL ENGINEER
16938
OREGON
JULY 14, 2018
CHRIS J. ANDERSON
EXPIRATION DATE: 06-30-20

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SEASIDE HIGH SCHOOL, WALL 'D'

PERMANENT RETAINING WALL
CROSS-SECTIONS

PROJ. NO. 18-28

SHEET NUMBER

SH4.0

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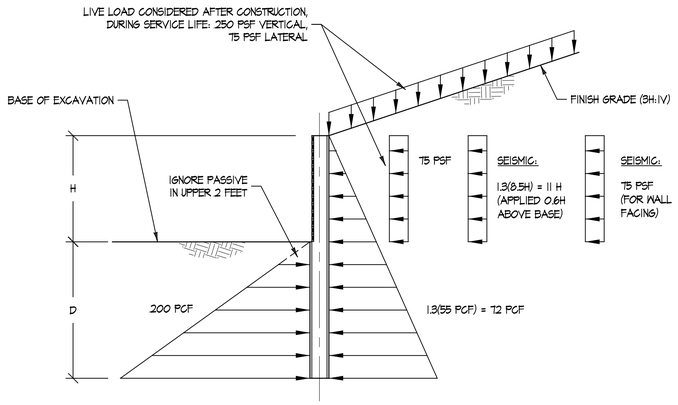


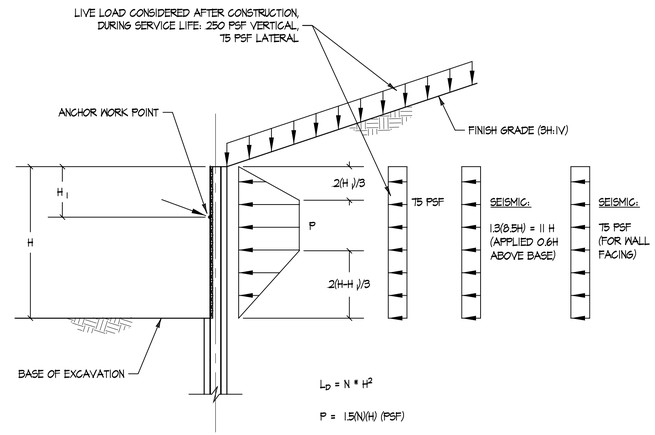
NOTES:

1. BELOW THE EXCAVATION BASE, ACTIVE AND PASSIVE PRESSURES ARE APPLIED TO AN EFFECTIVE PILE WIDTH EQUAL TO 1 AND 2.5 PILE DIAMETERS, RESPECTIVELY.

2. TOE EMBEDMENT IS DETERMINED BY ACHIEVING FORCE AND MOMENT BALANCE THROUGHOUT TOE OF PILE.

1 / SH5.0 WALL DESIGN DIAGRAM CANTILEVERED PILES

NOT TO SCALE



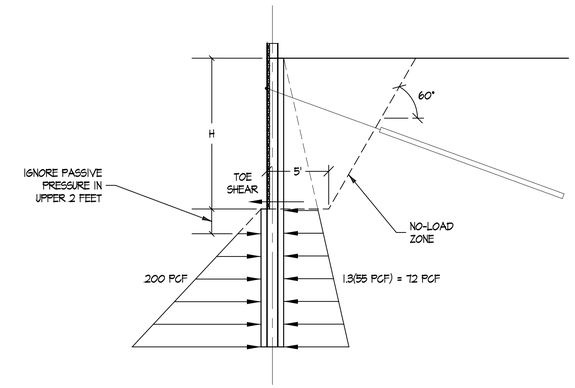
NOTES:

1) EQUIVALENT UNIFORM EARTH PRESSURE FACTOR, "N", EQUAL TO 1.3(0.65)(55 PCF) = 46.5 PCF BASED ON THE CONDITIONS REPORTED IN AND CONTENTS OF THE GEOTECHNICAL REPORT.

2) SHAPE OF DIAGRAM BASED ON PUBLICATION NO. FHWA-IF-99-015, GEOTECHNICAL ENGINEERING CIRCULAR NO. 4, GROUND ANCHORS AND ANCHORED SYSTEMS.

2 / SH5.0 WALL DESIGN DIAGRAM SINGLE-ANCHORED PILES

NOT TO SCALE

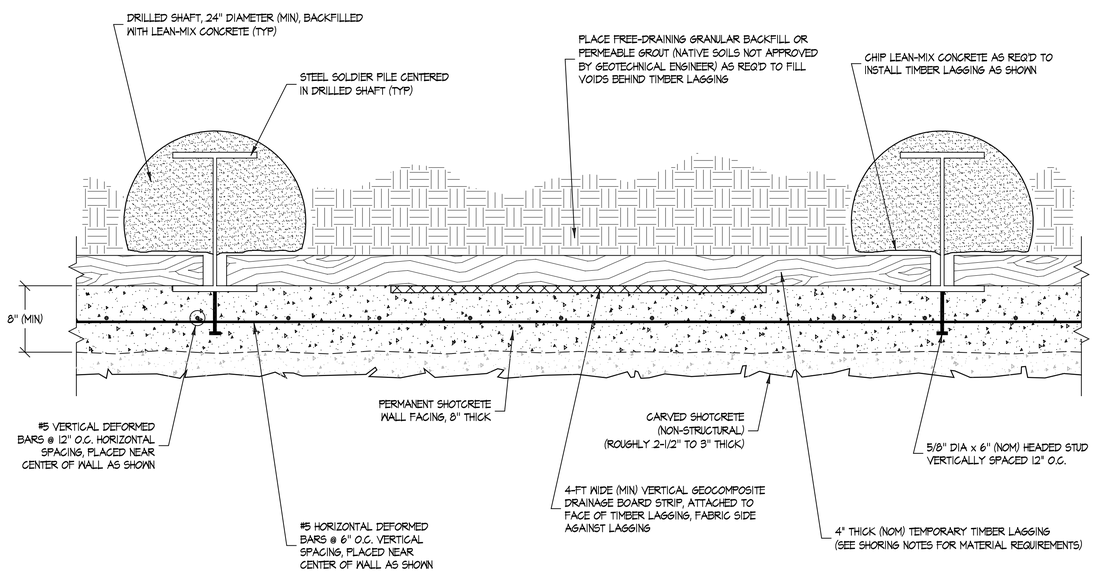


NOTE:

TOE EMBEDMENT DETERMINED BY APPLYING TOE SHEAR, AND APPLYING ACTIVE AND PASSIVE PRESSURES TO AN EFFECTIVE PILE WIDTH EQUAL TO 1 AND 2.5 PILE DIAMETERS, RESPECTIVELY, AND ADJUSTING DEPTH TO BALANCE LATERAL LOADS.

3 / SH5.0 NO-LOAD ZONE & TOE EMBEDMENT DIAGRAM

NOT TO SCALE



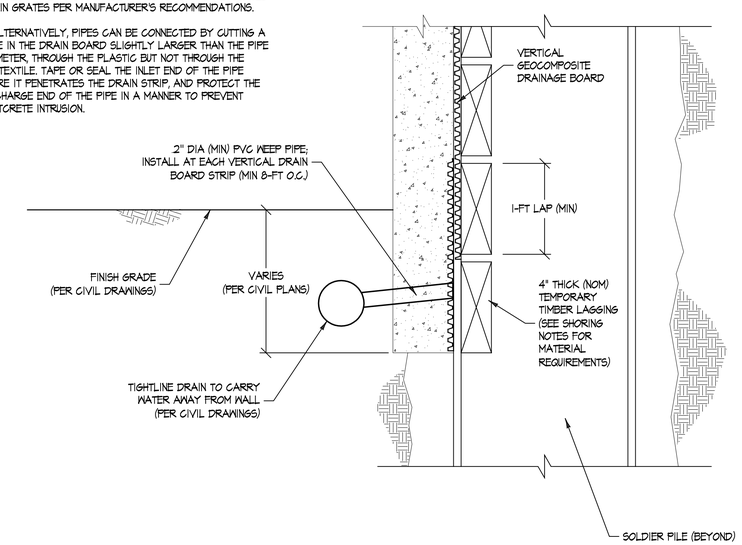
4 / SH5.0 PILE / SHAFT / FACING DETAIL PERMANENT WALL

NOT TO SCALE

NOTES:

1. CONNECT PIPE TO DRAINAGE PANEL USING PREFABRICATED DRAIN GRATES PER MANUFACTURER'S RECOMMENDATIONS.

2. ALTERNATIVELY, PIPES CAN BE CONNECTED BY CUTTING A HOLE IN THE DRAIN BOARD SLIGHTLY LARGER THAN THE PIPE DIAMETER, THROUGH THE PLASTIC BUT NOT THROUGH THE GEOTEXTILE. TAPE OR SEAL THE INLET END OF THE PIPE WHERE IT PENETRATES THE DRAIN STRIP, AND PROTECT THE DISCHARGE END OF THE PIPE IN A MANNER TO PREVENT SHOTCRETE INTRUSION.



5 / SH5.0 BOTTOM OF WALL DETAIL PERMANENT WALL

NOT TO SCALE

DESIGN	DRAWN	REVIEW	DATE	REV	DESCRIPTION
CJA	JSS	RJB	6/4/2018	0	PERMIT ISSUE
CJA	JSS	RJB	7/12/2018	1	RESPONSE TO COMMENTS

REGISTERED PROFESSIONAL ENGINEER 95784 OREGON JULY 14, 2018 CHRIS J. ANDERSCHAT 16938 EXPIRATION DATE: 06-30-20

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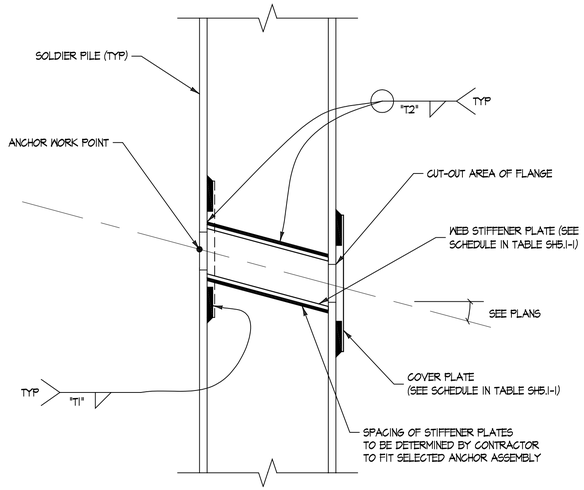
SEASIDE HIGH SCHOOL, WALL 'D'
PERMANENT RETAINING WALL DETAILS

PROJ. NO. 18-28

SHEET NUMBER

SH5.0

D:\Jobs\2018\18-28 (Seaside-OR-CJA)\(shoring)\(permitting)\R1 (20180712)\18228sh05sR1.dwg, 7/12/2018 12:15:37 PM

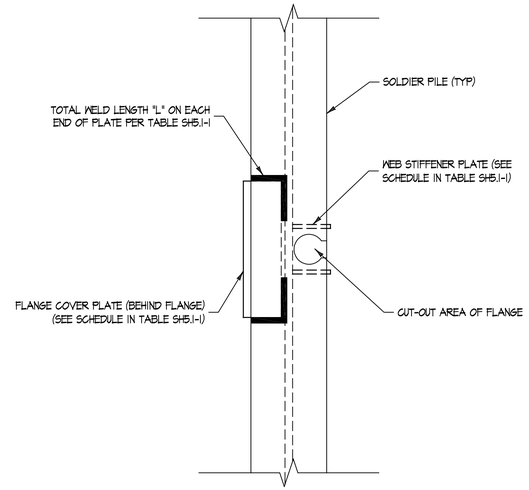


NOTE:

THE CONTRACTOR SHALL SUBMIT A SHOP DRAWING OF THE PROPOSED ANCHOR TO PILE CONNECTION TO THE ENGINEER FOR APPROVAL PRIOR TO FABRICATION.

1 / SH5.1 — ANCHOR TO PILE CONNECTION DETAIL (SIDE VIEW)

NOT TO SCALE



NOTE:

THE CONTRACTOR SHALL SUBMIT A SHOP DRAWING OF THE PROPOSED ANCHOR TO PILE CONNECTION TO THE ENGINEER FOR APPROVAL PRIOR TO FABRICATION.

2 / SH5.1 — ANCHOR TO PILE CONNECTION DETAIL (FRONT VIEW)

NOT TO SCALE

TABLE SH5.1-1
ANCHOR TO PILE CONNECTION SCHEDULE

PILE SECTION	GRADE 36 COVER PLATE DIMENSIONS (IN)	COVER PLATE WELD LENGTH L (IN)	COVER PLATE WELD SIZE T1 (IN)	WEB STIFFENER PLATE DIMENSIONS (IN)	WEB STIFFENER PLATE WELD SIZE T2 (IN)
W14X53	1 X 4 X 38	20	5/16	3/4 X 4 X FULL HT	5/16

NOTE:

WEB STIFFENER PLATES ARE FULL DEPTH, ARE FLUSH AT BEARING END, AND WELDED FULL LENGTH AND ALONG BEARING END ON ONE SIDE ONLY

3 / SH5.1 — ANCHOR TO PILE CONNECTION SCHEDULE

NOT TO SCALE

DESIGN	DRAWN	REVIEW	DATE	REV	DESCRIPTION
CJA	JSS	RJB	6/4/2018	0	PERMIT ISSUE
CJA	JSS	RJB	7/12/2018	1	RESPONSE TO COMMENTS

REGISTERED PROFESSIONAL ENGINEER 95736 OREGON JULY 14, 2018 CHRIS J. MCNICHOLAS

EXPIRATION DATE: 06-30-20

Ground Support PLLC
16932 Woodinville Redmond Rd NE, #210
Woodinville, WA 98072
Ph: (425) 488-1143 Fax: (425) 605-4057

SEASIDE HIGH SCHOOL, WALL 'D'

PERMANENT RETAINING WALL DETAILS

PROJ. NO. 18-28

SHEET NUMBER

SH5.1

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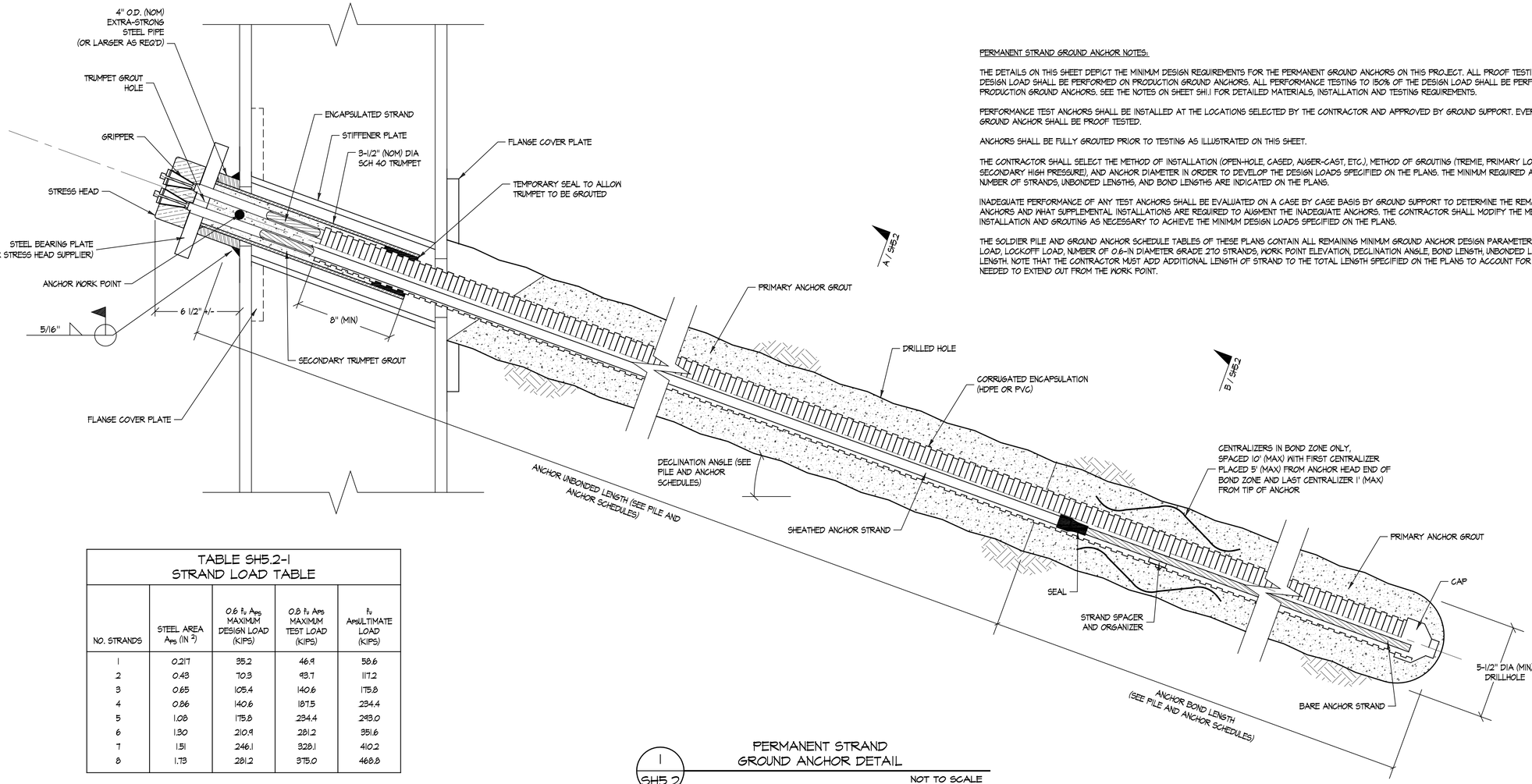


PERMANENT STRAND GROUND ANCHOR NOTES:

THE DETAILS ON THIS SHEET DEPICT THE MINIMUM DESIGN REQUIREMENTS FOR THE PERMANENT GROUND ANCHORS ON THIS PROJECT. ALL PROOF TESTING TO 133% OF THE DESIGN LOAD SHALL BE PERFORMED ON PRODUCTION GROUND ANCHORS. ALL PERFORMANCE TESTING TO 150% OF THE DESIGN LOAD SHALL BE PERFORMED ON PRODUCTION GROUND ANCHORS. SEE THE NOTES ON SHEET SH1.1 FOR DETAILED MATERIALS, INSTALLATION AND TESTING REQUIREMENTS.

