GEOTECHNICAL REVIEW CHECK PRINT

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

400 N 34th St, Suite 100; Seattle, WA 98103

PROJECT: Cleveland Innerbelt CCG1

CLIENT: HNTB / Walsh

CALC. NO: GC-073 REV4 Add 2

JOB NO: 21-1-21361-614

SHEETS: 32

SUBMITTAL NO.: GC-073 Addendum2

TITLE:
External stability of Wall C1

PURPOSE AND OBJECTIVE:
Evaluate external stability of Wall C1 after the wall bottom is deepened to the same elevation as the bottom of wall C.

SUMMARY AND CONCLUSIONS:
See summaries on Sheets 1 and 2

SIGN OFF

REV. NO.	ORIGINATOR Sign/Date	TECHNICAL REVIEW Sign/Date	PRINCIPAL REVIEW Sign/Date
0	MMY [signature] Yan 7/12/12	MIKE HARNEY [signature] 7/12/12	[signature] 8-2-2012

Rev. No	Revision Description	Revision Date

STATE OF OHIO
GERARD J. BUECHEL
72022
REGISTERED
PROFESSIONAL ENGINEER

[signature]
8-2-2012

CALCULATION GC-073 Rev 4 Addendum 2:
Wall C1 External Stability

Table of Contents

Calculation Objective:

Bottom elevation of MSE Wall C1 is considered to move down to the same elevation as Wall C (shown on Sheet 7). The external stability with the new wall height is calculated and checked in this addendum.

General Approach / Assumptions:

External stability for Wall C1 was checked in this calculation package considering discontinuous reinforcement at the base of the wall. An in-house, QA/QC'd Excel spreadsheet called "External_Stability_v2.2.xlsx" was used. This spreadsheet was originally designed for Allowable Stress Design (ASD) and has been updated for Load and Resistance Factor Design (LRFD). See Sheets 86 to 89 in GC-073 for more information about the spreadsheet.

The wall height at selected stations is measured from the latest wall plan (Sheets 3-13) and has been summarized in the following table. For the purposes of this calculation, the variable H is used for the as-design height of the wall (i.e., prior to deepening its base). A new variable, H' is defined for this calculation as the increased height of Wall C1 due to deepening its base to the same elevation as the base of gravity block wall C. The wall heights H and H' are both presented on Sheet 11. Other parameters for the spreadsheet input have been calculated in GC-012, GC-013, and GC-073. The cross section drawings were included in GC-073.

Summary and Conclusions:

The spreadsheets used for external stability analyses are attached on Sheets 15 through 26, and the analysis results are summarized as follows:

	Sta. 11+90[1]	Sta. 11+95	Sta. 12+00	Sta. 12+25	Sta. 12+70	Sta. 12+90
Height (H)[2], ft	6	7.3	10.5	18	36	23
Height (H')[2], ft	11	12	14	22	42	25
Backslope (β), degree	6.5	6.5	6.5	6.5	0	6.5
Friction angle of the foundation soils, degree	30	30	30	30	30	30
req. B/H_{min}	B=8'	B=15'[4]	1.1	1.1	1.1	1.1
Controlling Factor	AASHTO	Reinforced Earth Co. Shop Drawings	Global Stability GC-012 Sheet 2[3]	Global Stability GC-012 Sheet 2[3]	Global Stability GC-012 Sheet 2[3]	Global Stability GC-012 Sheet 2[3]
Spreadsheet Calculation	Sheets 15-17	Sheets 18-20	Sheets 21-23	Sheets 24-26	Sheets 27-29	Sheets 30-32

Note:

1. The wall station used in this calculation package refers to Wall C station. The selected stations have been marked on Sheet 7.
2. Wall heights H and H' have been shown on Sheet 11.
3. Global stability of Wall C1 in GC-012 indicated that the B/Hmin ratio needs to be 1.1 to reach required FS. Thus 1.1 is analyzed and checked in this calculation package.
4. Refer to Sheet 14 for the reinforcement length in this station.

The analyses indicate that (1) the wall design meets external stability requirements with a minimum B/H of 1.1 from Stations 12+00 through 14+00; and (2) a reinforcement length B of15ft is required from Stations 11+90 to 12+00 (refer to Sheet 14).

STATE OF OHIO

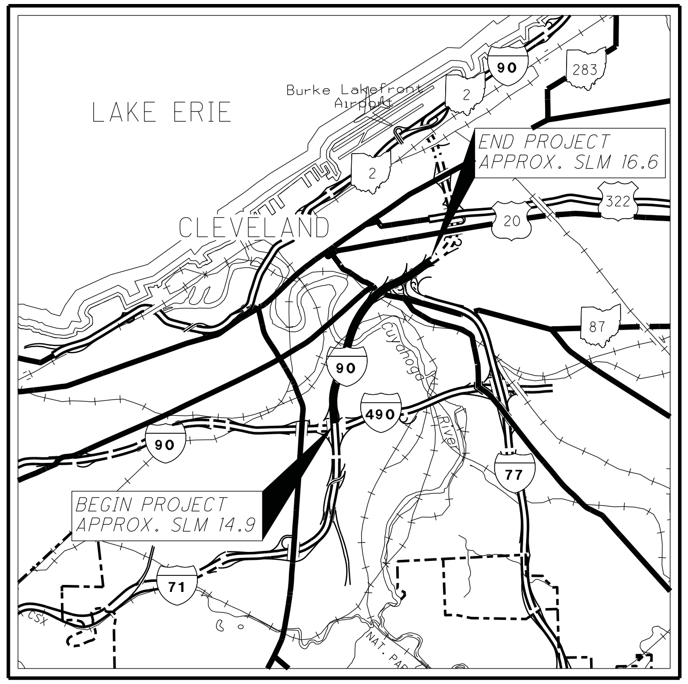
DEPARTMENT OF TRANSPORTATION

CUY-90-14.90

CITY OF CLEVELAND

CUYAHOGA COUNTY

(INDEX OF SHEETS - SEE DWG. NO. 2)



LOCATION MAP

LATITUDE: 41°29'12" LONGITUDE: 81°41'28"

SCALE IN MILES

0 0.5 1 1.5 2

N

PORTION TO BE IMPROVED

INTERSTATE HIGHWAY

STATE & FEDERAL ROUTES

COUNTY & TOWNSHIP ROADS

OTHER ROADS

DESIGN DESIGNATION

SEE DWG. NO. DD-002 INCLUDED IN SURVEY CONTROL.

PROJECT DESCRIPTION

WALL C - GRAVITY BLOCK RETAINING WALL ALONG I.R. 90 WESTBOUND, AND FAIRFIELD AVE.

WALL C1 - MSE RETAINING WALL ALONG FAIRFIELD AVE. AND FORWARD ABUTMENT OF BL-4.

WALL C2 - GRAVITY BLOCK RETAINING WALL ALONG RAMP A6

LIMITED ACCESS

SEE DWG. NO. TI-050 INCLUDED IN SURVEY CONTROL.

2010 SPECIFICATIONS

THE STANDARD SPECIFICATIONS OF THE STATE OF OHIO, DEPARTMENT OF TRANSPORTATION, INCLUDING CHANGES AND SUPPLEMENTAL SPECIFICATIONS LISTED IN THE PROPOSAL SHALL GOVERN THIS IMPROVEMENT.

WALL "C"
WALL "C1"
WALL "C2"

UNDERGROUND UTILITIES

CONTACT BOTH SERVICES
CALL TWO WORKING DAYS
BEFORE YOU DIG

CALL
1-800-362-2764
(TOLL FREE)
OHIO UTILITIES PROTECTION SERVICE
NON-MEMBERS
MUST BE CALLED DIRECTLY

OIL & GAS PRODUCERS PROTECTIVE
SERVICE CALL: 1-800-925-0988

WALSH CONSTRUCTION
929 WEST ADAMS STREET
CHICAGO, IL 60607

HNTB
1100 Superior Ave. Ste 1330
Cleveland, OH 44114

ENGINEERS SEAL:	ENGINEERS SEAL:
SIGNED: DATE:	SIGNED: DATE:

APPROVED ____________
DATE ______ DISTRICT DEPUTY DIRECTOR

APPROVED ____________
DATE ______ DIRECTOR, DEPARTMENT OF TRANSPORTATION

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A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH CONSTRUCTION / HNTB

CONSTRUCTION PROJECT NO. 10-3000

RAILROAD INVOLVEMENT

FEDERAL PROJECT NO. E090(546) E100(247)

PID NO. 77332/85531

DELIVERABLE ID 1440-WALL C

CUY-90-14.90

DWG. NO. 1/11

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File: 49633-S-BR-COV-C_C1_C2.dgn

INDEX OF SHEETS

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DESIGN AGENCY
WALSH CONSTRUCTION
HNTB

CLEVELAND'S INNERBELT BRIDGE
OHIO DEPARTMENT OF TRANSPORTATION

WALL C

SHEET INDEX
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FARIFIELD AVE. AND RAMP A6

DESIGNED AKS | CHECKED CAB | DRAWN CDD | CHECKED CAB | REVIEWED DBT | DATE 9-13-11
STRUCTURE FILE NUMBER

CUY-90-14.90
PID No. 77332/85531

THE CONSTRUCTION OF THIS BUILDABLE UNIT WILL BE IN CONJUNCTION WITH THE CONSTRUCTION OF THE FOLLOWING BUILDABLE UNITS:

1011	SURVEY CONTROL
1020	ROADWAY - TREMONT
1020B	GRADING - TREMONT #2
1040	MOT - PHASES 1-2
1050	MOT - PHASE 3
1060	MOT - PHASE 4
1070	MOT - PHASE 5
1080	MOT - PHASE 6
1120	LIGHTING - TREMONT - ODOT
1130	LIGHTING - TREMONT - CITY
1210	BRIDGES CUY-90-1526 (BL-4)
2150	SWPPP - TREMONT

STANDARD DRAWINGS AND SUPPLEMENTAL SPECIFICATIONS:

REFER TO THE FOLLOWING STANDARD CONSTRUCTION DRAWING(S):

DM-1.1	DATED (REVISED)	04-21-2006
A-1-69	DATED (REVISED)	07-19-2002

REFER TO APPENDIX SS-1 FOR THE FOLLOWING SUPPLEMENTAL SPECIFICATION:

MODIFIED SS 840	DATED (REVISED)	06-03-2010
SS 836	DATED (REVISED)	04-15-2005

DESIGN SPECIFICATIONS:

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS, (AASHTO) 2010, AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS, 5TH EDITION, AND 2007 EDITION OF THE OHIO DEPARTMENT OF TRANSPORTATION (ODOT) BRIDGE DESIGN MANUAL WITH SUBSEQUENT UPDATES THROUGH APRIL 2010.

DESIGN DATA:

CONCRETE CLASS C - REFER TO CMS 511, COMPRESSIVE STRENGTH 4,000 PSI (CONCRETE COPING AND LEVELING PAD)

REINFORCING STEEL - ASTM A615 OR A996 GRADE 60, MINIMUM YIELD STRENGTH 60,000 PSI. (EPOXY COATED)

WALL DESIGN CRITERIA:

REFER TO GEOTECHNICAL DESIGN MEMORANDUM GD-9, REVISION NO. 3, DATED 9-16-2011. WALL DESIGN BASED ON SUBGRADE SOIL EFFECTIVE FRICTION ANGLE ϕ = 30° (C AND C1), ϕ = 28° (C2)

UNSUITABLE SOILS:

NO UNSUITABLE SOILS ANTICIPATED

QUANTITIES:

THE FOLLOWING WALL C ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE ESTIMATED QUANTITIES FOR USE AS DIRECTED BY THE ENGINEER:

ITEM 203 SELECT GRANULAR BACKFILL, AS PER PLAN	39 CU YD
ITEM 304 OR 601 COMPACTED AGGREGATE	576 CU YD
ITEM 840 WALL EXCAVATION, ESTIMATED	290 CU YD

THE FOLLOWING WALL C1 ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE ESTIMATED QUANTITIES FOR USE AS DIRECTED BY THE ENGINEER:

ITEM 203 SELECT GRANULAR BACKFILL, AS PER PLAN	4508 CU YD
ITEM 512 EPOXY-URETHANE SEALER, AS PER PLAN	576 SQ YD
ITEM 840 WALL EXCAVATION, ESTIMATED	653 CU YD

THE FOLLOWING WALL C2 ESTIMATED QUANTITIES HAVE BEEN INCLUDED IN THE ESTIMATED QUANTITIES FOR USE AS DIRECTED BY THE ENGINEER:

ITEM 203 SELECT GRANULAR BACKFILL, AS PER PLAN	14 CU YD
ITEM 304 OR 601 COMPACTED AGGREGATE	286 CU YD
ITEM 840 WALL EXCAVATION, ESTIMATED	0 CU YD

PROPRIETARY RETAINING WALL DATA

THE PROPRIETARY WALL SUPPLIER SHALL DESIGN THE INTERNAL STABILITY OF A MECHANICALLY STABILIZED EARTH (MSE) WALL IN ACCORDANCE WITH MODIFIED SS840 (SS-01) TO SUPPORT THE ABUTMENT. THE DESIGN FOR INTERNAL STABILITY SHALL INCLUDE A NOMINAL (I.E., UNFACTORED) HORIZONTAL STRIP LOAD DUE TO FRICTION (FR) FROM THE SUPERSTRUCTURE OF 2.3 K/FT. APPLIED PERPENDICULAR TO THE FACE OF WALL AT THE BASE OF THE CONCRETE FOOTING. THIS STRIP LOAD DOES NOT INCLUDE EARTH PRESSURE LOADS FROM THE ABUTMENT BACKFILL. HOWEVER, THE PROPRIETARY WALL SUPPLIER SHALL INCLUDE AT REST EARTH PRESSURE LOADS FROM THE ABUTMENT BACKFILL IN THE DESIGN CALCULATIONS. CONTINUOUS REINFORCEMENT SHALL NOT BE USED BY THE PROPRIETARY WALL SUPPLIER.

EXCAVATION, SHEETING AND BRACING

EXCAVATION ENVELOPES AS DETAILED IN THE PLANS SHOULD BE PROTECTED FROM CAVING AND SLOUGHING. WHERE CLEARANCES AND CONSTRUCTION SEQUENCING WILL NOT ALLOW FOR SLOPED EXCAVATIONS, APPROPRIATE SHEETING OR BRACING METHODS SHALL BE EMPLOYED BY THE CONTRACTOR.

GRAVITY WALL

PART 1: GENERAL

1.1 SCOPE
WORK INCLUDES FURNISHING AND INSTALLING CONCRETE RETAINING WALL UNITS TO THE LINES AND GRADES DESIGNATED ON THE CONSTRUCTION DRAWINGS AND AS SPECIFIED HEREIN.

1.2 REFERENCE STANDARDS
ASTM C94 READY-MIXED CONCRETE
ASTM C1372 SEGMENTAL RETAINING WALL UNITS

1.3 DELIVERY, STORAGE, AND HANDLING
A. CONTRACTOR SHALL CHECK THE MATERIALS UPON DELIVERY TO ASSURE PROPER MATERIAL HAS BEEN RECEIVED.
B. CONTRACTOR SHALL PREVENT EXCESSIVE MUD, WET CEMENT AND LIKE MATERIALS FROM COMING IN CONTACT WITH THE SRW UNITS.
C. CONTRACTOR SHALL PROTECT THE MATERIALS FROM DAMAGE. DAMAGED MATERIAL SHALL NOT BE INCORPORATED IN THE PROJECT

PART 2: MATERIALS

2.1 WALL UNITS
A. WALL UNITS SHALL BE REDI-ROCK AS PRODUCED BY A LICENSED MANUFACTURER.
B. WALL UNITS SHALL BE MADE WITH READY-MIXED CONCRETE IN ACCORDANCE WITH ASTM C94, LATEST REVISION, AND PER THE FOLLOWING CHART:

CLIMATE	AIR CONTENT	28 DAY COMPRESSIVE STRENGTH (PSI)	SLUMP*
SEVERE	4½% - 7½%	4000	5" +/- 1½"

* HIGHER SLUMPS ARE ALLOWED IF ACHIEVED BY USE OF APPROPRIATE ADMIXTURES.
NOTWITHSTANDING ANYTHING STATED ABOVE, ALL MATERIAL USED IN THE WALL UNITS MUST MEET APPLICABLE ASTM AND LOCAL REQUIREMENTS FOR EXTERIOR CONCRETE.

C. EXTERIOR BLOCK DIMENSIONS SHALL BE UNIFORM AND CONSISTENT. MAXIMUM DIMENSIONAL DEVIATIONS SHALL BE 1% EXCLUDING THE ARCHITECTURAL SURFACE. MAXIMUM WIDTH (FACE TO BACK) DEVIATION INCLUDING THE ARCHITECTURAL SURFACE SHALL BE 1.0 INCH.
D. EXPOSED FACE SHALL BE FINISHED AS SPECIFIED. OTHER SURFACES TO BE SMOOTH FORM TYPE. DIME-SIZE BUG HOLES ON THE BLOCK FACE MAY BE PATCHED AND/OR SHAKE-ON COLOR STAIN CAN BE USED TO BLEND INTO THE REMAINDER OF THE BLOCK FACE.

2.2 LEVELING PAD AND FREE DRAINING BACKFILL
A. LEVELING PAD SHALL BE CRUSHED STONE. SEE DETAIL SHEET DEFINING LEVELING PAD OPTIONS FOR DRAIN PLACEMENT IN THE BOTTOM OF THE FOUNDATION LEVELING PAD.
B. FREE DRAINING BACKFILL MATERIAL SHALL BE WASHED STONE AND SHALL BE PLACED TO A MINIMUM OF 1" WIDTH BEHIND THE BACK OF THE WALL AND SHALL EXTEND VERTICALLY FROM THE LEVELING PAD TO AN ELEVATION 4" BELOW THE TOP OF WALL.
C. BACKFILL MATERIAL SHALL BE APPROVED BY THE GEOTECHNICAL ENGINEER. SITE EXCAVATED SOILS MAY BE USED IF APPROVED UNLESS OTHERWISE SPECIFIED IN THE DRAWINGS. UNSUITABLE SOILS WITH A PL>6, ORGANIC SOILS AND FROST SUSCEPTIBLE SOILS SHALL NOT BE USED WITHIN A 1 TO 1 INFLUENCE AREA.
D. WHERE ADDITIONAL FILL IS NEEDED, CONTRACTOR SHALL SUBMIT SAMPLE AND SPECIFICATIONS TO THE ENGINEER FOR APPROVAL.

2.3 BACKFILL MATERIAL
A. BACKFILL MATERIAL SHALL CONFORM TO CMS 703.17 (AGGREGATE MATERIALS FOR ITEM 304 AGGREGATE BASE) OR CMS 703.19A (CRUSHED AGGREGATE SLOPE PROTECTION AND FILTER AGGREGRATE FOR ITEM 601 SLOPE AND CHANNEL PROTECTION)

PART 3: CONSTRUCTION OF WALL SYSTEM

3.1 EXCAVATION
A. CONTRACTOR SHALL EXCAVATE TO THE LINES AND GRADES SHOWN ON THE CONSTRUCTION DRAWINGS.

3.2 FOUNDATION SOIL PREPARATION
A. NATIVE FOUNDATION SOIL SHALL BE COMPACTED TO 95% OF STANDARD PROCTOR OR 90% OF MODIFIED PROCTOR PRIOR TO PLACEMENT OF THE LEVELING PAD MATERIAL.
B. IN-SITU FOUNDATION SOIL SHALL BE EXAMINED BY THE ENGINEER TO ASSESS WHETHER THE ACTUAL FOUNDATION SOILS ARE CONSISTENT WITH FOUNDATION SOILS ASSUMED DURING DESIGN . SOIL NOT CONSISTENT WITH DESIGN SOIL SHALL BE REMOVED AND REPLACED WITH ACCEPTABLE, COMPACTED MATERIAL.