PERFORMANCE TEST ANCHORS SHALL BE INSTALLED AT THE LOCATIONS SELECTED BY THE CONTRACTOR AND APPROVED BY GROUND SUPPORT. EVERY PRODUCTION GROUND ANCHOR SHALL BE PROOF TESTED.

ANCHORS SHALL BE FULLY GROUTED PRIOR TO TESTING AS ILLUSTRATED ON THIS SHEET.

THE CONTRACTOR SHALL SELECT THE METHOD OF INSTALLATION (OPEN-HOLE, CASED, AUGER-CAST, ETC.), METHOD OF GROUTING (TREMIE, PRIMARY LOW-PRESSURE, SECONDARY HIGH PRESSURE), AND ANCHOR DIAMETER IN ORDER TO DEVELOP THE DESIGN LOADS SPECIFIED ON THE PLANS. THE MINIMUM REQUIRED ANCHOR DIAMETER, NUMBER OF STRANDS, UNBONDED LENGTHS, AND BOND LENGTHS ARE INDICATED ON THE PLANS.

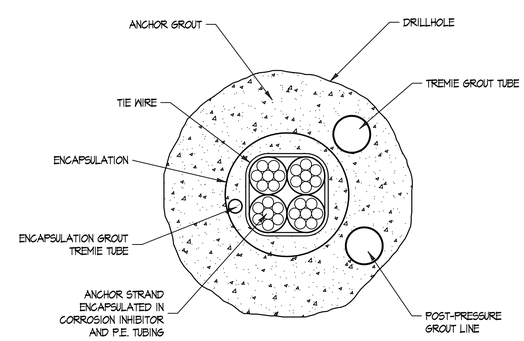
INADEQUATE PERFORMANCE OF ANY TEST ANCHORS SHALL BE EVALUATED ON A CASE BY CASE BASIS BY GROUND SUPPORT TO DETERMINE THE REMAINING VALUE OF THE ANCHORS AND WHAT SUPPLEMENTAL INSTALLATIONS ARE REQUIRED TO AUGMENT THE INADEQUATE ANCHORS. THE CONTRACTOR SHALL MODIFY THE METHOD OF INSTALLATION AND GROUTING AS NECESSARY TO ACHIEVE THE MINIMUM DESIGN LOADS SPECIFIED ON THE PLANS.

THE SOLDIER PILE AND GROUND ANCHOR SCHEDULE TABLES OF THESE PLANS CONTAIN ALL REMAINING MINIMUM GROUND ANCHOR DESIGN PARAMETERS INCLUDING: DESIGN LOAD, LOCKOFF LOAD, NUMBER OF 0.6-IN DIAMETER GRADE 270 STRANDS, WORK POINT ELEVATION, DECLINATION ANGLE, BOND LENGTH, UNBONDED LENGTH, AND TOTAL LENGTH. NOTE THAT THE CONTRACTOR MUST ADD ADDITIONAL LENGTH OF STRAND TO THE TOTAL LENGTH SPECIFIED ON THE PLANS TO ACCOUNT FOR ANY TAILS THAT ARE NEEDED TO EXTEND OUT FROM THE WORK POINT.

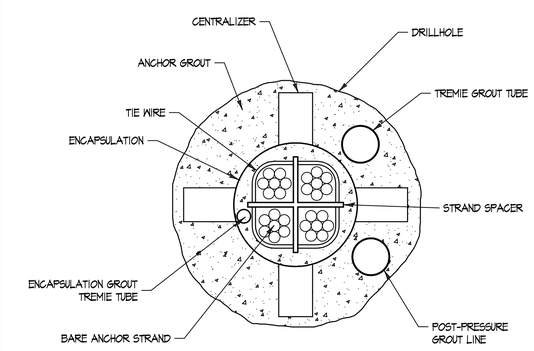
TABLE SH5.2-1
STRAND LOAD TABLE

NO. STRANDS	STEEL AREA A_{PS} (IN ^{2})	$0.6\ f_{pu}\ A_{PS}$ MAXIMUM DESIGN LOAD (KIPS)	$0.8\ f_{pu}\ A_{PS}$ MAXIMUM TEST LOAD (KIPS)	$f_{pu}\ A_{PS}$ ULTIMATE LOAD (KIPS)
1	0.217	35.2	46.9	58.6
2	0.43	70.3	93.7	117.2
3	0.65	105.4	140.6	175.8
4	0.86	140.6	187.5	234.4
5	1.08	175.8	234.4	293.0
6	1.30	210.9	281.2	351.6
7	1.51	246.1	328.1	410.2
8	1.73	281.2	375.0	468.8

1 / SH5.2 PERMANENT STRAND GROUND ANCHOR DETAIL
NOT TO SCALE



A / SH5.2 UNBONDED ZONE TYPICAL SECTION
NOT TO SCALE



B / SH5.2 BONDED ZONE TYPICAL SECTION
NOT TO SCALE

DESIGN	DRAWN	REV/CHK	DATE	REV	DESCRIPTION
CJA	JSS	RJB	6/4/2018	0	PERMIT ISSUE
CJA	JSS	RJB	7/12/2018	1	RESPONSE TO COMMENTS

REGISTERED PROFESSIONAL ENGINEER 95784 OREGON JULY 14, 2018 CHRIS J. MOLSCHLAG
EXPIRATION DATE: 06-30-20

Ground Support PLLC
16932 Woodinville Redmond Rd NE, #210
Woodinville, WA 98072
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SEASIDE HIGH SCHOOL, WALL 'D'
PERMANENT RETAINING WALL DETAILS

PROJ. NO. 18-28
SHEET NUMBER
SH5.2

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Ground Support PLLC

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Woodinville, WA 98072
Phone (425) 488-1143
Fax (425) 605-4057
www.groundsupport.com

July 12, 2018 Our ref: 18-28

Condon-Johnson & Associates, Inc.
9012 South 208th Street
Kent, Washington 98031

ATTENTION: Mr. Spark Johnston

RE: REVISION 1 PERMANENT RETAINING WALL DESIGN SUBMITTAL
NEW HIGH SCHOOL WALL "D"
1801 S. FRANKLIN ST., SEASIDE, OR

Dear Spark:

Ground Support PLLC is pleased to present to Condon-Johnson & Associates, Inc. (CJA) our design calculations and plans for a permanent anchored soldier pile retaining wall with carved shotcrete facing, referred to as Seaside High School Wall D, located in the town of Seaside, Oregon. We previously provided the Revision 0 retaining wall design submittal, dated June 4, 2018, in accordance with our scope of work dated June 1, 2018. The project team reviewed that design submittal and produced a number of review comments. The Revision 1 design plans dated July 12, 2018, and this design report, have been updated to address those review comments. The project background and soil conditions, and the retaining wall design calculations and plans are described in the following sections.

1. PROJECT BACKGROUND AND SOIL CONDITIONS

In preparing the permanent retaining wall design submittal, we have reviewed the following geotechnical report, geotechnical addendum, civil drawings, and electronic drawing files:

- "Report of Geotechnical Engineering Services, Seaside School District Campus, Seaside, Oregon", prepared by GeoDesign, Inc., dated November 20, 2017.

- "Addendum 1, Additional Recommendations for Foundations, Topsoil Placement, and Walls, Seaside New Middle/High School, Seaside, Oregon", prepared by GeoDesign, Inc., dated June 12, 2018.

- The drawings titled: "C5.02, Retaining Wall Enlargement", and "C5.21, Retaining Wall Profiles", of the plan set titled: "New Middle School / High School, Seaside School District", dated April 5, 2018, prepared by KPFF Consulting Engineers.

- The electronic drawing files named: "0377xss.dwg", "p377xsv.dwg", "o377xwt.dwg", "6377-eg.dwg", "6377.fg.dwg", and "0377xwall.dwg", files dated May 17 and May 24, 2018, prepared by KPFF Consulting Engineers.

We understand that the proposed development at the Seaside High School includes the construction of a new Retaining Wall D in order to support a permanent hillside cut up to 16-ft high. The wall is semicircular in shape and roughly 288 feet in length, with about 4,370 square feet of timber-lagged wall face area. The wall is permanent, with a roughly 3H:1V slope immediately behind the wall, 1-ft to 16-ft in permanent height, with a new roadway beyond. The wall is to be supported by thirty-seven cantilevered and single-anchored grade 50 steel soldier piles (W14x30 to W14x82; mostly W14x53), placed in 24" diameter (min) drilled holes, spaced 8-ft on center along the wall, with an 11-ft to 19-ft toe embedment. As the wall height reduces toward each end of the wall, four piles at each end are cantilevered, and the middle twenty-nine piles have one row of anchors consisting of a 53-ft long 4-strand tendon with a design load of 116 kips each. Temporary timber lagging will be installed as the wall is excavated; and a final carved shotcrete wall facing will be built from the bottom up full height. The structural thickness of the wall facing is 8" (min) on the plans, and the carved shotcrete may be applied to this facing at any time in the future and usually involves an additional 3" of shotcrete. Wall face drainage is to be provided by 4-ft wide vertical geocomposite drainage board drips located in each bay between piles, the water from which is to be collected with a weep pipe system through the facing at the bottom of the wall, as shown on our plans. However, the system by which surface water infiltration is controlled/diverted from behind the top of the wall, and the system by which the water from the weep pipes is collected and carried away from the wall, are not part of the scope of our work, and are assumed to be designed by the project civil engineer.

Based on the referenced project geotechnical report, the subsurface conditions at the project site generally consist of colluvium and ancient landslide debris overlying weathered claystone of the Astoria Formation. Localized areas of fill were also encountered. The landslide debris is primarily comprised of decomposed to weathered Astoria Formation soils and some decomposed to weathered intruded pillow basalt. Colluvium and ancient landslide debris comprise most of the soils that will be encountered at the site. Colluvium was generally encountered at shallow depths and is predominantly indistinguishable from the ancient landslide debris. The ancient landslide debris likely includes Astoria Formation soils/sedimentary rock and some intruded decomposed pillow basalt. The colluvium and landslide debris soils generally consist of medium stiff to hard clay with variable fractions of silt, sand, and gravel. Both silt and clay were encountered in the test pit explorations. Loose to very dense sand and gravel were also encountered at the site, particularly in boring B-2 where silty sand and silty gravel from decomposed pillow basalt was encountered to a depth of 74.0 feet BGS. Basalt sand, gravel, cobbles, and boulders, originating from intruded basalt lava flows, were also encountered in a clay or silt matrix resembling the Astoria Formation.

The geotechnical report describes a variety of ground water observations and readings. Slow groundwater seepage was observed in September 2017 in test pits TP-4, TP-9, and TP-12 at depths ranging between 10.0 and 11.0 feet BGS. In May/June 2017 they measured groundwater at depths ranging between 3.0 and 17.0 feet BGS in the following existing vibrating wire piezometers at the site: SI-1 at 25.0 and 55.0 feet BGS; SI-2 at 25.0 and 85.0 feet BGS; SI-3 at 25.0, 55.0, and 85.0 feet BGS; and SI-4 at 70 feet BGS. The piezometers in SI-1 at 25.0 and 55.0 feet BGS and SI-4 at 70.0 feet BGS were monitored until mid-September 2017 during which time the measured groundwater levels fell between 0.5 foot and 2.2 feet BGS. In mid-September 2017 they also measured groundwater at a depth of 10.1 feet BGS in a vibrating wire piezometer installed at 30.0 feet BGS in boring B-1. Pore pressure data from the CPT probes indicate deeper

groundwater at depths of roughly 40 to 55 feet BGS, suggesting groundwater likely perches at the site and takes longer to influence deeper low-permeability soils at the site. Based on all their observations and research, they anticipate water can be encountered at shallow depths below the ground surface, particularly near lower drainage areas and during the wet season. But these shallow sources appear to be localized and/or perched, and not indicative of a true through-going water table. Therefore, for design purposes, the groundwater table is assumed to be located beneath the base of the excavation. Nevertheless, localized wet zones and/or perched pockets and stringers of water-bearing soils may be encountered at any time. The wall face excavation must proceed cautiously to avoid excessive ground loss or disturbance in areas of water bearing soils. Gaps in the timber lagging will provide a free-draining face condition during construction, and sump pumps and trenches may be required at the excavation base to control water inside the site.

2. WALL DESIGN CALCULATIONS AND PLANS

2.1 General Design and Loading Considerations

We have performed the shoring wall design in accordance with the 2012 International Building Code, the 2010 Oregon Structural Specialty Code, generally accepted standards of practice for shoring wall design, and the following design standard: "Publication No. FHWA-IF-99-015, Geotechnical Engineering Circular No. 4, Ground Anchors and Anchored Systems". The retaining wall has a 3H:1V finished slope behind the wall and the adjacent roadway is generally 30-ft and up to 50-ft from the wall. During construction, no significant surcharge will be allowed behind the wall on the slope; and the general contractor has confirmed this is acceptable. Once the wall is built and the final grading completed, a live load surcharge of 250 psf vertical and 75 psf horizontal has been considered behind the wall in order to account for any unanticipated future loading.

The referenced geotechnical report recommends that for seismic design, an additional equivalent uniform loading of 8.5H be included in the permanent design. Considering the 3H:1V backslope and Table 1 in the geotechnical report, this is increased by 1.3 to a value of 11H. In addition, the roughly 12" permanent facing was accounted for with a lateral seismic component of 75 psf. Nevertheless, because the permanent wall height is 3-ft shorter than the temporary wall height, neither the live load surcharge nor the seismic loading were found to be critical to the wall design. Per the IBC, the critical load combination is H + 0.75(L + 0.7E). L is 75 psf; and for a 16-ft high wall, E is 11(16) + 75 = 251 psf. The *added* lateral pressure for the permanent load combination then is 0.75(75 + 0.7(251)) = 188 psf. The 11H component is applied 0.6H from the wall base.

2.2 Cantilevered Pile Design Calculations

For the cantilevered piles at the ends of the walls, the soldier piles must provide cantilevered support for the adjacent lateral earth loads. We have considered six different cantilevered wall heights for each of the temporary and permanent conditions. The temporary heights range from 4 feet up to 9 feet; and the permanent heights are 3-ft shorter, ranging from 1 foot up to 6 feet. The loading diagram for the cantilevered condition is based upon the recommendations contained in the geotechnical report and is illustrated on the shoring plans. Figure A-1 contains a summary of the cantilever analyses, including the required pile design moments and toe embedments. Toe embedment for the cantilever condition is determined by satisfying both force and moment equilibrium in the toe region. Example toe embedment calculations are attached in Figure A-2. In Figure A-1, the upper part of the table contains the analyses for the temporary conditions, while the bottom half contains the analyses for the permanent conditions. Notice that the wall

base shears and moments for the permanent conditions are always less than those for the temporary conditions. Hence, the permanent condition is not critical to the design, even though the live load and seismic pressures are applied.

2.3 Anchored Pile Wall Analysis and Design Calculations

The *anchored* soldier piles along the wall have been designed by considering one design cross-section, with two analyses, designated as P16-19 and P16-16. The design section name refers to the pile number along the wall and the design wall height. Nearly all of the analysis and design calculations are performed with a two-page Excel spreadsheet, and are presented in Figures B-1 and B-2 of Appendix B. The section at pile P16 contains a maximum 19-ft high temporary cut from finish grade down to the base of the excavation. The final permanent wall height of 16 feet is 3-ft less after the finish grade is achieved in front of the wall. Looking at both analyses, it is clear that the temporary analysis (Figure B-1) is more critical, and so we will examine that in detail. The input data is contained in the upper half of the first page of the spreadsheet. This is followed by some intermediate calculations of wall loading and soldier pile forces. The soldier pile beam is then designed in the lower portion of page 1 of Figure B-1. The pile axial load is determined based on the vertical component of the anchor force.