3.3 LEVELING PAD PLACEMENT
A. LEVELING PAD SHALL BE PLACED AS SHOWN ON THE CONSTRUCTION DRAWINGS.
B. LEVELING PAD SHALL BE PLACED ON UNDISTURBED NATIVE SOILS OR SUITABLE REPLACEMENTS FILLS.
C. LEVELING PAD SHALL BE COMPACTED TO 95% OF STANDARD PROCTOR OR 90% OF MODIFIED PROCTOR TO ENSURE A LEVEL, HARD SURFACE ON WHICH TO PLACE THE FIRST COURSE BLOCKS. PAD SHALL BE CONSTRUCTED TO THE PROPER ELEVATION TO ENSURE THE FINAL ELEVATION SHOWN ON THE PLANS.
D. LEVELING PAD SHALL HAVE A 6 INCH MINIMUM DEPTH FOR WALLS UNDER 8 FEET IN HEIGHT AND A 12 INCH MINIMUM DEPTH FOR WALLS OVER 8 FEET. PAD DIMENSIONS SHALL EXTEND BEYOND THE BLOCKS IN ALL DIRECTIONS TO A DISTANCE AT LEAST EQUAL TO THE DEPTH OF THE PAD OR AS DESIGNED BY ENGINEER.
E. FOR STEPS AND PAVERS, A MINIMUM OF 1" - 1½" OF FREE DRAINING SAND SHALL BE SCREEDED SMOOTH TO ACT AS A PLACEMENT BED FOR THE STEPS OR PAVERS.

3.4 UNIT INSTALLATION
A. THE FIRST COURSE OF WALL UNITS SHALL BE PLACED ON THE PREPARED LEVELING PAD WITH THE AESTHETIC SURFACE FACING OUT AND THE FRONT EDGES TIGHT TOGETHER. ALL UNITS SHALL BE CHECKED FOR LEVEL AND ALIGNMENT AS THEY ARE PLACED.
B. ENSURE THAT UNITS ARE IN FULL CONTACT WITH LEVELING PAD. PROPER CARE SHALL BE TAKEN TO DEVELOP STRAIGHT LINES AND SMOOTH CURVES ON BASE COURSE AS PER WALL LAYOUT.
C. THE BACKFILL IN FRONT AND BACK OF ENTIRE BASE ROW SHALL BE PLACED AND COMPACTED TO FIRMLY LOCK THEM IN PLACE. CHECK ALL UNITS AGAIN FOR LEVEL AND ALIGNMENT. ALL EXCESS MATERIAL SHALL BE SWEPT FROM TOP OF UNITS.
D. INSTALL NEXT COURSE OF WALL UNITS ON TOP OF BASE ROW. POSITION BLOCKS TO BE OFFSET FROM SEAMS OF BLOCKS BELOW. BLOCKS SHALL BE PLACED FULLY FORWARD SO KNOB AND GROOVE ARE ENGAGED. CHECK EACH BLOCK FOR PROPER ALIGNMENT AND LEVEL. BACKFILL TO 12 INCH WIDTH BEHIND BLOCK WITH FREE DRAINING BACKFILL. SPREAD BACKFILL IN UNIFORM LIFTS NOT EXCEEDING 9 INCHES. EMPLOY METHODS USING LIGHTWEIGHT COMPACTION EQUIPMENT THAT WILL NOT DISRUPT THE STABILITY OR BATTER OF THE WALL. HAND-OPERATED PLATE COMPACTION EQUIPMENT SHALL BE USED AROUND THE BLOCK AND WITHIN 3 FEET OF THE WALL TO ACHIEVE CONSOLIDATION. COMPACT BACKFILL TO 95% OF STANDARD PROCTOR (ASTM D 698, AASHTO T-99) DENSITY WITHIN 2% OF ITS OPTIMUM MOISTURE CONTENT.
E. INSTALL EACH SUBSEQUENT COURSE IN LIKE MANNER. REPEAT PROCEDURE TO THE EXTENT OF WALL HEIGHT.
F. ALLOWABLE CONSTRUCTION TOLERANCE AT THE WALL FACE IS 2 DEGREES VERTICALLY AND 1 INCH IN 10 FEET HORIZONTALLY.

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DESIGN AGENCY: WALSH CONSTRUCTION / HNTB

WALL C

GENERAL NOTES
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FARIFIELD AVE. AND RAMP A6

DESIGNED AKS | CHECKED CAB | DRAWN CDD | CHECKED CAB | REVIEWED DBT | DATE 9-13-11 | STRUCTURE FILE NUMBER

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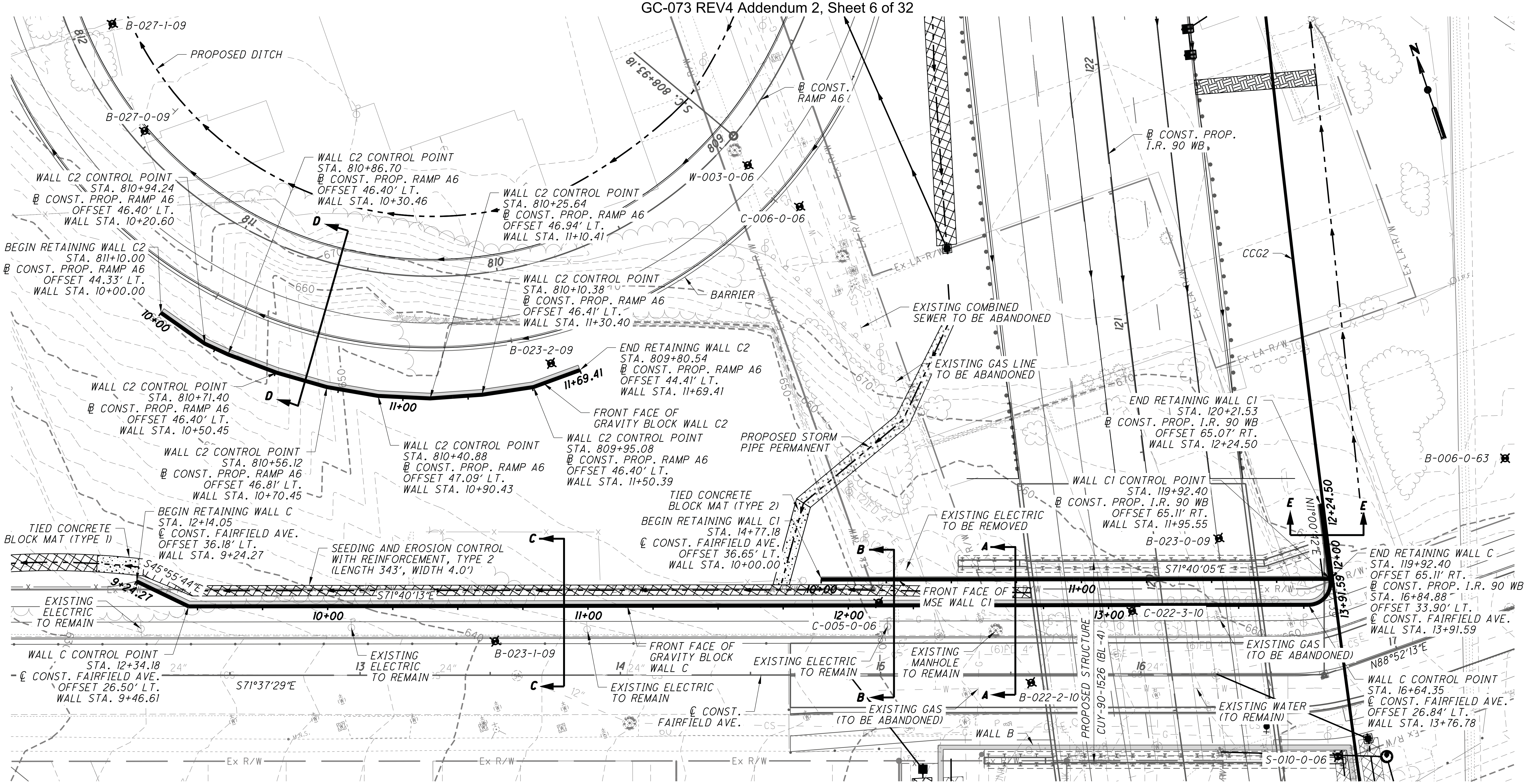

PLAN

BORING / CPT	STATION	OFFSET
S-010-0-06	119+24.00	59.0' RT.
B-022-2-10	119+68.00	54.0' LT.
B-023-0-09	120+13.44	24.67' RT
B-006-0-63	120+30.00	138.0' RT
C-022-3-10	119+90.00	12.0' LT
B-025-0-09	121+21.32	46.79' LT
C-005-0-06	120+05.00	108.00' LT

BORING AND CPT LOCATIONS

BORING / CPT	STATION	OFFSET
B-023-2-09	121+09.76	221.81' LT
B-027-0-09	122+13.00	367.00' LT
B-027-1-09	122+54.42	374.99' LT
W-003-0-06	121+76.00	138.00' LT
C-006-0-09	121+58.00	120.00' LT

LIST OF UTILITIES

EXIST. COMBINED SEWERS	IMPACTED
EXIST. ELECTRIC LINES	IMPACTED

BENCHMARK DATA

SEE BM24 ON DWG. NO. BM-004 INCLUDED IN SURVEY CONTROL

LEGEND

- BORING OR CPT LOCATION
- SEEDING AND EROSION CONTROL WITH TURF REINFORCING, TYPE 2, PER SS 836
- TIED CONCRETE BLOCK MAT (TYPE 1 OR TYPE 2)

'B', 'W' OR 'S' = BORINGS
'C' = CONE PENETROMETER TEST (CPT) SOUNDINGS

℄ CONST. PROP. I.R. 90 WB CURVE DATA:
P.I. = STA. 126+69.54
Δ = 16°25'51" RT.
Dc = 00°35'00"
R = 9822.14'
T = 1418.10'
L = 2816.74'
E = 101.84'

℄ CONST. PROP. RAMP A6:
P.I. = STA. 836+03.51
Δ = 173°37'54" RT.
Dc = 38°00'00"
R = 150.78'
T = 2710.33'
L = 456.93'
E = 2563.74'

℄ CONST. FAIRFIELD AVE. TANGENT DATA:
P.I. = STA. 16+70.39
†Dir = S71°37'29"E
L = 670.39'

NOTES:

1. WALL C1 BASELINE IS LOCATED AT FRONT FACE OF MSE WALL.
2. WALL C AND C2 BASELINE IS LOCATED AT FRONT FACE OF BOTTOM OF GRAVITY BLOCK WALL.
3. FOR ELEVATION OF WALL C AND C1, SEE SHEET 5 OF 11.
4. FOR ELEVATION OF WALL C2, SEE SHEET 6 OF 11.
5. FOR SECTION A-A, SEE SHEET 9 OF 11.
6. FOR SECTION B-B, SEE SHEET 10 OF 11.
7. FOR SECTIONS C-C AND D-D, SEE SHEET 11 OF 11.
8. BORING AND CPT STATION/OFFSET BASED ON ℄ CONST. PROP. I.R. 90 WB ALIGNMENT.
9. TURF REINFORCING MATERIALS SHALL MEET MANUFACTURER REQUIREMENTS FOR THE SLOPES AND GRADES SHOWN ON THE PLANS. INSTALLATION SHALL BE IN ACCORDANCE WITH SS 836 AND MANUFACTURER RECOMMENDATIONS.

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ENGINEER'S SEAL

NO.	REVISIONS	DATE
A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH CONSTRUCTION / HNTB

CLEVELAND'S INNERBELT BRIDGE

WALL C

SITE PLAN - 1
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FAIRFIELD AVE. AND RAMP A6

DESIGNED AKS | CHECKED CAB | DRAWN CDD | CHECKED CAB | REVIEWED DBT | DATE 9-13-11 | STRUCTURE FILE NUMBER

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4 / 11

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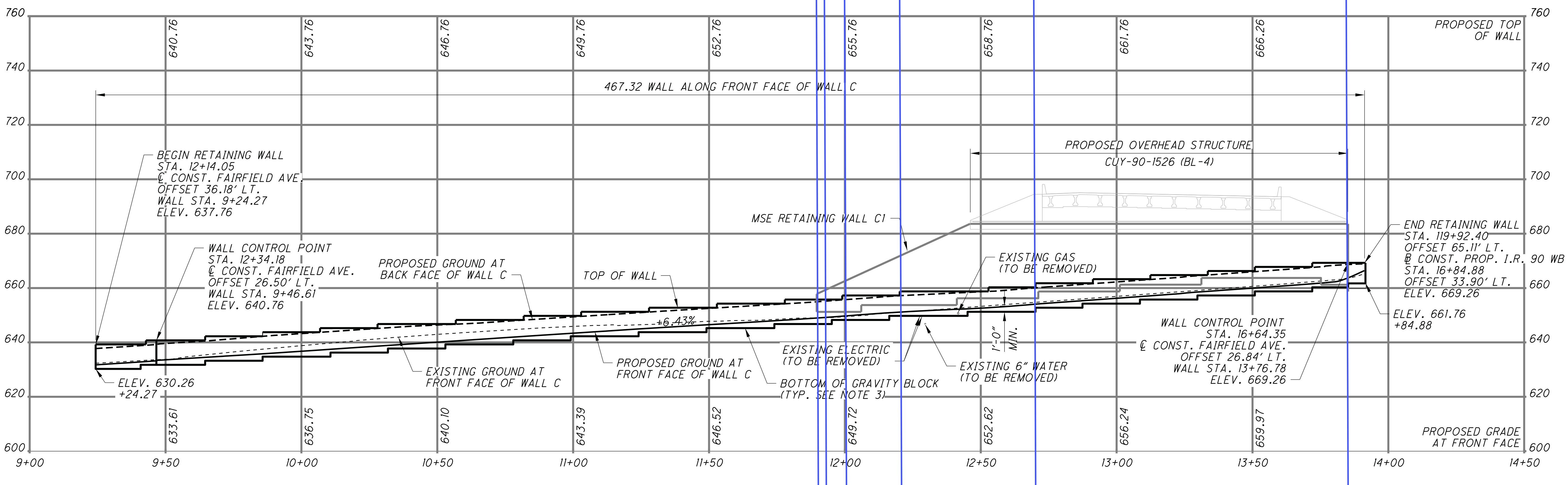
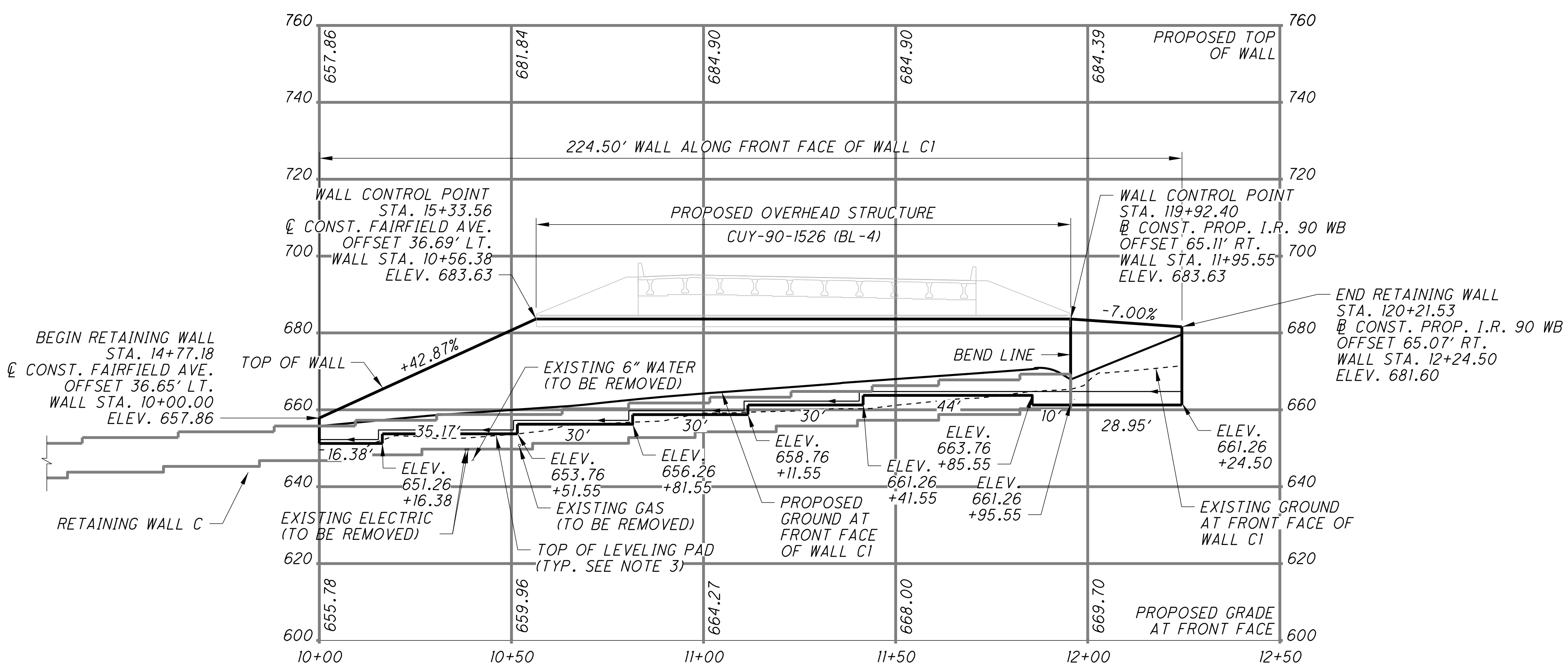


ELEVATION - GRAVITY BLOCK WALL C



ELEVATION - MSE RETAINING WALL C1

NOTES:

1. ALL TOP OF WALL C ELEVATIONS ARE GIVEN AT THE TOP OF GRAVITY BLOCK.
2. ALL TOP OF WALL C1 ELEVATIONS ARE GIVEN AT THE TOP OF COPING.
3. MINIMUM DISTANCE FROM PROPOSED GROUND SURFACE TO THE TOP OF LEVELING PAD FOR WALL C1 AND BOTTOM OF GRAVITY BLOCK FOR WALL C IS DETERMINED BASED ON MIN. EMBEDMENT = 1'-0".
4. FOR PLAN VIEW OF WALLS C AND C1, SEE SHEET 4 OF 11.

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NO.	REVISIONS	DATE
A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH CONSTRUCTION / HNTB

CLEVELAND'S INNERBELT BRIDGE — OHIO DEPARTMENT OF TRANSPORTATION

SITE PLAN - 2
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FAIRFIELD AVE. AND RAMP A6