The lateral loading given in the geotechnical report consists of a triangular loading ($K_a\gamma$) of 55 pcf for horizontal backslopes. When the 3H:1V backslope is accounted for, this is increased to (1.3)(55 pcf) = 72 pcf. However, because the wall is anchored with prestressed anchors, the load is locked into the wall and creates a different diagram than a triangular distribution in the soils when they react to the anchor prestressing. And the anchors will also draw load to them as well. Therefore, a more trapezoidal diagram is common in design for this condition. In terms of an equivalent *uniform* loading for this triangular load, it is often considered appropriate to use a FS of 1.3 by considering a loading of $0.65(K_a\gamma)$ = (0.65)(72 pcf) = 46.5 pcf as the equivalent uniform value. See the notes on detail 2 of SH5.0. This *uniform* design earth pressure is then applied to the wall as an unsymmetrical trapezoidal diagram based on the recommendations in the referenced 1999 FHWA publication. The anchor loads, the soldier pile moments, and the toe embedment shear force are all based on the recommendations in the FHWA publication (see Appendix C). The design soldier pile span moments are based on a cantilevered span condition for the portion above the upper anchor row, and a standard moment formula of $wL^2/10$ for continuous spans below the upper anchor level (to account for some degree of continuity over the anchor support levels). The lowest span moment formula is based on $wL^2/11$. Combined bending and axial load design calculations are performed based on the AISC Steel Design Specification. The W14x53 pile has a permanent design ratio of 0.62.

The next two sets of calculations in the middle part of page 2 of Figure B-1 address the pile toe embedment requirements for lateral kickout. Based on the allowable passive and active EFD values of 200 pcf and 72 pcf, applied to 2.5 and 1 pile diameters, respectively; and ignoring the upper 2 feet of the passive zone, horizontal force equilibrium is utilized to determine that the toe shear of 26.1 kips requires a minimum embedment of 11.9 feet. The requirements for vertical load transfer are much less critical. The maximum pile axial load is equal to 39.4 kips. Based on an allowable end-bearing pressure of say 5 ksf, the allowable end-bearing resistance is computed to be 15.7 kips. An allowable skin friction value of say just 1 ksf results in an allowable side resistance of 6.3 k/ft, resulting in a required toe embedment of 3.8 feet. We have specified a 12-ft embedment on the plans.

The last portion of page 2 of Figure B-1 contains the ground anchor design calculations. The first section is fairly self-explanatory where the vertical and horizontal total anchor loads are

determined, and the design loads are selected. The required number of steel strands are computed based on an allowable strand load given by (0.217 in^2)(0.6)(270 ksi) = 35.2 kips per strand for 0.6-inch diameter grade 270 strands. The desired bond lengths are estimated based on a pullout value of roughly 3 kips/foot. (For a 6" diameter drill hole, this is an allowable adhesion of about 1.9 ksf. The anchors will be drilled with 6" casing, but the pressure-capping will expand the grout body to an effective diameter of 8" or more, and produce an even higher adhesion value. For an 8" diameter drill hole, the allowable adhesion is about 1.4 ksf. Either way, our experience in this type of ground indicates these values are achievable, and the testing program will demonstrate this.) The unbonded length calculations are based on a no-load zone defined by a line emanating horizontally back from the toe of the wall a distance of 5 feet, and then upward at 60 degrees from horizontal.

2.4 Anchor Pocket Design Calculations

The connection between the ground anchors and the soldier piles is provided by a standard side pocket detail as shown on the shoring plans. This type of connection and its design methodology have been utilized in the Pacific Northwest continually for over 20 years and we have never experienced any problems in that they have always performed well. The design calculations are contained in Figure C-1 of Appendix C and address the size of the flange plates, web stiffeners, and associated fillet welding requirements.

2.5 Permanent Shotcrete Facing Design Calculations

For the permanent shotcrete wall facing, the facing acts as horizontal lagging and is connected to the face of the soldier piles with headed studs. The design calculations for this system are performed in the spreadsheet in Figure C-2 where the failure modes considered are horizontal flexure, 1-way shear, stud cone shear, and stud tension. It is evident that the 8-inch facing with #5 bars at 6" o.c. and 5/8"x6" headed studs at 12" o.c. is adequate to service the maximum apparent earth pressure of 1397 psf for the permanent condition (includes seismic) (Figure B-2).

See comments on Figure C-2.

2.6 Timber Lagging Design Criteria

Based on the expected ground conditions, the typical pile spacing, and the excavation depths, the lagging thickness recommended by the referenced 1999 FHWA publication is interpolated to be about 3 inches. This is completely in line with experience and precedent in the area for similar projects and depths. These guidelines are reproduced in Appendix C for reference. Note that 4" timber lagging has been used for temporary purposes in the Greater Portland region for excavations up to 40 to 50 feet deep. Yet, if "calculations" are performed using the maximum design wall pressure and a reduction of only 50% on moments, 4" lagging could not have been used. Nor could it be used on this 19-ft high wall. Therefore, we have gone with the FHWA guideline which is rooted in a large amount of experience and precedent.

2.7 Corrosion Protection Considerations

The anchors are protected by the standard sheathing system as shown on the plans. The connection is also permanently protected through the careful pipe trumpet attachment and grouting and the anchor head will be embedded in the shotcrete wall. These are all fairly standard provisions for permanent ground anchors. The soldier piles are placed in an alkaline environment with the lean-mix concrete; and where that is removed, the shotcrete is encapsulating them. Even so, the piles have been over-designed, having demand-to-supply ratios of anywhere from 0.22 to

Since lagging is temporary, design is means and methods and it is the designers/contractors risk to use lagging that does not calc out.

0.62, and therefore having roughly 35% to 50% strength reserve to allow for a corrosion thickness to develop if need be. One alternative to this would be to use lighter beams designed with no margin in them, and then paint the pile steel.

3. WALL DESIGN PLANS

Our design plans consist of eleven (11) drawing sheets bound separately from this letter report. The number and title for each sheet are indicated as follows:

SH1.0-1.2	Cover Sheet and Notes
SH2.0-2.1	Shoring Plan
SH3.0-3.1	Wall Elevation
SH4.0	Cross-Sections
SH5.0-5.2	Details

4. CLOSURE

We trust that the permanent retaining wall design submittal is in accordance with your needs at this time. We have enjoyed working with you on this project. If you have any questions please call us anytime at 425-488-1143 or 425-922-1501.

Sincerely,

GROUND SUPPORT PLLC

Chris J. Wolschlag, S.E., Ph.D.
Partner

seaside report r1 071218.docx

REGISTERED PROFESSIONAL ENGINEER 58784 OREGON JULY 14, 1980 CHRIS J. WOLSCHLAG 7/12/18

APPENDIX A

CANTILEVERED WALL DESIGN CALCULATIONS

CANTILEVER ANALYSIS SUMMARY H L E

Case	Vertical Height H (ft)	Passive Diameter B (ft)	Pile Spacing S (ft)	Soil Self-Weight EFDA (pcf)	Live Lateral Surch (psf)	Seismic Lateral Surch (psf)	Stress Increase Factor	Top Shear (lb/ft)	Factored Upper EFDP (pcf)	Factored Lower EFDP (pcf)	Ignore Depth (ft)	Change Depth (ft)	Base Shear (lb)	Base Moment (ft-lb)	Limiting Moment Factor	Req'd D (ft)	Embed Moment (ft-lb)
T-9-FT	9.0	2.0	8.0	72	0	0	1.00	0	200	200	2	10	23,166	69,498	5.0	19.2	241,859
T-4-FT	4.0	2.0	8.0	72	0	0	1.00	0	200	200	2	10	4,576	6,101	5.0	9.3	25,815
T-5-FT	5.0	2.0	8.0	72	0	0	1.00	0	200	200	2	10	7,150	11,917	5.0	11.2	46,678
T-6-FT	6.0	2.0	8.0	72	0	0	1.00	0	200	200	2	10	10,296	20,592	5.0	13.2	76,642
T-7-FT	7.0	2.0	8.0	72	0	0	1.00	0	200	200	2	10	14,014	32,699	5.0	15.2	118,227
T-8-FT	8.0	2.0	8.0	72	0	0	1.00	0	200	200	2	10	18,304	48,811	5.0	17.2	172,517
T-9-FT	9.0	2.0	8.0	72	0	0	1.00	0	200	200	2	10	23,166	69,498	5.0	19.2	241,859
P-1-FT	1.0	2.0	8.0	72	75	84	1.00	0	200	200	2	10	1,087	531	5.0		
P-2-FT	2.0	2.0	8.0	72	75	92	1.00	0	200	200	2	10	2,817	2,590	5.0		
P-3-FT	3.0	2.0	8.0	72	75	101	1.00	0	200	200	2	10	5,190	6,878	5.0		
P-4-FT	4.0	2.0	8.0	72	75	109	1.00	0	200	200	2	10	8,207	14,096	5.0		
P-5-FT	5.0	2.0	8.0	72	75	118	1.00	0	200	200	2	10	11,868	24,944	5.0		
P-6-FT	6.0	2.0	8.0	72	75	126	1.00	0	200	200	2	10	16,171	40,123	5.0		

Case	Computed Embed Moment Factor	Design Moment M (ft-k)	Steel Section	Steel Grade (ksi)	Pipe O.D. (in)	Wall Thick (in)	Pipe I.D. (in)	Section Modulus (in3)	fB (ksi)	Factored FB (ksi)	Design Ratio	Design Embed D (ft)
T-4-FT	4.2	25.8	W14x30	50			0.000	42.0	7.4	33.0	0.22	9.5
T-5-FT	3.9	46.7	W14x30	50			0.000	42.0	13.3	33.0	0.40	11.5
T-6-FT	3.7	76.6	W14x30	50			0.000	42.0	21.9	33.0	0.66	13.5
T-7-FT	3.6	118.2	W14x43	50			0.000	62.7	22.6	33.0	0.69	15.5
T-8-FT	3.5	172.5	W14x61	50			0.000	92.2	22.5	33.0	0.68	17.5
T-9-FT	3.5	241.9	W14x82	50			0.000	123.0	23.6	33.0	0.72	19.5
P-1-FT	0.0	2.7	W14x30	50			0.000	42.0	0.8	33.0	0.02	
P-2-FT	0.0	13.0	W14x30	50			0.000	42.0	3.7	33.0	0.11	
P-3-FT	0.0	34.4	W14x30	50			0.000	42.0	9.8	33.0	0.30	
P-4-FT	0.0	70.5	W14x43	50			0.000	62.7	13.5	33.0	0.41	
P-5-FT	0.0	124.7	W14x61	50			0.000	92.2	16.2	33.0	0.49	
P-6-FT	0.0	200.6	W14x82	50			0.000	123.0	19.6	33.0	0.59	

In lower half of tables, permanent heights are considered, and base shear and moment based on critical load combination of H + 0.75(L + 0.7E); by inspection these are less than the temporary case.

Live load during construction will be restricted to zero; permanent live load is 250 psf vertical, 75 psf horizontal.

Seismic loading is 8.5H per Geotechnical Report, plus 75 psf to account for wall facing.

FIGURE A-1

Cantilever Analysis Summary

CANTILEVER -TOE EMBEDMENT CALCULATIONS

General Notes
Discrete model of embeded pile wall with shear and moment acting at top of embedment.
D = Depth of Embedment.
Z = Distance above pile tip that transition from passive to active, and vice versa, begins.
V = Pile shear force at top of embedment.
M = Pile moment at top of embedment.
Two analysis models available for passive zone: (1) variable pile width model; (2) fixed pile width model.
Variable width model applies active over full pile spacing, and passive over variable width.
Variable width varies linearly from 1 pile diameter at grade, to the pile spacing at a specified critical depth.
Fixed width model applies the active and passive components to a specified number of pile diameters on each side.
Analysis proceeds through iteration on assumed values of D & Z until force and moment equilibrium are satisfied.

General Input Data	
Pile Shear Force @ Top of Embedment, V (F)	23,166
Pile Moment @ Top of Embedment, M (F-L)	69,498
Pile Width or Diameter, B (L)	2.00
Horizontal Pile Spacing, S (L)	8.00

Pile Width Model Input Data		
Pile Model Type	(0 for variable pile width mode; 1 for fixed pile width model.)	1
Critical Depth (L)	(Only used for variable pile width model.)	8.0
Number of Resisting Pile Diameters	(Only used for fixed pile width model.)	2.5
Number of Driving Pile Diameters	(Only used for fixed pile width model.)	1.0

Embedment Zone Earth Pressure Input Data

Resisting Side			Driving Side		
Depth (L)	Allow Passive Press (F/L/L)	Active Press (F/L/L)	Depth (L)	Allow Passive Press (F/L/L)	Active Press (F/L/L)
0.0	0	0	0.0	1,800	644
2.0	0	0	10.0	3,800	1,359
2.0	400	143	10.0	3,800	1,359
10.0	2,000	715	100.0	21,800	7,794
10.0	2,000	715			
100.0	20,000	7,150			

Iteration Parameters	
Assumed Depth of Embedment, D (L)	19.19
Assumed Transition Point, Z (L)	6.49
Computed Toe Shear (F)	0
Computed Toe Moment (F-L)	0

FIGURE A-2 (Page 1 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
0.00	2.00	5.00	0	0	1,800	644	0	1,287	-1,287	23,166	69,498
0.04	2.00	5.00	0	0	1,808	646	0	1,292	-1,292	23,215	70,388
0.08	2.00	5.00	0	0	1,815	649	0	1,298	-1,298	23,265	71,280
0.12	2.00	5.00	0	0	1,823	652	0	1,303	-1,303	23,315	72,174
0.15	2.00	5.00	0	0	1,831	654	0	1,309	-1,309	23,365	73,070
0.19	2.00	5.00	0	0	1,838	657	0	1,314	-1,314	23,416	73,967
0.23	2.00	5.00	0	0	1,846	660	0	1,320	-1,320	23,466	74,867
0.27	2.00	5.00	0	0	1,854	663	0	1,325	-1,325	23,517	75,769
0.31	2.00	5.00	0	0	1,861	665	0	1,331	-1,331	23,568	76,672
0.35	2.00	5.00	0	0	1,869	668	0	1,336	-1,336	23,619	77,578
0.38	2.00	5.00	0	0	1,877	671	0	1,342	-1,342	23,670	78,485
0.42	2.00	5.00	0	0	1,884	674	0	1,347	-1,347	23,722	79,394
0.46	2.00	5.00	0	0	1,892	676	0	1,353	-1,353	23,774	80,306
0.50	2.00	5.00	0	0	1,900	679	0	1,358	-1,358	23,826	81,219
0.54	2.00	5.00	0	0	1,907	682	0	1,364	-1,364	23,878	82,135
0.58	2.00	5.00	0	0	1,915	685	0	1,369	-1,369	23,931	83,052
0.61	2.00	5.00	0	0	1,923	687	0	1,375	-1,375	23,983	83,972
0.65	2.00	5.00	0	0	1,930	690	0	1,380	-1,380	24,036	84,893
0.69	2.00	5.00	0	0	1,938	693	0	1,386	-1,386	24,089	85,817
0.73	2.00	5.00	0	0	1,946	696	0	1,391	-1,391	24,142	86,742
0.77	2.00	5.00	0	0	1,954	698	0	1,397	-1,397	24,196	87,670
0.81	2.00	5.00	0	0	1,961	701	0	1,402	-1,402	24,250	88,599
0.84	2.00	5.00	0	0	1,969	704	0	1,408	-1,408	24,304	89,531
0.88	2.00	5.00	0	0	1,977	707	0	1,413	-1,413	24,358	90,465
0.92	2.00	5.00	0	0	1,984	709	0	1,419	-1,419	24,412	91,401
0.96	2.00	5.00	0	0	1,992	712	0	1,424	-1,424	24,467	92,339
1.00	2.00	5.00	0	0	2,000	715	0	1,430	-1,430	24,521	93,279
1.04	2.00	5.00	0	0	2,007	718	0	1,435	-1,435	24,576	94,221
1.07	2.00	5.00	0	0	2,015	720	0	1,441	-1,441	24,632	95,165
1.11	2.00	5.00	0	0	2,023	723	0	1,446	-1,446	24,687	96,112
1.15	2.00	5.00	0	0	2,030	726	0	1,452	-1,452	24,743	97,060
1.19	2.00	5.00	0	0	2,038	729	0	1,457	-1,457	24,798	98,011
1.23	2.00	5.00	0	0	2,046	731	0	1,463	-1,463	24,854	98,964
1.27	2.00	5.00	0	0	2,053	734	0	1,468	-1,468	24,911	99,918
1.30	2.00	5.00	0	0	2,061	737	0	1,474	-1,474	24,967	100,876
1.34	2.00	5.00	0	0	2,069	740	0	1,479	-1,479	25,024	101,835
1.38	2.00	5.00	0	0	2,076	742	0	1,485	-1,485	25,081	102,796
1.42	2.00	5.00	0	0	2,084	745	0	1,490	-1,490	25,138	103,760
1.46	2.00	5.00	0	0	2,092	748	0	1,496	-1,496	25,195	104,726
1.50	2.00	5.00	0	0	2,099	751	0	1,501	-1,501	25,253	105,694
1.54	2.00	5.00	0	0	2,107	753	0	1,507	-1,507	25,310	106,664
1.57	2.00	5.00	0	0	2,115	756	0	1,512	-1,512	25,368	107,637
1.61	2.00	5.00	0	0	2,122	759	0	1,518	-1,518	25,426	108,611
1.65	2.00	5.00	0	0	2,130	761	0	1,523	-1,523	25,485	109,588
1.69	2.00	5.00	0	0	2,138	764	0	1,528	-1,528	25,543	110,568
1.73	2.00	5.00	0	0	2,145	767	0	1,534	-1,534	25,602	111,549
1.77	2.00	5.00	0	0	2,153	770	0	1,539	-1,539	25,661	112,533