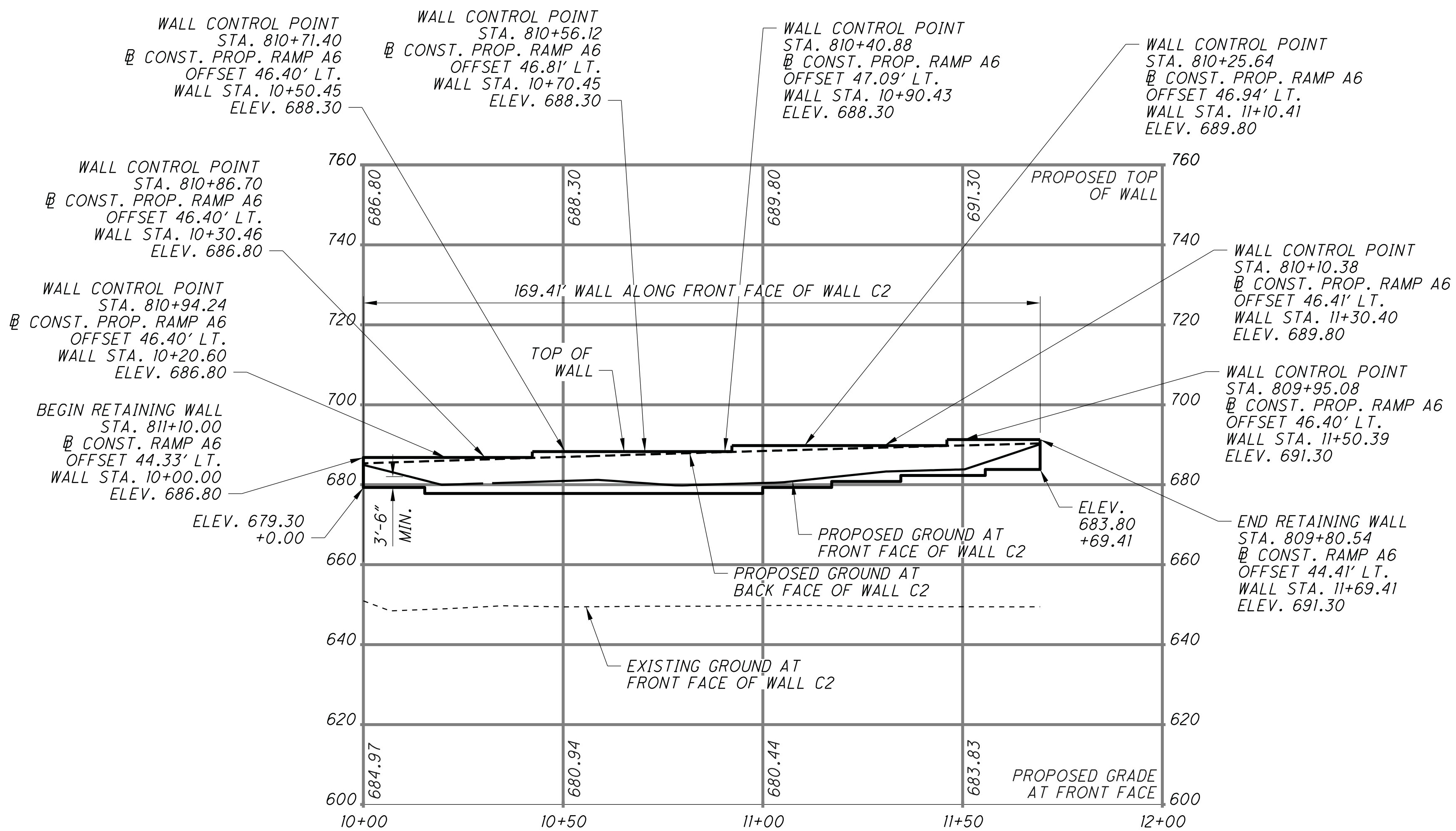
WALL C

DESIGNED	CHECKED	DRAWN	CHECKED	REVIEWED	DATE
AKS	CAB	CDD	CAB	DBT	9-13-11

STRUCTURE FILE NUMBER

CUY-90-14.90
PID No. 77332/85531

5 / 11



ELEVATION - GRAVITY BLOCK WALL C2

NOTES:

1. ALL TOP OF WALL C2 ELEVATIONS ARE GIVEN AT THE TOP OF GRAVITY BLOCK.
2. MINIMUM DISTANCE FROM PROPOSED GROUND SURFACE TO THE TOP OF GRAVITY BLOCK FOR WALL C2 IS DETERMINED BASED ON MIN. EMBEDMENT = 3'-6".
3 FOR PLAN VIEW OF WALL C2, SEE SHEET 4 OF 11.

PRELIMINARY NOT FOR CONSTRUCTION

ENGINEER'S SEAL

NO.	REVISIONS	DATE
A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH CONSTRUCTION / HNTB

CLEVELAND'S INNERBELT BRIDGE — OHIO DEPARTMENT OF TRANSPORTATION

SITE PLAN - 3
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FARIFIELD AVE. AND RAMP A6

WALL C

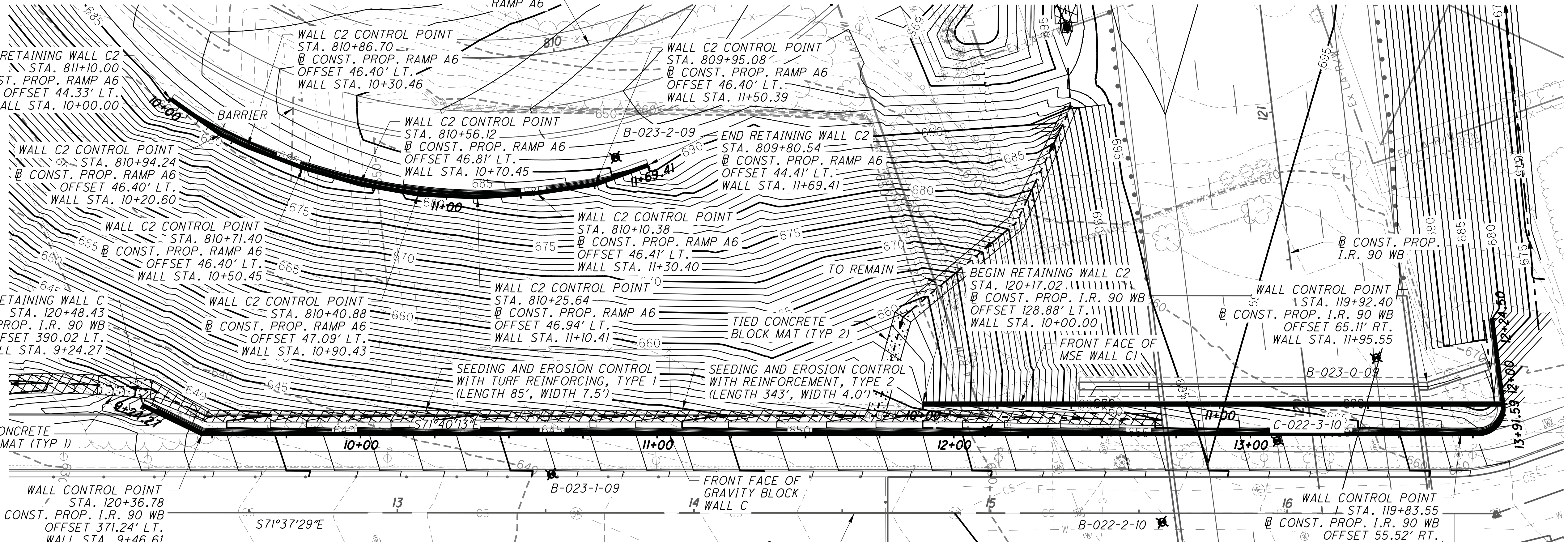
DESIGNED AKS — CHECKED CAB — DRAWN CDD — CHECKED CAB — REVIEWED DBT — DATE 9-13-11 — STRUCTURE FILE NUMBER

CUY-90-14.90
PID No. 77332/85531

6 / 11

CORRECTED BY: VERIFIED BY: CHECKED BY: BACKCHECKED BY: CHECK PRINT (INITIAL & DATE) MADE BY: (TO BE TURNED OFF AT AFC SUBMITTAL)

Date: 9/20/2011
Model: Sheet1
File: 49633-S-BR-RET-C2.dgn

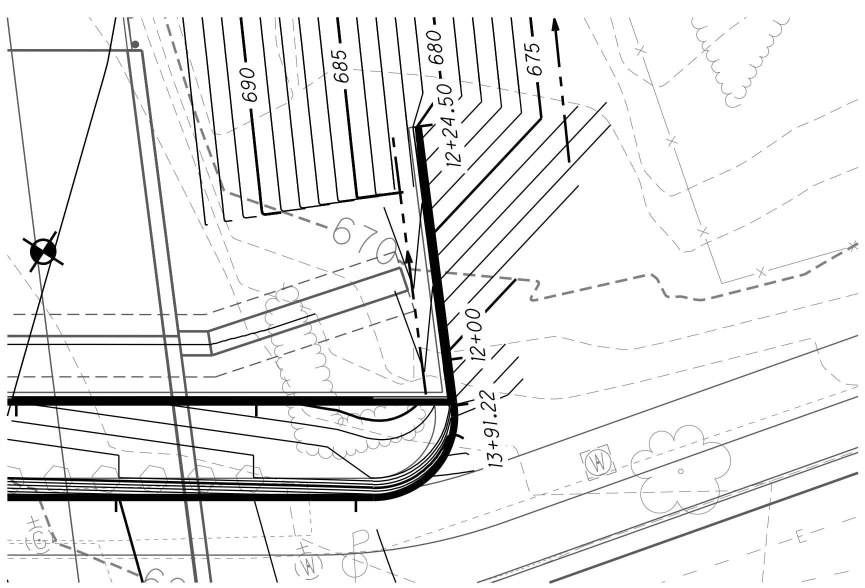


MSE RETAINING WALLS C, C1, AND C2

℄ CONST. PROP. I.R. 90 WB CURVE DATA:
P.I. = STA. 126+69.54
Δ = 16°25'51" RT.
Dc = 00°35'00"
R = 9822.14'
T = 1418.10'
L = 2816.74'
E = 101.84'

℄ CONST. FAIRFIELD AVE. TANGENT DATA:
P.I. = STA. 16+70.39
TDir = S71°37'29"E
L = 670.39'

℄ CONST. PROP. RAMP A6:
P.I. = STA. 836+03.51
Δ = 173°37'54" RT.
Dc = 38°00'00"
R = 150.78'
T = 2710.33'
L = 456.93'
E = 2563.74'



PROPOSED GRADING AT END WALL C (12+24.50)

PROPOSED GRADING AT END WALL C1 (13+91.22)

LEGEND

- SEEDING AND EROSION CONTROL WITH TURF REINFORCING, TYPE 2, PER SS 836
- TIED CONCRETE BLOCK MAT (TYPE 1 OR TYPE 2)

NOTES:

1. STATIONS AND OFFSETS ARE MEASURED FROM FRONT FACE OF MSE WALL FACING PANELS.
2. ELEVATION OF 6" ϕ PERFORATED PLASTIC PIPE WILL VARY TO PROVIDE INVERT ELEVATION AT OUTLET.

PRELIMINARY NOT FOR CONSTRUCTION

ENGINEER'S SEAL

NO.	REVISIONS	DATE
A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH CONSTRUCTION / HNTB

CLEVELAND'S INNERBELT BRIDGE — OHIO DEPARTMENT OF TRANSPORTATION

WALL C

WALL PAYMENT LIMITS - 1
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FAIRFIELD AVE. AND RAMP A6

DESIGNED	CHECKED	DRAWN	CHECKED	REVIEWED	DATE
AKS	CAB	CDD	CAB	DBT	9-13-11

STRUCTURE FILE NUMBER

CUY-90-14.90
PID No. 77332/85531

7 / 11

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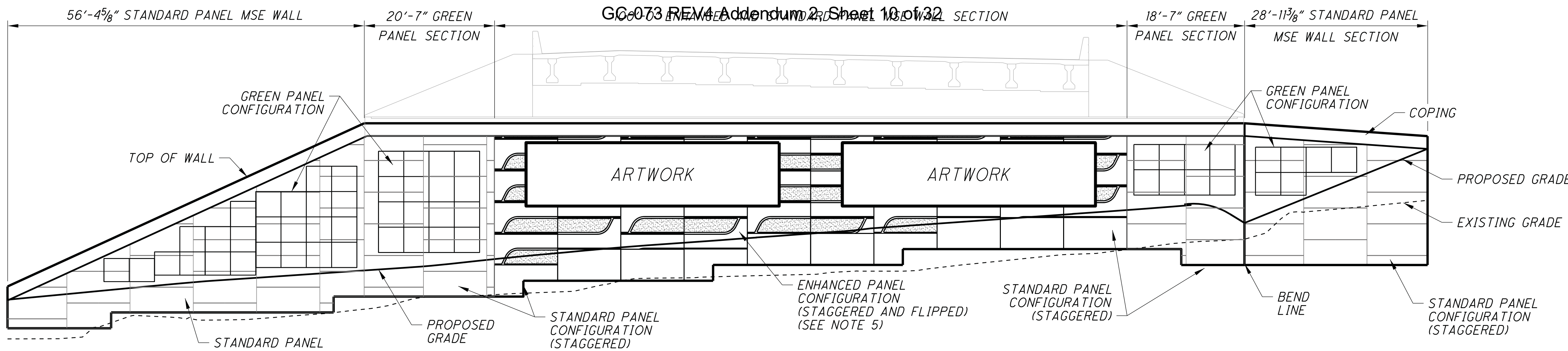
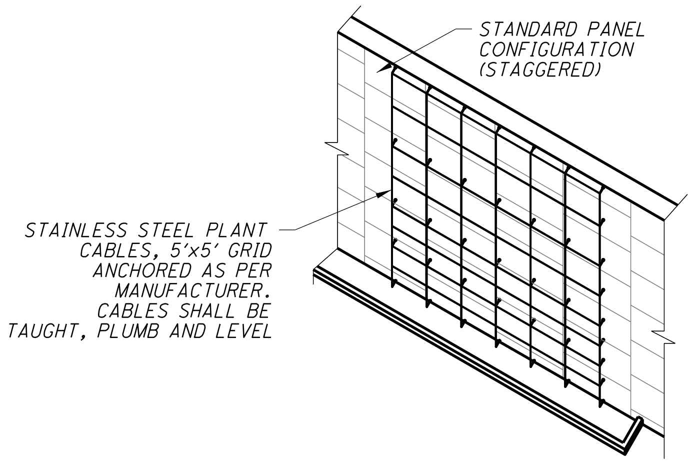
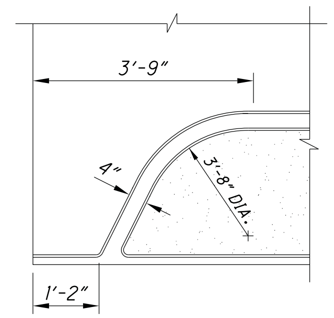
Date: 9/20/2011
Model: Sheet2
File: 49633-S-BR-RET-C.dgn



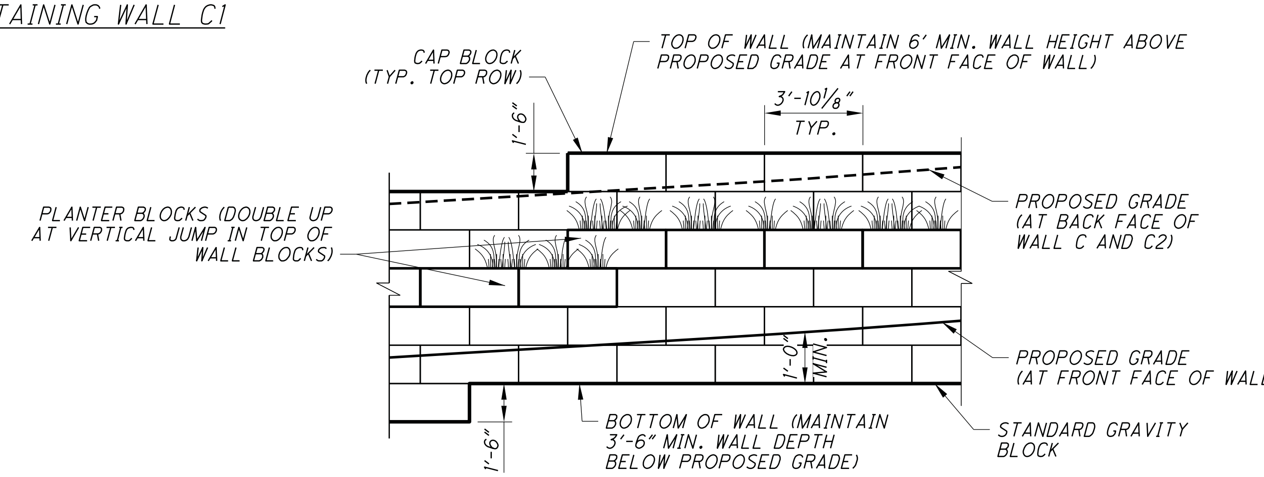
MSE RETAINING WALL C1



GREEN PANEL SECTION

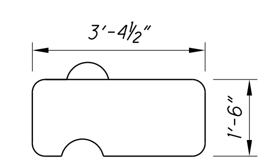


ENHANCED PANEL DETAIL

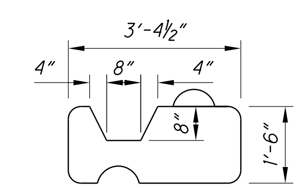


GRAVITY BLOCK WALL SECTION

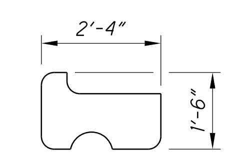
(RETAINING WALLS C AND C2)



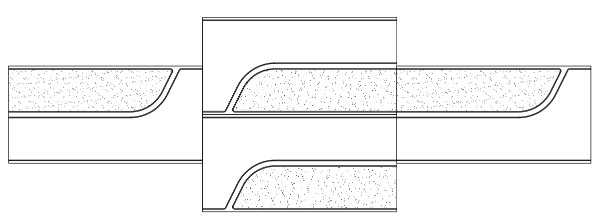
STANDARD BLOCK



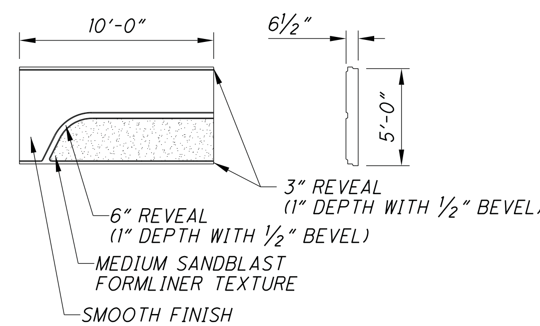
PLANTER BLOCK



CAP BLOCK



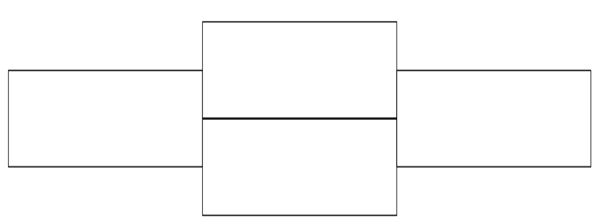
ENHANCED PANEL CONFIGURATION (STAGGERED AND FLIPPED)



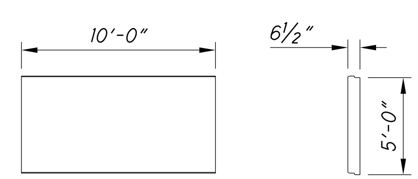
ENHANCED PANEL ELEVATION AND SECTION

NOTES:

1. FINISH COAT COLOR FOR WALL COPING SHALL BE SW 7022 (ALPACA).
   FINISH COAT COLOR FOR MSE ENHANCED PANELS SHALL BE SW 7565 (OYSTER BAR).
   FINISH COAT COLOR FOR MSE STANDARD PANELS SHALL BE SW 7565 (OYSTER BAR).
2. FINISH COAT TINT AS SPECIFIED SHALL BE ADDED TO EPOXY URETHANE SEALANT.
3. MSE ABUTMENT WALL - FUTURE ARTWORK TO BE COORDINATED WITH ODOT
4. INCLUDE STAINLESS STEEL PLANT CABLES FOR THIS WALL 5' x 5' GRID, ANCHORED AS PER MANUFACTURER, CABLES SHALL BE TAUGHT, PLUMB, AND LEVEL. FOR STEEL PLANT CABLE DETAILS REFER TO 1020 ROADWAY-TREMONT BUILDABLE UNIT.
5. ENHANCED PANELS SHALL EXTEND A MINIMUM OF 1'-0" BELOW PROPOSED GRADE.
6. GRAVITY BLOCKS TO BE PLACED IN A STAGGERED PATTERN.
7. FOR GREEN PANEL SECTION PLANTINGS AND GRAVITY BLOCK PLANTINGS REFER TO 1020 ROADWAY - TREMONT BUILDABLE UNIT.
8. INSTALLATION OF PLANTINGS SHALL BE IN ACCORDANCE WITH CMS 661.17.