FIGURE A-2 (Page 2 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
1.80	2.00	5.00	0	0	2,161	772	0	1,545	-1,545	25,720	113,519
1.84	2.00	5.00	0	0	2,168	775	0	1,550	-1,550	25,780	114,507
1.88	2.00	5.00	0	0	2,176	778	0	1,556	-1,556	25,839	115,498
1.92	2.00	5.00	0	0	2,184	781	0	1,561	-1,561	25,899	116,490
1.96	2.00	5.00	0	0	2,191	783	0	1,567	-1,567	25,959	117,485
2.00	2.00	5.00	0	0	2,199	786	0	1,572	-1,572	26,019	118,483
2.03	2.00	5.00	407	145	2,207	789	2,034	1,578	-1,578	26,041	119,482
2.07	2.00	5.00	414	148	2,214	792	2,072	1,583	-1,583	26,023	120,481
2.11	2.00	5.00	422	151	2,222	794	2,111	1,589	-1,589	26,003	121,480
2.15	2.00	5.00	430	154	2,230	797	2,149	1,594	-1,594	25,982	122,477
2.19	2.00	5.00	438	156	2,238	800	2,188	1,600	-1,600	25,961	123,474
2.23	2.00	5.00	445	159	2,245	803	2,226	1,605	-1,605	25,937	124,470
2.26	2.00	5.00	453	162	2,253	805	2,264	1,611	-1,611	25,913	125,465
2.30	2.00	5.00	461	165	2,261	808	2,303	1,616	-1,616	25,887	126,459
2.34	2.00	5.00	468	167	2,268	811	2,341	1,622	-1,622	25,860	127,452
2.38	2.00	5.00	476	170	2,276	814	2,379	1,627	-1,627	25,832	128,444
2.42	2.00	5.00	484	173	2,284	816	2,418	1,633	-1,633	25,802	129,435
2.46	2.00	5.00	491	176	2,291	819	2,456	1,638	-1,638	25,772	130,424
2.49	2.00	5.00	499	178	2,299	822	2,495	1,644	-1,644	25,740	131,413
2.53	2.00	5.00	507	181	2,307	825	2,533	1,649	-1,649	25,706	132,400
2.57	2.00	5.00	514	184	2,314	827	2,571	1,655	-1,655	25,672	133,386
2.61	2.00	5.00	522	187	2,322	830	2,610	1,660	-1,660	25,636	134,371
2.65	2.00	5.00	530	189	2,330	833	2,648	1,666	-1,666	25,599	135,354
2.69	2.00	5.00	537	192	2,337	836	2,687	1,671	-1,671	25,561	136,335
2.72	2.00	5.00	545	195	2,345	838	2,725	1,677	-1,677	25,521	137,316
2.76	2.00	5.00	553	198	2,353	841	2,763	1,682	-1,682	25,480	138,294
2.80	2.00	5.00	560	200	2,360	844	2,802	1,688	-1,688	25,438	139,271
2.84	2.00	5.00	568	203	2,368	847	2,840	1,693	-1,693	25,395	140,247
2.88	2.00	5.00	576	206	2,376	849	2,878	1,699	-1,699	25,350	141,221
2.92	2.00	5.00	583	209	2,383	852	2,917	1,704	-1,704	25,304	142,193
2.96	2.00	5.00	591	211	2,391	855	2,955	1,710	-1,710	25,257	143,163
2.99	2.00	5.00	599	214	2,399	858	2,994	1,715	-1,715	25,208	144,131
3.03	2.00	5.00	606	217	2,406	860	3,032	1,721	-1,721	25,159	145,098
3.07	2.00	5.00	614	220	2,414	863	3,070	1,726	-1,726	25,108	146,062
3.11	2.00	5.00	622	222	2,422	866	3,109	1,732	-1,732	25,056	147,025
3.15	2.00	5.00	629	225	2,429	869	3,147	1,737	-1,737	25,002	147,986
3.19	2.00	5.00	637	228	2,437	871	3,185	1,743	-1,743	24,947	148,944
3.22	2.00	5.00	645	231	2,445	874	3,224	1,748	-1,748	24,891	149,901
3.26	2.00	5.00	652	233	2,452	877	3,262	1,753	-1,753	24,834	150,855
3.30	2.00	5.00	660	236	2,460	879	3,301	1,759	-1,759	24,776	151,807
3.34	2.00	5.00	668	239	2,468	882	3,339	1,764	-1,764	24,716	152,756
3.38	2.00	5.00	675	241	2,475	885	3,377	1,770	-1,770	24,655	153,704
3.42	2.00	5.00	683	244	2,483	888	3,416	1,775	-1,775	24,592	154,649
3.45	2.00	5.00	691	247	2,491	890	3,454	1,781	-1,781	24,529	155,592
3.49	2.00	5.00	698	250	2,498	893	3,492	1,786	-1,786	24,464	156,532
3.53	2.00	5.00	706	252	2,506	896	3,531	1,792	-1,792	24,398	157,469
3.57	2.00	5.00	714	255	2,514	899	3,569	1,797	-1,797	24,330	158,404

FIGURE A-2 (Page 3 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
3.61	2.00	5.00	722	258	2,522	901	3,608	1,803	-1,803	24,262	159,337
3.65	2.00	5.00	729	261	2,529	904	3,646	1,808	-1,808	24,192	160,267
3.68	2.00	5.00	737	263	2,537	907	3,684	1,814	-1,814	24,121	161,194
3.72	2.00	5.00	745	266	2,545	910	3,723	1,819	-1,819	24,048	162,118
3.76	2.00	5.00	752	269	2,552	912	3,761	1,825	-1,825	23,975	163,040
3.80	2.00	5.00	760	272	2,560	915	3,800	1,830	-1,830	23,900	163,958
3.84	2.00	5.00	768	274	2,568	918	3,838	1,836	-1,836	23,824	164,874
3.88	2.00	5.00	775	277	2,575	921	3,876	1,841	-1,841	23,746	165,787
3.91	2.00	5.00	783	280	2,583	923	3,915	1,847	-1,847	23,667	166,697
3.95	2.00	5.00	791	283	2,591	926	3,953	1,852	-1,852	23,587	167,604
3.99	2.00	5.00	798	285	2,598	929	3,991	1,858	-1,858	23,506	168,507
4.03	2.00	5.00	806	288	2,606	932	4,030	1,863	-1,863	23,424	169,408
4.07	2.00	5.00	814	291	2,614	934	4,068	1,869	-1,869	23,340	170,305
4.11	2.00	5.00	821	294	2,621	937	4,107	1,874	-1,874	23,255	171,199
4.14	2.00	5.00	829	296	2,629	940	4,145	1,880	-1,880	23,168	172,090
4.18	2.00	5.00	837	299	2,637	943	4,183	1,885	-1,885	23,081	172,978
4.22	2.00	5.00	844	302	2,644	945	4,222	1,891	-1,891	22,992	173,862
4.26	2.00	5.00	852	305	2,652	948	4,260	1,896	-1,896	22,902	174,742
4.30	2.00	5.00	860	307	2,660	951	4,298	1,902	-1,902	22,811	175,620
4.34	2.00	5.00	867	310	2,667	954	4,337	1,907	-1,907	22,718	176,493
4.38	2.00	5.00	875	313	2,675	956	4,375	1,913	-1,913	22,624	177,363
4.41	2.00	5.00	883	316	2,683	959	4,414	1,918	-1,918	22,529	178,230
4.45	2.00	5.00	890	318	2,690	962	4,452	1,924	-1,924	22,433	179,093
4.49	2.00	5.00	898	321	2,698	965	4,490	1,929	-1,929	22,335	179,952
4.53	2.00	5.00	906	324	2,706	967	4,529	1,935	-1,935	22,236	180,807
4.57	2.00	5.00	913	327	2,713	970	4,567	1,940	-1,940	22,136	181,659
4.61	2.00	5.00	921	329	2,721	973	4,605	1,946	-1,946	22,034	182,506
4.64	2.00	5.00	929	332	2,729	976	4,644	1,951	-1,951	21,932	183,350
4.68	2.00	5.00	936	335	2,736	978	4,682	1,957	-1,957	21,828	184,190
4.72	2.00	5.00	944	338	2,744	981	4,721	1,962	-1,962	21,722	185,025
4.76	2.00	5.00	952	340	2,752	984	4,759	1,968	-1,968	21,616	185,857
4.80	2.00	5.00	959	343	2,759	987	4,797	1,973	-1,973	21,508	186,684
4.84	2.00	5.00	967	346	2,767	989	4,836	1,979	-1,979	21,399	187,508
4.87	2.00	5.00	975	349	2,775	992	4,874	1,984	-1,984	21,289	188,327
4.91	2.00	5.00	983	351	2,783	995	4,913	1,989	-1,989	21,177	189,142
4.95	2.00	5.00	990	354	2,790	997	4,951	1,995	-1,995	21,064	189,952
4.99	2.00	5.00	998	357	2,798	1,000	4,989	2,000	-2,000	20,950	190,759
5.03	2.00	5.00	1,006	359	2,806	1,003	5,028	2,006	-2,006	20,835	191,561
5.07	2.00	5.00	1,013	362	2,813	1,006	5,066	2,011	-2,011	20,718	192,358
5.10	2.00	5.00	1,021	365	2,821	1,008	5,104	2,017	-2,017	20,601	193,151
5.14	2.00	5.00	1,029	368	2,829	1,011	5,143	2,022	-2,022	20,481	193,939
5.18	2.00	5.00	1,036	370	2,836	1,014	5,181	2,028	-2,028	20,361	194,723
5.22	2.00	5.00	1,044	373	2,844	1,017	5,220	2,033	-2,033	20,239	195,502
5.26	2.00	5.00	1,052	376	2,852	1,019	5,258	2,039	-2,039	20,116	196,276
5.30	2.00	5.00	1,059	379	2,859	1,022	5,296	2,044	-2,044	19,992	197,046
5.33	2.00	5.00	1,067	381	2,867	1,025	5,335	2,050	-2,050	19,867	197,811
5.37	2.00	5.00	1,075	384	2,875	1,028	5,373	2,055	-2,055	19,740	198,571

FIGURE A-2 (Page 4 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
5.41	2.00	5.00	1,082	387	2,882	1,030	5,411	2,061	-2,061	19,612	199,326
5.45	2.00	5.00	1,090	390	2,890	1,033	5,450	2,066	-2,066	19,483	200,076
5.49	2.00	5.00	1,098	392	2,898	1,036	5,488	2,072	-2,072	19,352	200,822
5.53	2.00	5.00	1,105	395	2,905	1,039	5,527	2,077	-2,077	19,221	201,562
5.56	2.00	5.00	1,113	398	2,913	1,041	5,565	2,083	-2,083	19,088	202,297
5.60	2.00	5.00	1,121	401	2,921	1,044	5,603	2,088	-2,088	18,953	203,027
5.64	2.00	5.00	1,128	403	2,928	1,047	5,642	2,094	-2,094	18,818	203,752
5.68	2.00	5.00	1,136	406	2,936	1,050	5,680	2,099	-2,099	18,681	204,471
5.72	2.00	5.00	1,144	409	2,944	1,052	5,718	2,105	-2,105	18,543	205,186
5.76	2.00	5.00	1,151	412	2,951	1,055	5,757	2,110	-2,110	18,404	205,895
5.80	2.00	5.00	1,159	414	2,959	1,058	5,795	2,116	-2,116	18,263	206,598
5.83	2.00	5.00	1,167	417	2,967	1,061	5,834	2,121	-2,121	18,121	207,297
5.87	2.00	5.00	1,174	420	2,974	1,063	5,872	2,127	-2,127	17,978	207,989
5.91	2.00	5.00	1,182	423	2,982	1,066	5,910	2,132	-2,132	17,834	208,677
5.95	2.00	5.00	1,190	425	2,990	1,069	5,949	2,138	-2,138	17,688	209,358
5.99	2.00	5.00	1,197	428	2,997	1,072	5,987	2,143	-2,143	17,541	210,034
6.03	2.00	5.00	1,205	431	3,005	1,074	6,025	2,149	-2,149	17,393	210,705
6.06	2.00	5.00	1,213	434	3,013	1,077	6,064	2,154	-2,154	17,244	211,369
6.10	2.00	5.00	1,220	436	3,020	1,080	6,102	2,160	-2,160	17,093	212,028
6.14	2.00	5.00	1,228	439	3,028	1,083	6,141	2,165	-2,165	16,941	212,681
6.18	2.00	5.00	1,236	442	3,036	1,085	6,179	2,171	-2,171	16,788	213,328
6.22	2.00	5.00	1,243	445	3,043	1,088	6,217	2,176	-2,176	16,633	213,970
6.26	2.00	5.00	1,251	447	3,051	1,091	6,256	2,182	-2,182	16,478	214,605
6.29	2.00	5.00	1,259	450	3,059	1,094	6,294	2,187	-2,187	16,321	215,235
6.33	2.00	5.00	1,267	453	3,067	1,096	6,333	2,193	-2,193	16,162	215,858
6.37	2.00	5.00	1,274	456	3,074	1,099	6,371	2,198	-2,198	16,003	216,475
6.41	2.00	5.00	1,282	458	3,082	1,102	6,409	2,204	-2,204	15,842	217,086
6.45	2.00	5.00	1,290	461	3,090	1,105	6,448	2,209	-2,209	15,680	217,691
6.49	2.00	5.00	1,297	464	3,097	1,107	6,486	2,215	-2,215	15,517	218,290
6.52	2.00	5.00	1,305	466	3,105	1,110	6,524	2,220	-2,220	15,352	218,882
6.56	2.00	5.00	1,313	469	3,113	1,113	6,563	2,225	-2,225	15,186	219,468
6.60	2.00	5.00	1,320	472	3,120	1,115	6,601	2,231	-2,231	15,019	220,048
6.64	2.00	5.00	1,328	475	3,128	1,118	6,640	2,236	-2,236	14,851	220,621
6.68	2.00	5.00	1,336	477	3,136	1,121	6,678	2,242	-2,242	14,681	221,188
6.72	2.00	5.00	1,343	480	3,143	1,124	6,716	2,247	-2,247	14,510	221,748
6.75	2.00	5.00	1,351	483	3,151	1,126	6,755	2,253	-2,253	14,338	222,302
6.79	2.00	5.00	1,359	486	3,159	1,129	6,793	2,258	-2,258	14,165	222,849
6.83	2.00	5.00	1,366	488	3,166	1,132	6,831	2,264	-2,264	13,990	223,389
6.87	2.00	5.00	1,374	491	3,174	1,135	6,870	2,269	-2,269	13,814	223,922
6.91	2.00	5.00	1,382	494	3,182	1,137	6,908	2,275	-2,275	13,637	224,449
6.95	2.00	5.00	1,389	497	3,189	1,140	6,947	2,280	-2,280	13,459	224,969
6.98	2.00	5.00	1,397	499	3,197	1,143	6,985	2,286	-2,286	13,279	225,482
7.02	2.00	5.00	1,405	502	3,205	1,146	7,023	2,291	-2,291	13,098	225,988
7.06	2.00	5.00	1,412	505	3,212	1,148	7,062	2,297	-2,297	12,916	226,488
7.10	2.00	5.00	1,420	508	3,220	1,151	7,100	2,302	-2,302	12,732	226,980
7.14	2.00	5.00	1,428	510	3,228	1,154	7,138	2,308	-2,308	12,547	227,465
7.18	2.00	5.00	1,435	513	3,235	1,157	7,177	2,313	-2,313	12,361	227,943

FIGURE A-2 (Page 5 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
7.22	2.00	5.00	1,443	516	3,243	1,159	7,215	2,319	-2,319	12,174	228,414
7.25	2.00	5.00	1,451	519	3,251	1,162	7,254	2,324	-2,324	11,986	228,877
7.29	2.00	5.00	1,458	521	3,258	1,165	7,292	2,330	-2,330	11,796	229,334
7.33	2.00	5.00	1,466	524	3,266	1,168	7,330	2,335	-2,335	11,605	229,783
7.37	2.00	5.00	1,474	527	3,274	1,170	7,369	2,341	-2,341	11,412	230,224
7.41	2.00	5.00	1,481	530	3,281	1,173	7,407	2,346	-2,346	11,219	230,659
7.45	2.00	5.00	1,489	532	3,289	1,176	7,446	2,352	-2,352	11,024	231,085
7.48	2.00	5.00	1,497	535	3,297	1,179	7,484	2,357	-2,357	10,828	231,505
7.52	2.00	5.00	1,504	538	3,304	1,181	7,522	2,363	-2,363	10,630	231,917
7.56	2.00	5.00	1,512	541	3,312	1,184	7,561	2,368	-2,368	10,432	232,321
7.60	2.00	5.00	1,520	543	3,320	1,187	7,599	2,374	-2,374	10,232	232,717
7.64	2.00	5.00	1,527	546	3,327	1,190	7,637	2,379	-2,379	10,031	233,106
7.68	2.00	5.00	1,535	549	3,335	1,192	7,676	2,385	-2,385	9,828	233,487
7.71	2.00	5.00	1,543	552	3,343	1,195	7,714	2,390	-2,390	9,624	233,860
7.75	2.00	5.00	1,551	554	3,351	1,198	7,753	2,396	-2,396	9,420	234,226
7.79	2.00	5.00	1,558	557	3,358	1,201	7,791	2,401	-2,401	9,213	234,583
7.83	2.00	5.00	1,566	560	3,366	1,203	7,829	2,407	-2,407	9,006	234,933
7.87	2.00	5.00	1,574	563	3,374	1,206	7,868	2,412	-2,412	8,797	235,275
7.91	2.00	5.00	1,581	565	3,381	1,209	7,906	2,418	-2,418	8,587	235,608
7.94	2.00	5.00	1,589	568	3,389	1,212	7,944	2,423	-2,423	8,376	235,934
7.98	2.00	5.00	1,597	571	3,397	1,214	7,983	2,429	-2,429	8,163	236,251
8.02	2.00	5.00	1,604	574	3,404	1,217	8,021	2,434	-2,434	7,949	236,560
8.06	2.00	5.00	1,612	576	3,412	1,220	8,060	2,440	-2,440	7,734	236,861
8.10	2.00	5.00	1,620	579	3,420	1,223	8,098	2,445	-2,445	7,518	237,154
8.14	2.00	5.00	1,627	582	3,427	1,225	8,136	2,450	-2,450	7,300	237,438
8.17	2.00	5.00	1,635	584	3,435	1,228	8,175	2,456	-2,456	7,082	237,714
8.21	2.00	5.00	1,643	587	3,443	1,231	8,213	2,461	-2,461	6,862	237,982
8.25	2.00	5.00	1,650	590	3,450	1,233	8,251	2,467	-2,467	6,640	238,241
8.29	2.00	5.00	1,658	593	3,458	1,236	8,290	2,472	-2,472	6,418	238,492
8.33	2.00	5.00	1,666	595	3,466	1,239	8,328	2,478	-2,478	6,194	238,734
8.37	2.00	5.00	1,673	598	3,473	1,242	8,367	2,483	-2,483	5,968	238,967
8.40	2.00	5.00	1,681	601	3,481	1,244	8,405	2,489	-2,489	5,742	239,192
8.44	2.00	5.00	1,689	604	3,489	1,247	8,443	2,494	-2,494	5,514	239,408
8.48	2.00	5.00	1,696	606	3,496	1,250	8,482	2,500	-2,500	5,285	239,615
8.52	2.00	5.00	1,704	609	3,504	1,253	8,520	2,505	-2,505	5,055	239,813
8.56	2.00	5.00	1,712	612	3,512	1,255	8,559	2,511	-2,511	4,824	240,003
8.60	2.00	5.00	1,719	615	3,519	1,258	8,597	2,516	-2,516	4,591	240,184
8.64	2.00	5.00	1,727	617	3,527	1,261	8,635	2,522	-2,522	4,357	240,355
8.67	2.00	5.00	1,735	620	3,535	1,264	8,674	2,527	-2,527	4,122	240,518
8.71	2.00	5.00	1,742	623	3,542	1,266	8,712	2,533	-2,533	3,885	240,672
8.75	2.00	5.00	1,750	626	3,550	1,269	8,750	2,538	-2,538	3,647	240,816
8.79	2.00	5.00	1,758	628	3,558	1,272	8,789	2,544	-2,544	3,408	240,952
8.83	2.00	5.00	1,765	631	3,565	1,275	8,827	2,549	-2,549	3,168	241,078
8.87	2.00	5.00	1,773	634	3,573	1,277	8,866	2,555	-2,555	2,927	241,195
8.90	2.00	5.00	1,781	637	3,581	1,280	8,904	2,560	-2,560	2,684	241,303
8.94	2.00	5.00	1,788	639	3,588	1,283	8,942	2,566	-2,566	2,440	241,401
8.98	2.00	5.00	1,796	642	3,596	1,286	8,981	2,571	-2,571	2,194	241,490

FIGURE A-2 (Page 6 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
9.02	2.00	5.00	1,804	645	3,604	1,288	9,019	2,577	-2,577	1,948	241,569
9.06	2.00	5.00	1,811	648	3,611	1,291	9,057	2,582	-2,582	1,700	241,639
9.10	2.00	5.00	1,819	650	3,619	1,294	9,096	2,588	-2,588	1,451	241,700
9.13	2.00	5.00	1,827	653	3,627	1,297	9,134	2,593	-2,593	1,200	241,751
9.17	2.00	5.00	1,835	656	3,635	1,299	9,173	2,599	-2,599	949	241,792
9.21	2.00	5.00	1,842	659	3,642	1,302	9,211	2,604	-2,604	696	241,823
9.25	2.00	5.00	1,850	661	3,650	1,305	9,249	2,610	-2,610	441	241,845
9.29	2.00	5.00	1,858	664	3,658	1,308	9,288	2,615	-2,615	186	241,857
9.33	2.00	5.00	1,865	667	3,665	1,310	9,326	2,621	-2,621	-71	241,859
9.36	2.00	5.00	1,873	670	3,673	1,313	9,364	2,626	-2,626	-329	241,852
9.40	2.00	5.00	1,881	672	3,681	1,316	9,403	2,632	-2,632	-588	241,834
9.44	2.00	5.00	1,888	675	3,688	1,319	9,441	2,637	-2,637	-849	241,807
9.48	2.00	5.00	1,896	678	3,696	1,321	9,480	2,643	-2,643	-1,110	241,769
9.52	2.00	5.00	1,904	681	3,704	1,324	9,518	2,648	-2,648	-1,373	241,721
9.56	2.00	5.00	1,911	683	3,711	1,327	9,556	2,654	-2,654	-1,638	241,664
9.59	2.00	5.00	1,919	686	3,719	1,330	9,595	2,659	-2,659	-1,903	241,596
9.63	2.00	5.00	1,927	689	3,727	1,332	9,633	2,665	-2,665	-2,170	241,518
9.67	2.00	5.00	1,934	692	3,734	1,335	9,671	2,670	-2,670	-2,438	241,429
9.71	2.00	5.00	1,942	694	3,742	1,338	9,710	2,676	-2,676	-2,707	241,330
9.75	2.00	5.00	1,950	697	3,750	1,341	9,748	2,681	-2,681	-2,978	241,221
9.79	2.00	5.00	1,957	700	3,757	1,343	9,787	2,686	-2,686	-3,250	241,102
9.83	2.00	5.00	1,965	702	3,765	1,346	9,825	2,692	-2,692	-3,523	240,972
9.86	2.00	5.00	1,973	705	3,773	1,349	9,863	2,697	-2,697	-3,797	240,831
9.90	2.00	5.00	1,980	708	3,780	1,351	9,902	2,703	-2,703	-4,073	240,680
9.94	2.00	5.00	1,988	711	3,788	1,354	9,940	2,708	-2,708	-4,350	240,519
9.98	2.00	5.00	1,996	713	3,796	1,357	9,979	2,714	-2,714	-4,628	240,346
10.02	2.00	5.00	2,003	716	3,803	1,360	10,017	2,719	-2,719	-4,908	240,163
10.06	2.00	5.00	2,011	719	3,811	1,362	10,055	2,725	-2,725	-5,188	239,970
10.09	2.00	5.00	2,019	722	3,819	1,365	10,094	2,730	-2,730	-5,470	239,765
10.13	2.00	5.00	2,026	724	3,826	1,368	10,132	2,736	-2,736	-5,753	239,550
10.17	2.00	5.00	2,034	727	3,834	1,371	10,170	2,741	-2,741	-6,038	239,324
10.21	2.00	5.00	2,042	730	3,842	1,373	10,209	2,747	-2,747	-6,324	239,086
10.25	2.00	5.00	2,049	733	3,849	1,376	10,247	2,752	-2,752	-6,611	238,838
10.29	2.00	5.00	2,057	735	3,857	1,379	10,286	2,758	-2,758	-6,899	238,579
10.32	2.00	5.00	2,065	738	3,865	1,382	10,324	2,763	-2,763	-7,188	238,309
10.36	2.00	5.00	2,072	741	3,872	1,384	10,362	2,769	-2,769	-7,479	238,027
10.40	2.00	5.00	2,080	744	3,880	1,387	10,401	2,774	-2,774	-7,771	237,734
10.44	2.00	5.00	2,088	746	3,888	1,390	10,439	2,780	-2,780	-8,065	237,431
10.48	2.00	5.00	2,095	749	3,895	1,393	10,477	2,785	-2,785	-8,359	237,115
10.52	2.00	5.00	2,103	752	3,903	1,395	10,516	2,791	-2,791	-8,655	236,789
10.55	2.00	5.00	2,111	755	3,911	1,398	10,554	2,796	-2,796	-8,952	236,451
10.59	2.00	5.00	2,119	757	3,919	1,401	10,593	2,802	-2,802	-9,251	236,102
10.63	2.00	5.00	2,126	760	3,926	1,404	10,631	2,807	-2,807	-9,550	235,741
10.67	2.00	5.00	2,134	763	3,934	1,406	10,669	2,813	-2,813	-9,851	235,369
10.71	2.00	5.00	2,142	766	3,942	1,409	10,708	2,818	-2,818	-10,153	234,985
10.75	2.00	5.00	2,149	768	3,949	1,412	10,746	2,824	-2,824	-10,457	234,589
10.78	2.00	5.00	2,157	771	3,957	1,415	10,784	2,829	-2,829	-10,761	234,182

FIGURE A-2 (Page 7 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
10.82	2.00	5.00	2,165	774	3,965	1,417	10,823	2,835	-2,835	-11,067	233,763
10.86	2.00	5.00	2,172	777	3,972	1,420	10,861	2,840	-2,840	-11,375	233,333
10.90	2.00	5.00	2,180	779	3,980	1,423	10,900	2,846	-2,846	-11,683	232,890
10.94	2.00	5.00	2,188	782	3,988	1,426	10,938	2,851	-2,851	-11,993	232,436
10.98	2.00	5.00	2,195	785	3,995	1,428	10,976	2,857	-2,857	-12,304	231,970
11.01	2.00	5.00	2,203	788	4,003	1,431	11,015	2,862	-2,862	-12,616	231,491
11.05	2.00	5.00	2,211	790	4,011	1,434	11,053	2,868	-2,868	-12,930	231,001
11.09	2.00	5.00	2,218	793	4,018	1,437	11,092	2,873	-2,873	-13,244	230,499
11.13	2.00	5.00	2,226	796	4,026	1,439	11,130	2,879	-2,879	-13,560	229,985
11.17	2.00	5.00	2,234	799	4,034	1,442	11,168	2,884	-2,884	-13,878	229,458
11.21	2.00	5.00	2,241	801	4,041	1,445	11,207	2,890	-2,890	-14,196	228,919
11.25	2.00	5.00	2,249	804	4,049	1,448	11,245	2,895	-2,895	-14,516	228,368
11.28	2.00	5.00	2,257	807	4,057	1,450	11,283	2,901	-2,901	-14,837	227,805
11.32	2.00	5.00	2,264	810	4,064	1,453	11,322	2,906	-2,906	-15,160	227,230
11.36	2.00	5.00	2,272	812	4,072	1,456	11,360	2,912	-2,912	-15,483	226,642
11.40	2.00	5.00	2,280	815	4,080	1,458	11,399	2,917	-2,917	-15,808	226,041
11.44	2.00	5.00	2,287	818	4,087	1,461	11,437	2,922	-2,922	-16,134	225,428
11.48	2.00	5.00	2,295	820	4,095	1,464	11,475	2,928	-2,928	-16,462	224,803
11.51	2.00	5.00	2,303	823	4,103	1,467	11,514	2,933	-2,933	-16,790	224,165
11.55	2.00	5.00	2,310	826	4,110	1,469	11,552	2,939	-2,939	-17,120	223,514
11.59	2.00	5.00	2,318	829	4,118	1,472	11,590	2,944	-2,944	-17,451	222,850
11.63	2.00	5.00	2,326	831	4,126	1,475	11,629	2,950	-2,950	-17,784	222,174
11.67	2.00	5.00	2,333	834	4,133	1,478	11,667	2,955	-2,955	-18,118	221,485
11.71	2.00	5.00	2,341	837	4,141	1,480	11,706	2,961	-2,961	-18,453	220,784
11.74	2.00	5.00	2,349	840	4,149	1,483	11,744	2,966	-2,966	-18,789	220,069
11.78	2.00	5.00	2,356	842	4,156	1,486	11,782	2,972	-2,972	-19,126	219,341
11.82	2.00	5.00	2,364	845	4,164	1,489	11,821	2,977	-2,977	-19,465	218,601
11.86	2.00	5.00	2,372	848	4,172	1,491	11,859	2,983	-2,983	-19,805	217,847
11.90	2.00	5.00	2,379	851	4,179	1,494	11,897	2,988	-2,988	-20,146	217,081
11.94	2.00	5.00	2,387	853	4,187	1,497	11,936	2,994	-2,994	-20,489	216,301
11.97	2.00	5.00	2,395	856	4,195	1,500	11,974	2,999	-2,999	-20,833	215,508
12.01	2.00	5.00	2,403	859	4,203	1,502	12,013	3,005	-3,005	-21,178	214,702
12.05	2.00	5.00	2,410	862	4,210	1,505	12,051	3,010	-3,010	-21,524	213,882
12.09	2.00	5.00	2,418	864	4,218	1,508	12,089	3,016	-3,016	-21,872	213,050
12.13	2.00	5.00	2,426	867	4,226	1,511	12,128	3,021	-3,021	-22,221	212,203
12.17	2.00	5.00	2,433	870	4,233	1,513	12,166	3,027	-3,027	-22,571	211,344
12.20	2.00	5.00	2,441	873	4,241	1,516	12,205	3,032	-3,032	-22,922	210,471
12.24	2.00	5.00	2,449	875	4,249	1,519	12,243	3,038	-3,038	-23,275	209,584
12.28	2.00	5.00	2,456	878	4,256	1,522	12,281	3,043	-3,043	-23,629	208,684
12.32	2.00	5.00	2,464	881	4,264	1,524	12,320	3,049	-3,049	-23,984	207,771
12.36	2.00	5.00	2,472	884	4,272	1,527	12,358	3,054	-3,054	-24,340	206,843
12.40	2.00	5.00	2,479	886	4,279	1,530	12,396	3,060	-3,060	-24,698	205,902
12.43	2.00	5.00	2,487	889	4,287	1,533	12,435	3,065	-3,065	-25,057	204,948
12.47	2.00	5.00	2,495	892	4,295	1,535	12,473	3,071	-3,071	-25,417	203,979
12.51	2.00	5.00	2,502	895	4,302	1,538	12,512	3,076	-3,076	-25,779	202,997
12.55	2.00	5.00	2,510	897	4,310	1,541	12,550	3,082	-3,082	-26,141	202,000
12.59	2.00	5.00	2,518	900	4,318	1,544	12,588	3,087	-3,087	-26,505	200,990