STANDARD PANEL CONFIGURATION (STAGGERED)



STANDARD PANEL ELEVATION AND SECTION

PRELIMINARY NOT FOR CONSTRUCTION

NO.	REVISIONS	DATE
A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH CONSTRUCTION / HNTB

WALL C

WALL AESTHETICS PLAN

WALLS C, C1, AND C2

ALONG I.R. 90 WESTBOUND, FARIFIELD AVE. AND RAMP A6

DESIGNED AKS | CHECKED CAB | DRAWN CDD | CHECKED CAB | REVIEWED DBT | DATE 9-13-11 | STRUCTURE FILE NUMBER

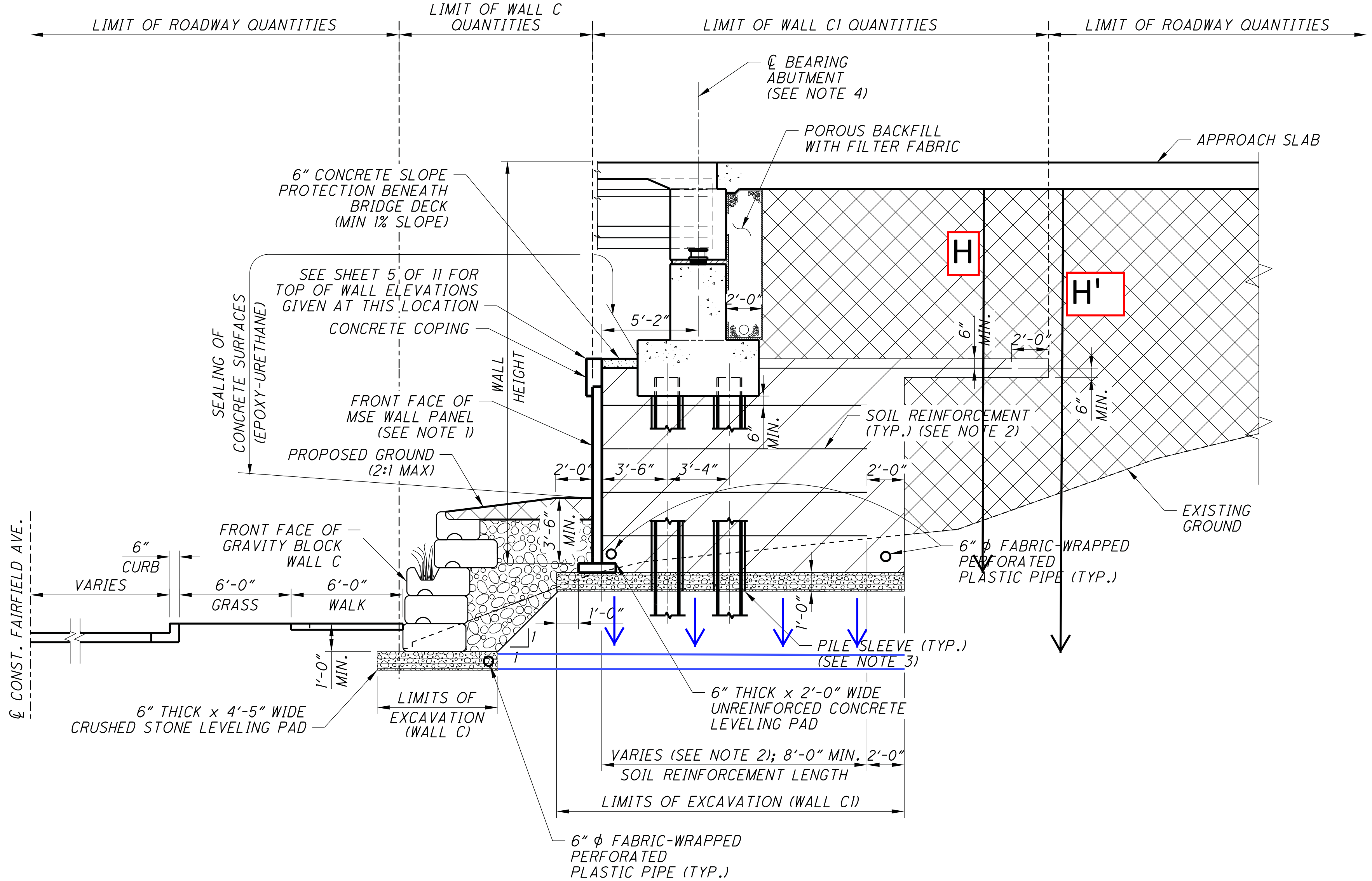
CUY-90-14.90

PID No. 77332/85531

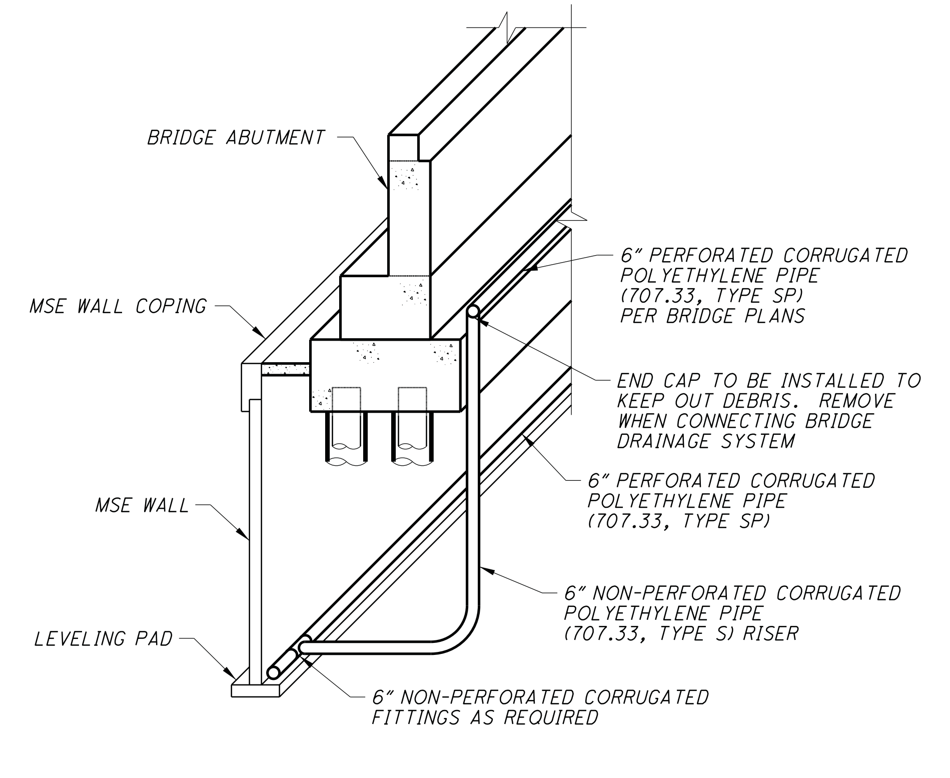
8 / 11

CHECK PRINT (INITIAL & DATE) | MADE BY: | CHECKED BY: | BACKCHECKED BY: | CORRECTED BY: | VERIFIED BY:

Date: 9/20/2011
Model: Sheet2
File: 49633-S-BR-RET-C1.dgn



SECTION A-A

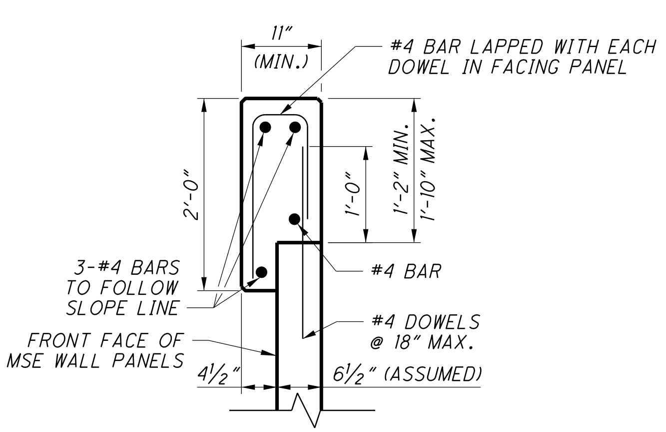


TYPICAL RISER DETAIL
(CONNECTION FROM BRIDGE DRAINAGE SYSTEM TO MSE WALL DRAINAGE)

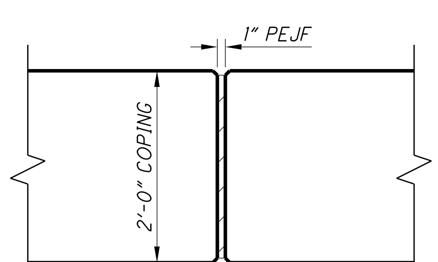
MINIMUM SOIL REINFORCEMENT LENGTH		
BEGIN STATION	END STATION	STRAP LENGTH
10+00.00	12+24.50	1.1 x (WALL HEIGHT)

NOTES:

1. THICKNESS OF MSE WALL PANELS IS ASSUMED AT 6½". ACTUAL THICKNESS DEPENDS ON THE APPROVED WALL SYSTEM.
2. SOIL REINFORCEMENT LENGTH TO BE DETERMINED BY WALL SUPPLIER ON THE APPROVED WALL SYSTEM, BUT SHALL NOT BE LESS THAN 110% OF THE WALL HEIGHT OR 8'-0", WHICHEVER IS GREATER
3. INSTALL PILE PIPE SLEEVES WITH MINIMUM 2'-6" ϕ DURING THE CONSTRUCTION OF MSE WALL. PLACE THE BOTTOM OF THE SLEEVES AT THE BOTTOM OF THE SELECT GRANULAR BACKFILL OR AT THE BOTTOM OF THE UNDERCUT, WHICHEVER IS DEEPER. INSTALL PILES THROUGH THE SLEEVES AND BACKFILL WITH GRANULAR FILL IN ACCORDANCE WITH MODIFIED SS 840 (SS-01) AFTER THE MSE WALL CONSTRUCTION IS COMPLETE. PILE SLEEVES SHALL CONFORM TO SS 840.
4. FOR ADDITIONAL ABUTMENT DETAILS SEE SHEETS 5 THRU 8 AND 14 OF THE BRIDGE CUY-90-1526 - BRIDGE 4 PLANS.
5. FACTORED BEARING RESISTANCE AT BASE OF WALL C IS 2.5 KSF. FACTORED BEARING RESISTANCE AT BASE OF REINFORCED SOIL MASS FOR WALL C1 VARIES LINEARLY FROM 5.4 KSF TO 16.8 KSF FOR STRAP LENGTHS 8'-0" TO 35'-0". FACTORED BEARING RESISTANCE AT BASE OF WALL C2 IS 2.9 KSF. REFER TO GEOTECHNICAL DESIGN MEMORANDUM GD-9, REVISION NO. 3, DATED 9/16/2011.
6. ELEVATION OF 6" ϕ PERFORATED PLASTIC PIPE WILL VARY TO PROVIDE INVERT ELEVATION AT OUTLET (MIN. SLOPE ⅛" PER FT).
7. COPING EXPANSION JOINTS SHALL BE SPACED NO MORE THAN 20 FEET APART AND ALIGNED WITH JOINTS BETWEEN FACING PANELS.
8. DO NOT PLACE GEOTEXTILE BELOW THE BASE OF WALL WITHOUT APPROVAL OF GEOTECHNICAL ENGINEER OF RECORD.
9. BEFORE CONSTRUCTION OF WALL C1, WALL C MUST BE CONSTRUCTED TO A POINT THAT WALL C IS EQUAL OR HIGHER THAN THE TOP OF LEVELING PAD ELEVATION OF WALL C1.