FIGURE A-2 (Page 8 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
12.63	2.00	5.00	2,525	903	4,325	1,546	12,627	3,093	-3,093	-26,871	199,966
12.67	2.00	5.00	2,533	906	4,333	1,549	12,665	3,098	-3,098	-27,237	198,928
12.70	2.00	5.00	2,541	908	4,341	1,552	12,697	3,119	-3,119	-27,605	197,875
12.74	2.00	5.00	2,548	911	4,348	1,555	12,687	3,234	-3,234	-27,970	196,809
12.78	2.00	5.00	2,556	914	4,356	1,557	12,676	3,350	-3,350	-28,330	195,728
12.82	2.00	5.00	2,564	917	4,364	1,560	12,666	3,467	-3,467	-28,686	194,634
12.86	2.00	5.00	2,571	919	4,371	1,563	12,655	3,584	-3,584	-29,036	193,527
12.90	2.00	5.00	2,579	922	4,379	1,566	12,644	3,701	-3,701	-29,382	192,405
12.93	2.00	5.00	2,587	925	4,387	1,568	12,632	3,819	-3,819	-29,723	191,271
12.97	2.00	5.00	2,594	928	4,394	1,571	12,620	3,937	-3,937	-30,058	190,124
13.01	2.00	5.00	2,602	930	4,402	1,574	12,608	4,055	-4,055	-30,389	188,964
13.05	2.00	5.00	2,610	933	4,410	1,576	12,596	4,174	-4,174	-30,715	187,792
13.09	2.00	5.00	2,617	936	4,417	1,579	12,583	4,293	-4,293	-31,036	186,607
13.13	2.00	5.00	2,625	938	4,425	1,582	12,570	4,413	-4,413	-31,351	185,409
13.16	2.00	5.00	2,633	941	4,433	1,585	12,557	4,533	-4,533	-31,662	184,200
13.20	2.00	5.00	2,640	944	4,440	1,587	12,543	4,653	-4,653	-31,967	182,979
13.24	2.00	5.00	2,648	947	4,448	1,590	12,530	4,774	-4,774	-32,267	181,747
13.28	2.00	5.00	2,656	949	4,456	1,593	12,516	4,895	-4,895	-32,563	180,502
13.32	2.00	5.00	2,663	952	4,463	1,596	12,501	5,016	-5,016	-32,852	179,247
13.36	2.00	5.00	2,671	955	4,471	1,598	12,486	5,138	-5,138	-33,137	177,981
13.39	2.00	5.00	2,679	958	4,479	1,601	12,471	5,260	-5,260	-33,416	176,704
13.43	2.00	5.00	2,687	960	4,487	1,604	12,456	5,383	-5,383	-33,691	175,416
13.47	2.00	5.00	2,694	963	4,494	1,607	12,441	5,506	-5,506	-33,959	174,118
13.51	2.00	5.00	2,702	966	4,502	1,609	12,425	5,630	-5,630	-34,223	172,809
13.55	2.00	5.00	2,710	969	4,510	1,612	12,408	5,754	-5,754	-34,481	171,491
13.59	2.00	5.00	2,717	971	4,517	1,615	12,392	5,878	-5,878	-34,734	170,163
13.62	2.00	5.00	2,725	974	4,525	1,618	12,375	6,002	-6,002	-34,981	168,825
13.66	2.00	5.00	2,733	977	4,533	1,620	12,358	6,127	-6,127	-35,223	167,478
13.70	2.00	5.00	2,740	980	4,540	1,623	12,341	6,253	-6,253	-35,459	166,121
13.74	2.00	5.00	2,748	982	4,548	1,626	12,323	6,379	-6,379	-35,690	164,756
13.78	2.00	5.00	2,756	985	4,556	1,629	12,305	6,505	-6,505	-35,915	163,382
13.82	2.00	5.00	2,763	988	4,563	1,631	12,287	6,631	-6,631	-36,135	161,999
13.85	2.00	5.00	2,771	991	4,571	1,634	12,269	6,758	-6,758	-36,350	160,608
13.89	2.00	5.00	2,779	993	4,579	1,637	12,250	6,886	-6,886	-36,558	159,209
13.93	2.00	5.00	2,786	996	4,586	1,640	12,231	7,013	-7,013	-36,761	157,802
13.97	2.00	5.00	2,794	999	4,594	1,642	12,211	7,141	-7,141	-36,959	156,388
14.01	2.00	5.00	2,802	1,002	4,602	1,645	12,192	7,270	-7,270	-37,150	154,965
14.05	2.00	5.00	2,809	1,004	4,609	1,648	12,172	7,399	-7,399	-37,336	153,536
14.09	2.00	5.00	2,817	1,007	4,617	1,651	12,152	7,528	-7,528	-37,517	152,100
14.12	2.00	5.00	2,825	1,010	4,625	1,653	12,131	7,658	-7,658	-37,691	150,656
14.16	2.00	5.00	2,832	1,013	4,632	1,656	12,110	7,788	-7,788	-37,860	149,207
14.20	2.00	5.00	2,840	1,015	4,640	1,659	12,089	7,918	-7,918	-38,023	147,750
14.24	2.00	5.00	2,848	1,018	4,648	1,662	12,068	8,049	-8,049	-38,180	146,288
14.28	2.00	5.00	2,855	1,021	4,655	1,664	12,046	8,180	-8,180	-38,332	144,820
14.32	2.00	5.00	2,863	1,024	4,663	1,667	12,024	8,312	-8,312	-38,477	143,346
14.35	2.00	5.00	2,871	1,026	4,671	1,670	12,002	8,444	-8,444	-38,616	141,867
14.39	2.00	5.00	2,878	1,029	4,678	1,673	11,979	8,577	-8,577	-38,750	140,382

FIGURE A-2 (Page 9 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
14.43	2.00	5.00	2,886	1,032	4,686	1,675	11,956	8,709	-8,709	-38,878	138,892
14.47	2.00	5.00	2,894	1,035	4,694	1,678	11,933	8,842	-8,842	-38,999	137,398
14.51	2.00	5.00	2,901	1,037	4,701	1,681	11,910	8,976	-8,976	-39,115	135,899
14.55	2.00	5.00	2,909	1,040	4,709	1,684	11,886	9,110	-9,110	-39,224	134,396
14.58	2.00	5.00	2,917	1,043	4,717	1,686	11,862	9,244	-9,244	-39,328	132,888
14.62	2.00	5.00	2,924	1,046	4,724	1,689	11,837	9,379	-9,379	-39,425	131,377
14.66	2.00	5.00	2,932	1,048	4,732	1,692	11,813	9,514	-9,514	-39,517	129,862
14.70	2.00	5.00	2,940	1,051	4,740	1,694	11,788	9,650	-9,650	-39,602	128,344
14.74	2.00	5.00	2,948	1,054	4,748	1,697	11,763	9,786	-9,786	-39,681	126,822
14.78	2.00	5.00	2,955	1,056	4,755	1,700	11,737	9,922	-9,922	-39,753	125,298
14.81	2.00	5.00	2,963	1,059	4,763	1,703	11,711	10,059	-10,059	-39,820	123,771
14.85	2.00	5.00	2,971	1,062	4,771	1,705	11,685	10,196	-10,196	-39,880	122,242
14.89	2.00	5.00	2,978	1,065	4,778	1,708	11,659	10,333	-10,333	-39,934	120,710
14.93	2.00	5.00	2,986	1,067	4,786	1,711	11,632	10,471	-10,471	-39,982	119,176
14.97	2.00	5.00	2,994	1,070	4,794	1,714	11,605	10,609	-10,609	-40,023	117,641
15.01	2.00	5.00	3,001	1,073	4,801	1,716	11,578	10,748	-10,748	-40,058	116,104
15.04	2.00	5.00	3,009	1,076	4,809	1,719	11,551	10,887	-10,887	-40,087	114,566
15.08	2.00	5.00	3,017	1,078	4,817	1,722	11,523	11,026	-11,026	-40,109	113,028
15.12	2.00	5.00	3,024	1,081	4,824	1,725	11,495	11,166	-11,166	-40,125	111,488
15.16	2.00	5.00	3,032	1,084	4,832	1,727	11,466	11,306	-11,306	-40,135	109,948
15.20	2.00	5.00	3,040	1,087	4,840	1,730	11,437	11,447	-11,447	-40,137	108,407
15.24	2.00	5.00	3,047	1,089	4,847	1,733	11,408	11,588	-11,588	-40,134	106,867
15.27	2.00	5.00	3,055	1,092	4,855	1,736	11,379	11,729	-11,729	-40,124	105,327
15.31	2.00	5.00	3,063	1,095	4,863	1,738	11,350	11,871	-11,871	-40,107	103,787
15.35	2.00	5.00	3,070	1,098	4,870	1,741	11,320	12,013	-12,013	-40,084	102,248
15.39	2.00	5.00	3,078	1,100	4,878	1,744	11,290	12,155	-12,155	-40,054	100,711
15.43	2.00	5.00	3,086	1,103	4,886	1,747	11,259	12,298	-12,298	-40,017	99,174
15.47	2.00	5.00	3,093	1,106	4,893	1,749	11,228	12,442	-12,442	-39,974	97,639
15.51	2.00	5.00	3,101	1,109	4,901	1,752	11,197	12,585	-12,585	-39,924	96,106
15.54	2.00	5.00	3,109	1,111	4,909	1,755	11,166	12,729	-12,729	-39,867	94,575
15.58	2.00	5.00	3,116	1,114	4,916	1,758	11,134	12,874	-12,874	-39,804	93,046
15.62	2.00	5.00	3,124	1,117	4,924	1,760	11,103	13,019	-13,019	-39,734	91,519
15.66	2.00	5.00	3,132	1,120	4,932	1,763	11,070	13,164	-13,164	-39,657	89,996
15.70	2.00	5.00	3,139	1,122	4,939	1,766	11,038	13,310	-13,310	-39,573	88,475
15.74	2.00	5.00	3,147	1,125	4,947	1,769	11,005	13,456	-13,456	-39,483	86,958
15.77	2.00	5.00	3,155	1,128	4,955	1,771	10,972	13,602	-13,602	-39,385	85,445
15.81	2.00	5.00	3,162	1,131	4,962	1,774	10,939	13,749	-13,749	-39,281	83,935
15.85	2.00	5.00	3,170	1,133	4,970	1,777	10,905	13,896	-13,896	-39,169	82,430
15.89	2.00	5.00	3,178	1,136	4,978	1,780	10,871	14,044	-14,044	-39,051	80,929
15.93	2.00	5.00	3,185	1,139	4,985	1,782	10,837	14,191	-14,191	-38,926	79,433
15.97	2.00	5.00	3,193	1,142	4,993	1,785	10,802	14,340	-14,340	-38,794	77,941
16.00	2.00	5.00	3,201	1,144	5,001	1,788	10,767	14,489	-14,489	-38,654	76,455
16.04	2.00	5.00	3,208	1,147	5,008	1,791	10,732	14,638	-14,638	-38,508	74,974
16.08	2.00	5.00	3,216	1,150	5,016	1,793	10,697	14,787	-14,787	-38,354	73,499
16.12	2.00	5.00	3,224	1,153	5,024	1,796	10,661	14,937	-14,937	-38,194	72,030
16.16	2.00	5.00	3,232	1,155	5,032	1,799	10,625	15,087	-15,087	-38,026	70,568
16.20	2.00	5.00	3,239	1,158	5,039	1,802	10,589	15,238	-15,238	-37,851	69,112

FIGURE A-2 (Page 10 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
16.23	2.00	5.00	3,247	1,161	5,047	1,804	10,552	15,389	-15,389	-37,669	67,662
16.27	2.00	5.00	3,255	1,163	5,055	1,807	10,515	15,541	-15,541	-37,480	66,220
16.31	2.00	5.00	3,262	1,166	5,062	1,810	10,478	15,692	-15,692	-37,284	64,786
16.35	2.00	5.00	3,270	1,169	5,070	1,812	10,441	15,845	-15,845	-37,080	63,358
16.39	2.00	5.00	3,278	1,172	5,078	1,815	10,403	15,997	-15,997	-36,869	61,939
16.43	2.00	5.00	3,285	1,174	5,085	1,818	10,365	16,150	-16,150	-36,650	60,529
16.46	2.00	5.00	3,293	1,177	5,093	1,821	10,327	16,304	-16,304	-36,425	59,126
16.50	2.00	5.00	3,301	1,180	5,101	1,823	10,288	16,458	-16,458	-36,192	57,733
16.54	2.00	5.00	3,308	1,183	5,108	1,826	10,249	16,612	-16,612	-35,951	56,348
16.58	2.00	5.00	3,316	1,185	5,116	1,829	10,210	16,766	-16,766	-35,703	54,973
16.62	2.00	5.00	3,324	1,188	5,124	1,832	10,170	16,921	-16,921	-35,448	53,608
16.66	2.00	5.00	3,331	1,191	5,131	1,834	10,131	17,077	-17,077	-35,185	52,253
16.69	2.00	5.00	3,339	1,194	5,139	1,837	10,091	17,232	-17,232	-34,915	50,907
16.73	2.00	5.00	3,347	1,196	5,147	1,840	10,050	17,388	-17,388	-34,637	49,573
16.77	2.00	5.00	3,354	1,199	5,154	1,843	10,010	17,545	-17,545	-34,351	48,249
16.81	2.00	5.00	3,362	1,202	5,162	1,845	9,969	17,702	-17,702	-34,058	46,936
16.85	2.00	5.00	3,370	1,205	5,170	1,848	9,927	17,859	-17,859	-33,758	45,635
16.89	2.00	5.00	3,377	1,207	5,177	1,851	9,886	18,017	-18,017	-33,450	44,345
16.93	2.00	5.00	3,385	1,210	5,185	1,854	9,844	18,175	-18,175	-33,134	43,067
16.96	2.00	5.00	3,393	1,213	5,193	1,856	9,802	18,333	-18,333	-32,810	41,802
17.00	2.00	5.00	3,400	1,216	5,200	1,859	9,759	18,492	-18,492	-32,479	40,549
17.04	2.00	5.00	3,408	1,218	5,208	1,862	9,717	18,651	-18,651	-32,140	39,309
17.08	2.00	5.00	3,416	1,221	5,216	1,865	9,674	18,811	-18,811	-31,793	38,082
17.12	2.00	5.00	3,423	1,224	5,223	1,867	9,631	18,971	-18,971	-31,438	36,869
17.16	2.00	5.00	3,431	1,227	5,231	1,870	9,587	19,132	-19,132	-31,076	35,669
17.19	2.00	5.00	3,439	1,229	5,239	1,873	9,543	19,292	-19,292	-30,706	34,483
17.23	2.00	5.00	3,446	1,232	5,246	1,876	9,499	19,453	-19,453	-30,328	33,312
17.27	2.00	5.00	3,454	1,235	5,254	1,878	9,454	19,615	-19,615	-29,942	32,156
17.31	2.00	5.00	3,462	1,238	5,262	1,881	9,410	19,777	-19,777	-29,548	31,014
17.35	2.00	5.00	3,469	1,240	5,269	1,884	9,365	19,939	-19,939	-29,146	29,888
17.39	2.00	5.00	3,477	1,243	5,277	1,887	9,319	20,102	-20,102	-28,736	28,777
17.42	2.00	5.00	3,485	1,246	5,285	1,889	9,274	20,265	-20,265	-28,318	27,682
17.46	2.00	5.00	3,492	1,249	5,292	1,892	9,228	20,429	-20,429	-27,892	26,603
17.50	2.00	5.00	3,500	1,251	5,300	1,895	9,182	20,593	-20,593	-27,458	25,541
17.54	2.00	5.00	3,508	1,254	5,308	1,898	9,135	20,757	-20,757	-27,017	24,496
17.58	2.00	5.00	3,516	1,257	5,316	1,900	9,088	20,922	-20,922	-26,566	23,468
17.62	2.00	5.00	3,523	1,260	5,323	1,903	9,041	21,087	-21,087	-26,108	22,457
17.65	2.00	5.00	3,531	1,262	5,331	1,906	8,994	21,252	-21,252	-25,642	21,464
17.69	2.00	5.00	3,539	1,265	5,339	1,909	8,946	21,418	-21,418	-25,167	20,489
17.73	2.00	5.00	3,546	1,268	5,346	1,911	8,898	21,584	-21,584	-24,685	19,532
17.77	2.00	5.00	3,554	1,271	5,354	1,914	8,850	21,751	-21,751	-24,194	18,594
17.81	2.00	5.00	3,562	1,273	5,362	1,917	8,802	21,918	-21,918	-23,694	17,675
17.85	2.00	5.00	3,569	1,276	5,369	1,920	8,753	22,085	-22,085	-23,187	16,775
17.88	2.00	5.00	3,577	1,279	5,377	1,922	8,704	22,253	-22,253	-22,671	15,895
17.92	2.00	5.00	3,585	1,281	5,385	1,925	8,654	22,421	-22,421	-22,147	15,035
17.96	2.00	5.00	3,592	1,284	5,392	1,928	8,605	22,590	-22,590	-21,614	14,196
18.00	2.00	5.00	3,600	1,287	5,400	1,930	8,555	22,759	-22,759	-21,073	13,376

FIGURE A-2 (Page 11 of 12)

Example Toe Embedment Calculations

Discrete Calculations Throughout the Depth of Embedment											
	Effect Driving Pile	Effect Resist Pile	Resist Pressure		Driving Pressure		Resist	Driving	Neg Driving	Shear	Bending
Depth (L)	Width (L)	Width (L)	Passive (F/L/L)	Active (F/L/L)	Passive (F/L/L)	Active (F/L/L)	Force (F/L)	Force (F/L)	Force (F/L)	Force (F)	Moment (F-L)
18.04	2.00	5.00	3,608	1,290	5,408	1,933	8,504	22,928	-22,928	-20,524	12,578
18.08	2.00	5.00	3,615	1,292	5,415	1,936	8,454	23,098	-23,098	-19,966	11,801
18.11	2.00	5.00	3,623	1,295	5,423	1,939	8,403	23,268	-23,268	-19,400	11,046
18.15	2.00	5.00	3,631	1,298	5,431	1,941	8,352	23,439	-23,439	-18,825	10,312
18.19	2.00	5.00	3,638	1,301	5,438	1,944	8,300	23,609	-23,609	-18,242	9,601
18.23	2.00	5.00	3,646	1,303	5,446	1,947	8,248	23,781	-23,781	-17,650	8,912
18.27	2.00	5.00	3,654	1,306	5,454	1,950	8,196	23,952	-23,952	-17,049	8,246
18.31	2.00	5.00	3,661	1,309	5,461	1,952	8,144	24,124	-24,124	-16,440	7,603
18.35	2.00	5.00	3,669	1,312	5,469	1,955	8,092	24,297	-24,297	-15,823	6,984
18.38	2.00	5.00	3,677	1,314	5,477	1,958	8,039	24,470	-24,470	-15,197	6,389
18.42	2.00	5.00	3,684	1,317	5,484	1,961	7,985	24,643	-24,643	-14,562	5,818
18.46	2.00	5.00	3,692	1,320	5,492	1,963	7,932	24,817	-24,817	-13,918	5,271
18.50	2.00	5.00	3,700	1,323	5,500	1,966	7,878	24,991	-24,991	-13,266	4,750
18.54	2.00	5.00	3,707	1,325	5,507	1,969	7,824	25,165	-25,165	-12,604	4,253
18.58	2.00	5.00	3,715	1,328	5,515	1,972	7,770	25,340	-25,340	-11,934	3,782
18.61	2.00	5.00	3,723	1,331	5,523	1,974	7,715	25,515	-25,515	-11,256	3,337
18.65	2.00	5.00	3,730	1,334	5,530	1,977	7,660	25,691	-25,691	-10,568	2,919
18.69	2.00	5.00	3,738	1,336	5,538	1,980	7,605	25,867	-25,867	-9,872	2,526
18.73	2.00	5.00	3,746	1,339	5,546	1,983	7,549	26,043	-26,043	-9,166	2,161
18.77	2.00	5.00	3,753	1,342	5,553	1,985	7,494	26,220	-26,220	-8,452	1,823
18.81	2.00	5.00	3,761	1,345	5,561	1,988	7,437	26,397	-26,397	-7,729	1,512
18.84	2.00	5.00	3,769	1,347	5,569	1,991	7,381	26,574	-26,574	-6,997	1,230
18.88	2.00	5.00	3,776	1,350	5,576	1,994	7,324	26,752	-26,752	-6,256	975
18.92	2.00	5.00	3,784	1,353	5,584	1,996	7,267	26,931	-26,931	-5,506	750
18.96	2.00	5.00	3,792	1,356	5,592	1,999	7,210	27,109	-27,109	-4,746	553
19.00	2.00	5.00	3,800	1,358	5,600	2,002	7,152	27,288	-27,288	-3,978	385
19.04	2.00	5.00	3,807	1,361	5,607	2,005	7,095	27,468	-27,468	-3,201	248
19.07	2.00	5.00	3,815	1,364	5,615	2,007	7,036	27,648	-27,648	-2,414	140
19.11	2.00	5.00	3,823	1,367	5,623	2,010	6,978	27,828	-27,828	-1,619	62
19.15	2.00	5.00	3,830	1,369	5,630	2,013	6,919	28,008	-28,008	-814	16
19.19	2.00	5.00	3,838	1,372	5,638	2,016	6,860	28,189	-28,189	0	0

FIGURE A-2 (Page 12 of 12)
Example Toe Embedment Calculations

APPENDIX B

ANCHORED WALL DESIGN CALCULATIONS

Single-Level Anchored Pile Design	P16-19

Input Data	
Uniform Earth Pressure Factor, N (pcf)	46.5
Excavation Height, H (ft)	19.0
Superimposed Foundation Load (k/ft)	0.0
Horizontal Component of Surcharge Loading (psf)	0.0
Upper Cantilever Span, H_{TOP} (ft)	6.0
Lower Span, H_{BOT} (ft)	13.0
Pile Diameter, B (ft)	2.0
Tributary Pile Spacing, S (ft)	8.0
Pile Steel Section	W14x53
Pile Steel Grade (ksi)	50.0
Pile Moment Reduction Factor	1.00
Anchor Declination (deg)	20.0
Design Pullout Resistance (k/ft)	3.0
No-Load Zone Horizontal Offset Denominator	3.8
No-Load Zone Inclination From Horizontal (deg)	60.0
Allowable Passive EFD (pcf)	200.0
Above Base Active EFD (pcf)	71.5
Below Base Active EFD (pcf)	71.5
Below Base Surcharge Factor	0.0
Ignore Depth (ft)	2.0
Number of Diameters on Active Side	1.0
Number of Diameters on Passive Side	2.5

Intermediate Wall Loading and Pile Force Calculations	
Horizontal Wall Load, l (k/ft)	16.8
Horizontal Wall Load, L (k)	134.2
Maximum AEP (ksf)	1.325
Maximum Wall Loading, q (k/ft)	10.6
Toe Shear, R (k)	26.1
Total Horizontal Anchor Load (k)	108.1

Design Calculations for Pile Axial Load & Flexure	
Pile Axial Load, P (k)	39.4
Cantilever Moment, M_C (ft-k)	91.8
Zero Shear Point, X (ft)	6.5
Design Span Moment (ft-k)	113.7
Maximum Pile Moment, M_{MAX} (ft-k)	113.7
Maximum Span, KL (ft)	13.0
Gross Area, A (in^2)	15.6
Section Modulus, S (in^3)	77.8
Radius of Gyration, r (in)	5.9
C_C	108.8
KL/r	26.5
Allowable Axial Stress, F_A (ksi)	27.6
Allowable Bending Stress, F_B (ksi)	33.0
Axial Stress, f_A (ksi)	2.5
Bending Stress, f_B (ksi)	17.5
Combined Axial Load & Flexure Design Ratio	0.62

FIGURE B-1

Anchored Pile Wall Design Calculations

Design Case P16-19 (Page 1 of 2)

Single-Level Anchored Pile Design	P16-19

Input Data	
Uniform Earth Pressure Factor, N (pcf)	46.5
Excavation Height, H (ft)	19.0
Superimposed Foundation Load (k/ft)	0.0
Horizontal Component of Surcharge Loading (psf)	0.0
Upper Cantilever Span, H_{TOP} (ft)	6.0
Lower Span, H_{BOT} (ft)	13.0
Pile Diameter, B (ft)	2.0
Tributary Pile Spacing, S (ft)	8.0
Pile Steel Section	W14x53
Pile Steel Grade (ksi)	50.0
Pile Moment Reduction Factor	1.00
Anchor Declination (deg)	20.0
Design Pullout Resistance (k/ft)	3.0
No-Load Zone Horizontal Offset Denominator	3.8
No-Load Zone Inclination From Horizontal (deg)	60.0

Toe Embedment for Force Balance	
Active Pressure @ Base of Excavation (psf)	1,358.5
Active Load 1 (k)	32.2
Active Load 2 (k)	10.1
Passive Load 1 (k)	19.7
Passive Load 2 (k)	48.7
Net Load Resisted by Toe Embedment (k)	26.1
Force Sum (Toe Shear Minus Net Resistance)	0.0
Embedment Depth (ft) (Use Solver)	11.9

Strand & Bond Zone Calculations for Anchors

Row	Calc T_H (k)	Calc T (k)	Design T (k)	Req'd # Strands	Design # Strands	Calc Bond (ft)	Design Bond (ft)
1	108.1	115.1	116.0	3.30	4	38.7	38

Unbonded & Total Length Calculations for Anchors

Row	Y (ft)	Calc Unbond (ft)	Design Unbond (ft)	Design Total (ft)
1	13.0	11.0	15	53

FIGURE B-1
Anchored Pile Wall Design Calculations
Design Case P16-19 (Page 2 of 2)

Single-Level Anchored Pile Design	P16-16

Input Data	
Uniform Earth Pressure Factor, N (pcf)	46.5
Excavation Height, H (ft)	16.0
Superimposed Foundation Load (k/ft)	0.0
Horizontal Component of Surcharge Loading (psf)	188.0
Upper Cantilever Span, H_{TOP} (ft)	6.0
Lower Span, H_{BOT} (ft)	10.0
Pile Diameter, B (ft)	2.0
Tributary Pile Spacing, S (ft)	8.0
Pile Steel Section	W14x53
Pile Steel Grade (ksi)	50.0
Pile Moment Reduction Factor	1.00
Anchor Declination (deg)	20.0
Design Pullout Resistance (k/ft)	3.0
No-Load Zone Horizontal Offset Denominator	3.2
No-Load Zone Inclination From Horizontal (deg)	60.0
Allowable Passive EFD (pcf)	200.0
Above Base Active EFD (pcf)	71.5
Below Base Active EFD (pcf)	71.5
Below Base Surcharge Factor	0.0
Ignore Depth (ft)	2.0
Number of Diameters on Active Side	1.0
Number of Diameters on Passive Side	2.5

Intermediate Wall Loading and Pile Force Calculations	
Horizontal Wall Load, l (k/ft)	14.9
Horizontal Wall Load, L (k)	119.2
Maximum AEP (ksf)	1.397
Maximum Wall Loading, q (k/ft)	11.2
Toe Shear, R (k)	17.2
Total Horizontal Anchor Load (k)	102.0

Design Calculations for Pile Axial Load & Flexure	
Pile Axial Load, P (k)	37.1
Cantilever Moment, M_C (ft-k)	96.9
Zero Shear Point, X (ft)	4.5
Design Span Moment (ft-k)	52.0
Maximum Pile Moment, M_{MAX} (ft-k)	96.9
Maximum Span, KL (ft)	10.0
Gross Area, A (in^2)	15.6
Section Modulus, S (in^3)	77.8
Radius of Gyration, r (in)	5.9
C_C	108.8
KL/r	20.4
Allowable Axial Stress, F_A (ksi)	28.3
Allowable Bending Stress, F_B (ksi)	33.0
Axial Stress, f_A (ksi)	2.4
Bending Stress, f_B (ksi)	14.9
Combined Axial Load & Flexure Design Ratio	0.54

FIGURE B-2

Anchored Pile Wall Design Calculations

Design Case P16-16 (Page 1 of 2)

Single-Level Anchored Pile Design	P16-16

Input Data	
Uniform Earth Pressure Factor, N (pcf)	46.5
Excavation Height, H (ft)	16.0
Superimposed Foundation Load (k/ft)	0.0
Horizontal Component of Surcharge Loading (psf)	188.0
Upper Cantilever Span, H_{TOP} (ft)	6.0
Lower Span, H_{BOT} (ft)	10.0
Pile Diameter, B (ft)	2.0
Tributary Pile Spacing, S (ft)	8.0
Pile Steel Section	W14x53
Pile Steel Grade (ksi)	50.0
Pile Moment Reduction Factor	1.00
Anchor Declination (deg)	20.0
Design Pullout Resistance (k/ft)	3.0
No-Load Zone Horizontal Offset Denominator	3.2
No-Load Zone Inclination From Horizontal (deg)	60.0

Toe Embedment for Force Balance	
Active Pressure @ Base of Excavation (psf)	1,144.0
Active Load 1 (k)	22.6
Active Load 2 (k)	7.0
Passive Load 1 (k)	15.8
Passive Load 2 (k)	31.1
Net Load Resisted by Toe Embedment (k)	17.2
Force Sum (Toe Shear Minus Net Resistance)	0.0
Embedment Depth (ft) (Use Solver)	9.9

Strand & Bond Zone Calculations for Anchors

Row	Calc T_H (k)	Calc T (k)	Design T (k)	Req'd # Strands	Design # Strands	Calc Bond (ft)	Design Bond (ft)
1	102.0	108.6	116.0	3.30	4	38.7	38

Unbonded & Total Length Calculations for Anchors

Row	Y (ft)	Calc Unbond (ft)	Design Unbond (ft)	Design Total (ft)
1	10.0	9.5	15	53

FIGURE B-2

Anchored Pile Wall Design Calculations

Design Case P16-16 (Page 2 of 2)

APPENDIX C

ANCHOR POCKET AND WALL FACING DESIGN CALCULATIONS AND TIMBER LAGGING REFERENCE DATA

ANCHOR POCKET DESIGN SPREADSHEET	VERSION 3 (1/10/03)

DESIGN ASSUMPTIONS
E70XX Electrodes For All Welding
Cover Plates Welded to Flange at Each End, Along Narrow End & Returned Down Edge Along Pile Web
Web Stiffener Plates Are Full Depth, Are Flush At Bearing End, & Welded Full Length & Along Bearing End On One Side Only

CONNECTION INPUT DATA

Case	Pile Section	Pile Grade (ksi)	Plate Steel Grade (ksi)	Maximum Design Anchor Load (k)	Actual Pile Moment (ft-k)	Allow Pile Moment (ft-k)	Flange Width b_f (in)	Flange Thick t_f (in)	Beam Depth d (in)	Web Thick t_w (in)	Assume Cutout Width (in)	Req'd Flange Area (in)
1	W14x53	50.0	36.0	116.0	214.0	214.0	8.060	0.660	13.920	0.370	3.85	5.32

DESIGN CALCULATIONS FOR COVER PLATE

Case	Req'd Cover Plate Area (in^2)	Req'd Cover Plate Force (k)	Cover Plate E70XX Weld Size (in)	Req'd Weld Length L (in)	Design Weld Length L (in)	Design Weld Width (in)	Req'd Weld Return Length (in)	Design Cover Plate Thick (in)	Req'd Cover Plate Width (in)	Design Cover Plate Width (in)	Req'd Cover Plate Length (in)	Design Cover Plate Length (in)
1	3.52	83.7	0.3125	18.0	20.0	4.0	16.0	1.000	3.52	4.00	38.0	38.0

DESIGN CALCULATIONS FOR WEB STIFFENER

Case	Single Stiffener Force (k)	Total Stiffener E70XX Weld Size (in)	Stiffener Thickness (in)	Req'd Weld Length (in)	Design Weld & Stiffener Length (in)	Req'd Stiffener Compress Area (in^2)	Req'd Stiffener Width (in)	Design Stiffener Width (in)	Stiffener "b/t" Ratio	Allowable Stiffener "b/t" Ratio
1	58.0	0.3125	0.750	12.5	14.0	2.685	3.6	4.0	5.3	10.7

FIGURE C-1

Pile Design Calculations for Anchor Pockets

It is unclear how this factor is used. This calc appears to be for a single condition (i.e. interior span). If only providing calcs for one condition it should be for the worst case condition (i.e. first support). Ref ACI 318-11 or AISC beam span tables for design moments at first support, first interior span, interior support and interior span condition. For a wall this long it may be prudent to provide more reinforcing at the ends and then drop down to less for the interior spans and supports.

I think this should 4.5ksi which may help a little.

Concrete is supported by shear studs, not concrete pile. Clear span seems irrelevant. Should be using span to center of supports (i.e. 8ft.)

GENERAL INPUT DATA						FACING FLEXURE									
Case	Max Service AEP (psf)	Load Factor	Strength Reduc Factor	Pile Spacing (ft)	Pile Diam (ft)	Mom Reduc Factor	Cont Factor	Steel Area (in2/ft)	Wall Thick (in)	Steel Depth (in)	Shot Strength (ksi)	Steel Yield (ksi)	Clear Span (ft)	Req'd Nom Mom Strength (ft-k/ft)	Comp'd Nom Mom Strength (ft-k/ft)
1	1,397	1.50	0.90	8.0	2.0	1.00	2	0.62	8.0	4.0	4.0	60.0	6.0	8.73	10.99

FACING ONE-WAY SHEAR					STUD CONE-SHEAR					STUD TENSION					
Case	Strength Reduc Factor	Shear Reduc Factor	Req'd Nom Shear Strength (k/ft)	Comp'd Nom Shear Strength (k/ft)	Strength Reduc Factor	Vert Stud Spacing (in)	Nominal Stud Embed (in)	Req'd Nom Cone Strength (k)	Comp'd Nom Cone Strength (k)	Strength Reduc Factor	Stud Tensile Strength (ksi)	Stud Diam (in)	Stud Area (in2)	Req'd Nom Stud Strength (k)	Comp'd Nom Stud Strength (k)
1	0.85	0.80	5.92	6.07	0.85	12.0	6.0	14.79	28.61	0.90	60.0	0.625	0.307	13.97	18.41

FIGURE C-2

Shotcrete Facing Design Calculations

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Federal Highway Administration

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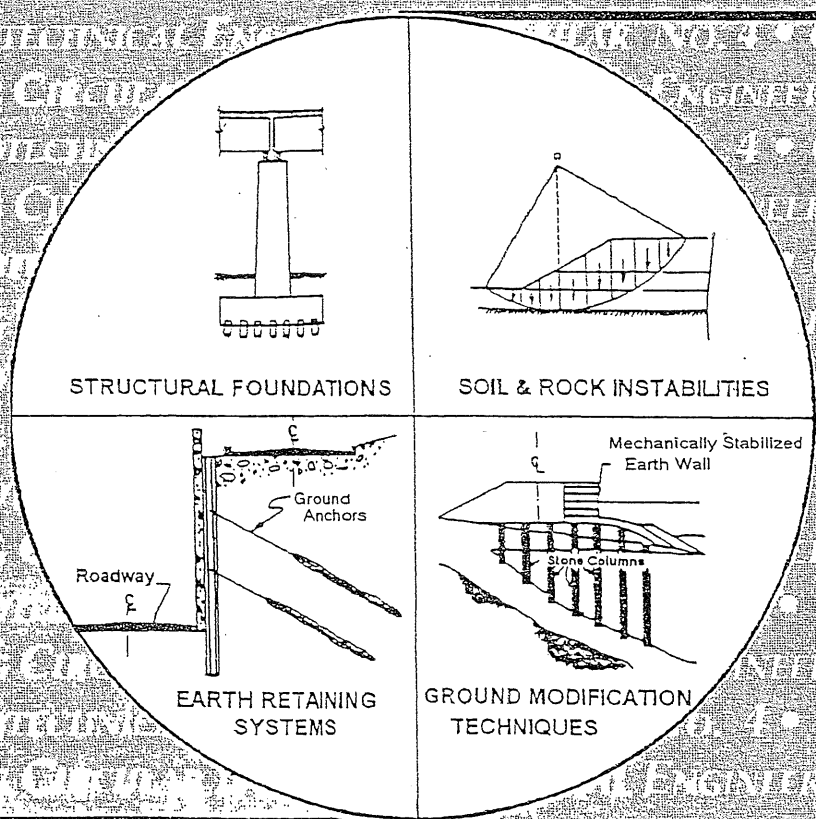
OFFICE OF BRIDGE TECHNOLOGY
400 SEVENTH STREET, SW
WASHINGTON, DC 20590

GEOTECHNICAL ENGINEERING CIRCULAR NO. 4

GROUND ANCHORS AND ANCHORED SYSTEMS



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15. Supplementary Notes
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16. Abstract:

This document presents state-of-the-practice information on the design and installation of cement-grouted ground anchors and anchored systems for highway applications. The anchored systems discussed include flexible anchored walls, slopes supported using ground anchors, landslide stabilization systems, and structures that incorporate tiedown anchors.

This document draws extensively from the FHWA-DP-68-IR (1988) design manual in describing issues such as subsurface investigation and laboratory testing, basic anchoring principles, ground anchor load testing, and inspection of construction materials and methods used for anchored systems. This document provides detailed information on design analyses for ground anchored systems. Topics discussed include selection of design earth pressures, ground anchor design, design of corrosion protection system for ground anchors, design of wall components to resist lateral and vertical loads, evaluation of overall anchored system stability, and seismic design of anchored systems. Also included in the document are two detailed design examples and technical specifications for ground anchors and for anchored walls.

17. Key Words Ground anchors, soldier beam and lagging walls, limit equilibrium, earth pressures, axial capacity, tiedowns, seismic design, contracting, specifications	18. Distribution Statement No Restrictions. This document is available to the public from the National Technical Information Service, Springfield, Virginia 22161

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For permanent walls and temporary walls that are considered critical, an allowable bending stress in the soldier beam, F_b, of 0.55 F_y, where F_y is the yield stress of the steel, is recommended. Steel sheet-pile and soldier beams are commonly either Grade 36 (F_y = 248 MPa) or Grade 50 (F_y = 345 MPa). For temporary SOE walls, a 20 percent increase in the allowable stress may be allowed for positive wall bending moments between anchor locations; no allowable stress increase is recommended for negative wall bending movements at the anchor locations. The required section modulus S_{req}, is calculated as:

$$S_{req} = \frac{M_{max}}{F_b} \qquad \text{(Equation 22)}$$

Standard SI units are S(mm^3), M_{max} (kN-m), and F_b (MPa). In most cases, several available steel sections will typically meet this requirement. The actual wall section selected will be based on contractor/owner preference, cost, constructability, and details of the anchor/wall connection.

When designing permanent anchored walls in relatively uniform competent materials, it is usually only necessary to check the final stage of construction provided that: (1) the ground can develop adequate passive resistance below the excavation to support the wall; (2) apparent earth pressure diagrams are used to assess the loading on the wall; and (3) there is minimal over excavation below each anchor level (FHWA-RD-97-130, 1998). For cases where there are large concentrated surcharges or berms at the ground surface, it is prudent to check wall bending moments for the initial cantilever stage (i.e., stage just prior to installation and lock-off of uppermost anchor).

Where the final excavation height is not the most critical condition, designers commonly use a staged construction analysis where the maximum wall bending moment, wall deflections, and wall embedment depth are evaluated for several stages of construction. An analysis is required for this case since the maximum bending moment may occur at an intermediate stage of construction (i.e., before the final excavation depth is reached). Intermediate construction stages may be critical when: (1) triangular earth pressure diagrams are used to design the wall; (2) the excavation extends significantly below an anchor level prior to stressing that anchor; (3) a cutoff wall is used to maintain the water level behind the wall; (4) the soil below the bottom of the excavation is weak resulting in active earth pressures that are greater than available resistance provided by the toe of the wall; and (5) structures are located near the wall.

5.4.2 Design of Lagging for Temporary Support

The thickness of temporary timber lagging for soldier beam and lagging walls is based primarily on experience or semi-empirical rules. Table 12 presents recommended thicknesses of construction grade lumber for temporary timber lagging. For temporary SOE walls, contractors may use other lagging thicknesses provided they can demonstrate good performance of the lagging thickness for walls constructed in similar ground.

Permanent timber lagging has been used in lieu of a concrete face to carry permanent wall loads. For permanent applications, the timber grade and dimensions should be designed according to structural guidelines. Several problems may exist for permanent timber lagging including: (1) need to provide fire protection for the lagging; (2) limited service life for timber; and (3) difficulty in providing

Table 12. Recommended thickness of temporary timber lagging (after FHWA-RD-75-130, 1976)

	Soil Description	Unified Soil Classification	Depth (m)	Recommended thickness of lagging (roughcut) for clear spans of:					
				1.5 m	1.8 m	2.1 m	2.4 m	2.7 m	3.0 m
COMPETENT SOILS	Silt or fine sand and silt above water table	ML, SM-ML							
	Sands and gravels (medium dense to dense)	GW, GP, GM, GS, SW, SP, SM	0 - 8	50 mm	75 mm	75 mm	75 mm	100 mm	100 mm
	Clays (stiff to very stiff); non-fissured	CL, CH	8 - 18	75 mm	75 mm	75 mm	100 mm	100 mm	125 mm
	Clays, medium consistency and $\frac{\gamma H}{S_u} < 5$	CL, CH							
DIFFICULT SOILS	Sand and silty sand (loose)	SW, SP, SM							
	Clayey sands (medium dense to dense) below water table	SC	0 - 8	75 mm	75 mm	75 mm	100 mm	100 mm	125 mm
	Clay, heavily overconsolidated, fissured	CL, CH	8 - 18	75 mm	75 mm	100 mm	100 mm	125 mm	125 mm
	Cohesionless silt or fine sand and silt below water table	ML, SM-SL							
POTENTIALLY DANGEROUS SOILS	Soft clays $\frac{\gamma H}{S_u} > 5$	CL, CH	0 - 5	75 mm	75 mm	100 mm	125 mm	--------	--------
	Slightly plastic silts below water table	ML	5 - 8	75 mm	100 mm	125 mm	150 mm	--------	--------
	Clayey Sands (loose), below water table	SC	8-11	100 mm	125 mm	150 mm	--------	--------	--------

Notes:
1) In the category of "potentially dangerous soils", use of soldier beam and lagging wall systems is questionable.
2) The values shown are based on construction grade lumber.
3) Local experience may take precedence over recommended values in this table.

Table 10. Properties of 15-mm diameter prestressing steel strands (ASTM A416, Grade 270 (metric 1860)).

Number of 15-mm diameter strands	Cross section area		Ultimate strength		Prestressing force					
					$0.8\ f_{pu}A_{ps}$		$0.7\ f_{pu}A_{ps}$		$0.6\ f_{pu}A_{ps}$	
	(in.^{2})	(mm^2)	(kips)	(kN)	(kips)	(kN)	(kips)	(kN)	(kips)	(kN)
1	0.217	140	58.6	260.7	46.9	209	41.0	182	35.2	156
3	0.651	420	175.8	782.1	140.6	626	123.1	547	105.5	469
4	0.868	560	234.4	1043	187.5	834	164.1	730	140.6	626
5	1.085	700	293.0	1304	234.4	1043	205.1	912	175.8	782
7	1.519	980	410.2	1825	328.2	1460	287.1	1277	246.1	1095
9	1.953	1260	527.4	2346	421.9	1877	369.2	1642	316.4	1408
12	2.604	1680	703.2	3128	562.6	2503	492.2	2190	421.9	1877
15	3.255	2100	879.0	3911	703.2	3128	615.3	2737	527.4	2346
19	4.123	2660	1113.4	4953	890.7	3963	779.4	3467	668.0	2972

The type and size of the anchors should be evaluated prior to design of the anchor bond zone because the required hole diameter varies as a function of the tendon size. Table 11 can be used to estimate the minimum trumpet opening for strand or bar tendons.

Table 11. Guidance relationship between tendon size and trumpet opening size.

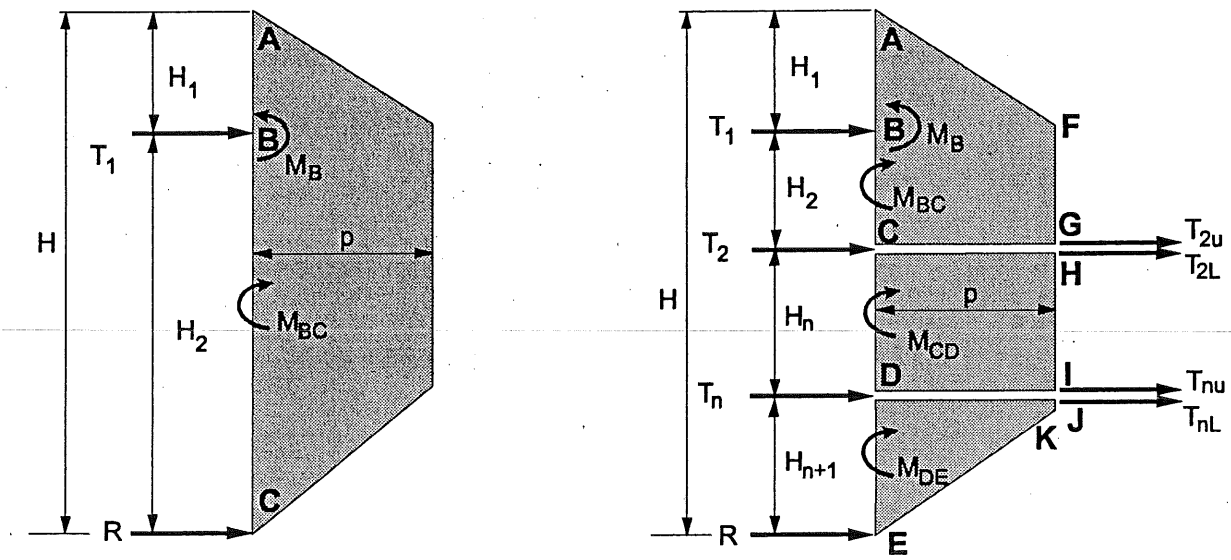
Tendon type	Minimum suggested trumpet opening size (mm)	
	Class II corrosion protection	Class I corrosion protection
Number of 15-mm diameter strands		
4	102	150
7	115	165
9	127	178
11	140	191
13	153	203
17	165	216
Bar diameter (mm)		
26	64	89
32	70	95
36	76	102

5.4 WALL DESIGN BASED ON LATERAL PRESSURES

5.4.1 Design of Soldier Beams and Sheet-Piles

Anchored soldier beam and lagging walls and sheet-pile walls are designed to resist lateral loads resulting from apparent pressure envelopes including appropriate surcharges, water forces, and seismic forces. Figure 38 illustrates the method used to calculate wall bending moments for single-level and multi-level walls for the exposed portion of the wall using the hinge method. The exposed portion of the wall refers to the height of wall between the ground surface and the bottom of the excavation. Figure 39 shows the equations that may be used to calculate wall bending moments for

single-level and multi-level walls using the tributary area method. For walls constructed in competent soils such as most sands and stiff clays, the maximum bending moment, M_{max}, occurs in the exposed portion of the wall. For walls that penetrate deep deposits of weak material, the maximum bending moment may occur in the embedded portion of the wall. The embedded portion of the wall refers to the length of wall that is below the base of the excavation. Bending moment calculation for the embedded portion of the wall is provided in section 5.5.



$M_B = \Sigma M_B$

M_{BC}= Maximum moment between B and C; located at point where shear = 0

(a) Walls with one level of ground anchors

$M_B = \Sigma M_B$

$M_C = M_D = M_E = 0$

M_{BC} = Maximum moment between B and C; located at point where shear = 0

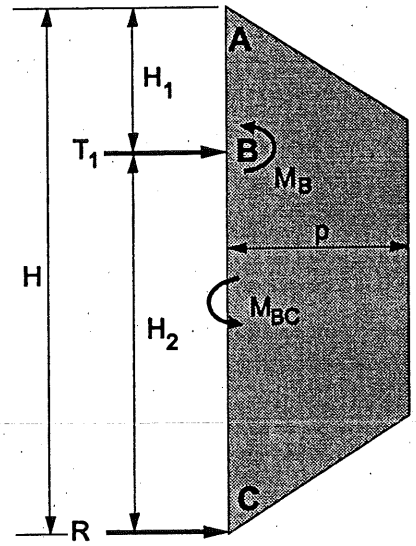
M_{CD} ; M_{DE} : Calculated as for M_{BC}

(b) Walls with multiple levels of ground anchors

Figure 38. Calculation of wall bending moments using hinge method.

Selection of an appropriate wall section is based on the calculated maximum bending moment in the vertical wall element. The negative bending moment calculated at the location of the first anchor is evaluated by summing moments about the first anchor location. The vertical wall elements are commonly assumed to be continuous between each support location. The maximum positive bending moment between each ground anchor is, for the tributary area method, assumed equal to $1/10\ p\ell^2$ where p is the maximum ordinate of the apparent pressure envelope and ℓ is the vertical spacing between adjacent anchors. For the hinge method, the maximum positive bending moment between each ground anchor corresponds to the point of zero shear. These methods provide conservative estimates of the calculated bending moments, but may not accurately predict the specific location. For continuous sheet-pile walls, the bending moment per unit of wall is used to select an appropriate sheet-pile section. To evaluate the maximum bending moment for design of a

soldier beam, the maximum bending moment per unit of wall calculated from figure 38 and 39 is multiplied by the center-to-center spacing of the soldier beams.



$$M_B = \frac{13}{54} H_1^2 p$$

$$T_1 = \frac{(23H^2 - 10HH_1)}{54(H-H_1)} p$$

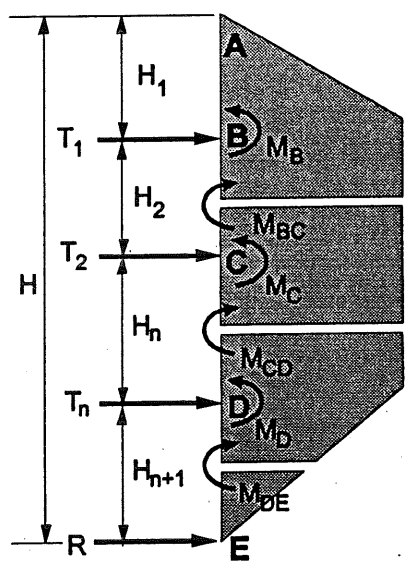
$$R = \frac{2}{3}Hp - T_1$$

Solve for point of zero shear

$$x = \frac{1}{9}\sqrt{(26H^2 - 52HH_1)}$$

$$M_{BC} = Rx - \frac{px^3}{4(H-H_1)}$$

(a) Walls with single level of ground anchors



$$M_B = \frac{13}{54} H_1^2 p$$

$$T_1 = \left(\frac{2}{3}H_1 + \frac{H_2}{2}\right) p$$

$$T_2 = \left(\frac{H_2}{2} + \frac{H_n}{2}\right) p$$

$$T_n = \left(\frac{H_n}{2} + \frac{23H_{n+1}}{48}\right) p$$

$$R = \left(\frac{3}{16} H_{n+1}\right) p$$

Maximum moment below B = $pL^2/10$
where L is the larger of H_2, H_n, H_{n+1}

(b) Walls with multiple level of ground anchors

Figure 39. Calculation of wall bending moments using tributary area method.