MSE WALL CONCRETE COPING
ALL REINFORCING STEEL TO BE EPOXY COATED



COPING EXPANSION JOINT

LEGEND:

- ITEM 203 EMBANKMENT
- SELECT GRANULAR BACKFILL PER MODIFIED SUPPLEMENTAL SPECIFICATION 840 (SS-01) (NO MORE THAN 5% PASSING #200 SIEVE)
- ITEM 203, GRANULAR MATERIAL TYPE C
- AGGREGATE MATERIALS FOR ITEM 304 AGGREGATE BASE OR CRUSHED AGGREGATE SLOPE PROTECTION AND FILTER AGGREGATE FOR ITEM 601 SLOPE AND CHANNEL PROTECTION

PRELIMINARY NOT FOR CONSTRUCTION

NO.	REVISIONS	DATE
A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH HNTB

WALL C

RETAINING WALL DETAILS - 1
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FARIFIELD AVE. AND RAMP A6

DESIGNED AKS | CHECKED CAB | DRAWN CDD | CHECKED CAB | REVIEWED DBT | DATE 9-13-11 | STRUCTURE FILE NUMBER

CUY-90-14.90
PID No. 77332/85531

9/11

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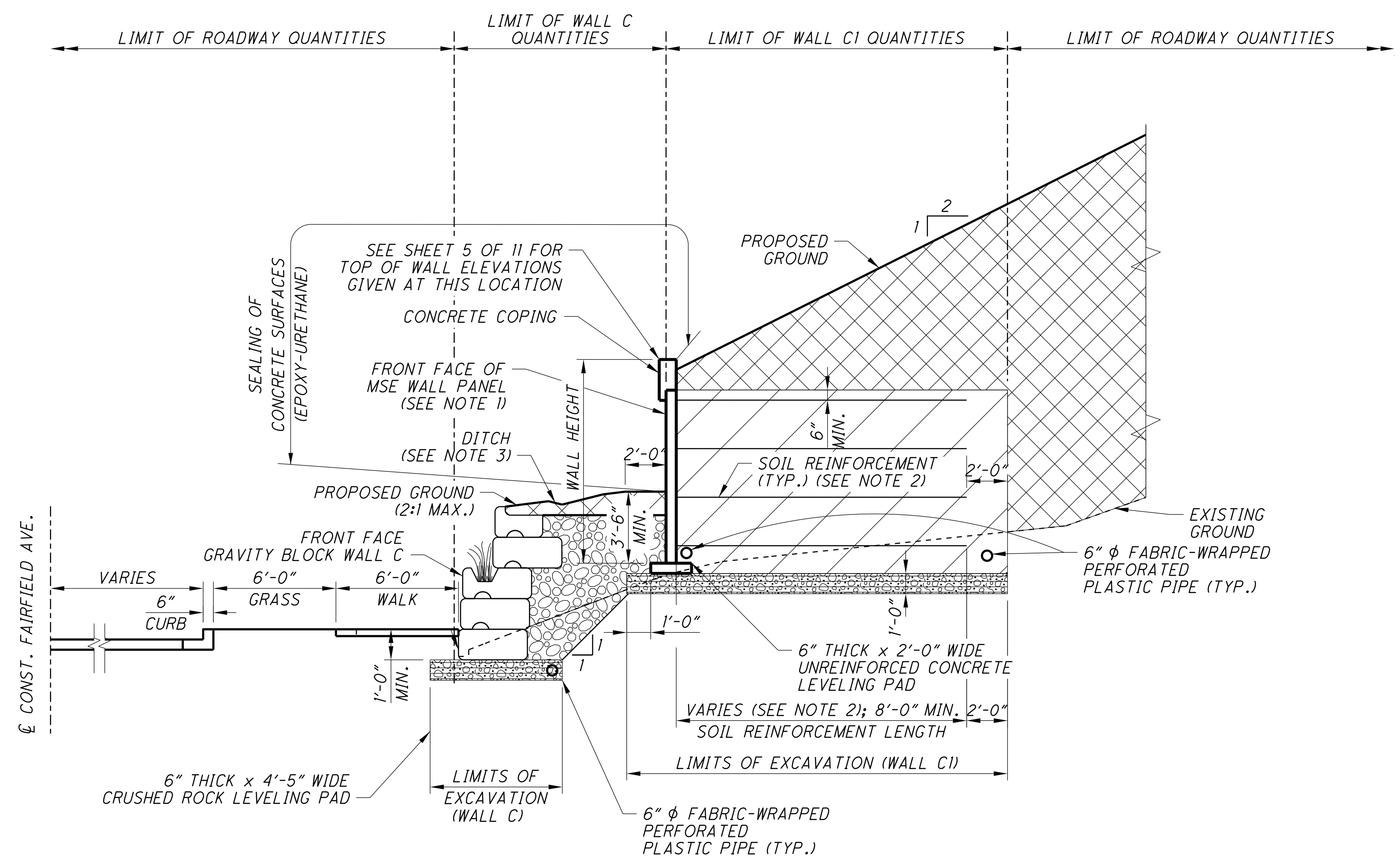
Date:9/20/2011
Model:Sheet1
File:49633-S-BR-DET-C1.dgn



SECTION B-B

LEGEND:

- ITEM 203 EMBANKMENT
- SELECT GRANULAR BACKFILL PER MODIFIED SUPPLEMENTAL SPECIFICATION 840 (SS-01) (NO MORE THAN 5% PASSING #200 SIEVE)
- ITEM 203, GRANULAR MATERIAL TYPE C
- AGGREGATE MATERIALS FOR ITEM 304 AGGREGATE BASE OR CRUSHED AGGREGATE SLOPE PROTECTION AND FILTER AGGREGATE FOR ITEM 601 SLOPE AND CHANNEL PROTECTION

NOTES:

1. THICKNESS OF MSE WALL PANELS IS ASSUMED AT 6I#2". ACTUAL THICKNESS DEPENDS ON THE APPROVED WALL SYSTEM.
2. SOIL REINFORCEMENT LENGTH TO BE DETERMINED BY WALL SUPPLIER ON THE APPROVED WALL SYSTEM, BUT SHALL NOT BE LESS THAN 110% OF THE WALL HEIGHT OR 8'-0", WHICHEVER IS GREATER.
3. DITCH BEHIND WALL IS TRANSITIONING BETWEEN FULL DITCH (SHOWN IN SECTION C-C ON SHEET 11 OF 11) AND 2:1 SLOPE (SHOWN IN SECTION A-A ON SHEET 9 OF 11) FROM WALL C1 STATION 10+56.38 TO STATION 10+00.
4. FOR ADDITIONAL NOTES, SEE 9 OF 11.

PRELIMINARY NOT FOR CONSTRUCTION

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Date: 9/20/2011
Model: Sheet2
File: 49633-S-BR-DET-C1.dgn

NO.	REVISIONS	DATE
A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH CONSTRUCTION | HNTB

CLEVELAND'S INNERBELT BRIDGE — OHIO DEPARTMENT OF TRANSPORTATION

WALL C

RETAINING WALL DETAILS - 2
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FAIRFIELD AVE. AND RAMP A6

DESIGNED AKS | CHECKED CAB | DRAWN CDD | CHECKED CAB | REVIEWED DBT | DATE 9-13-11 | STRUCTURE FILE NUMBER

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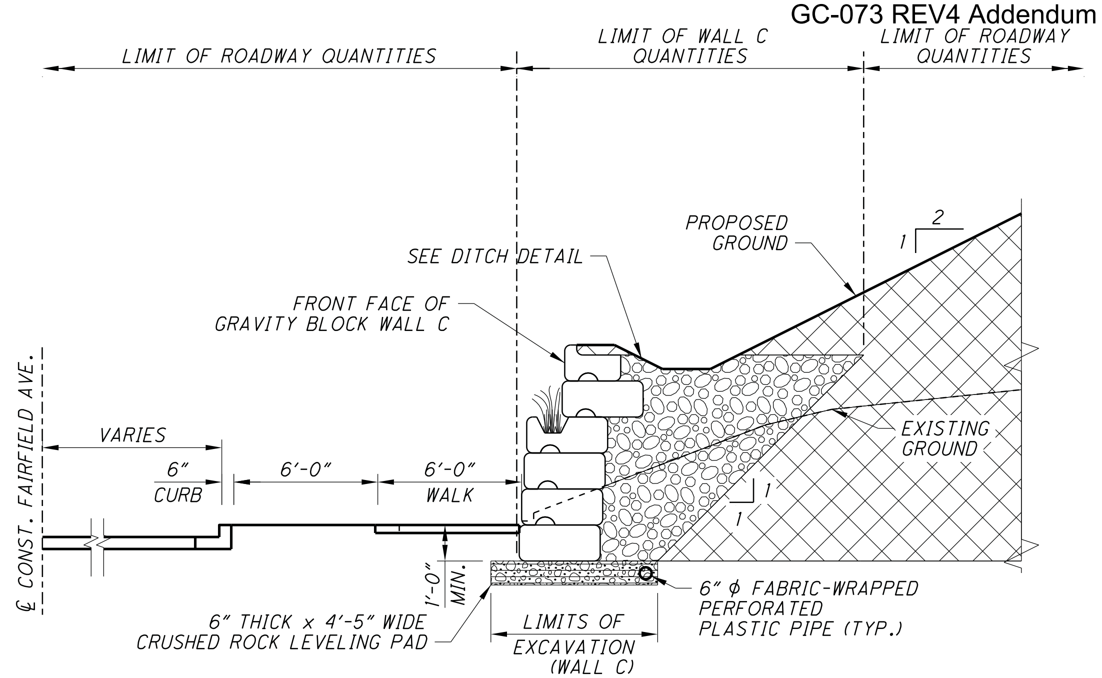
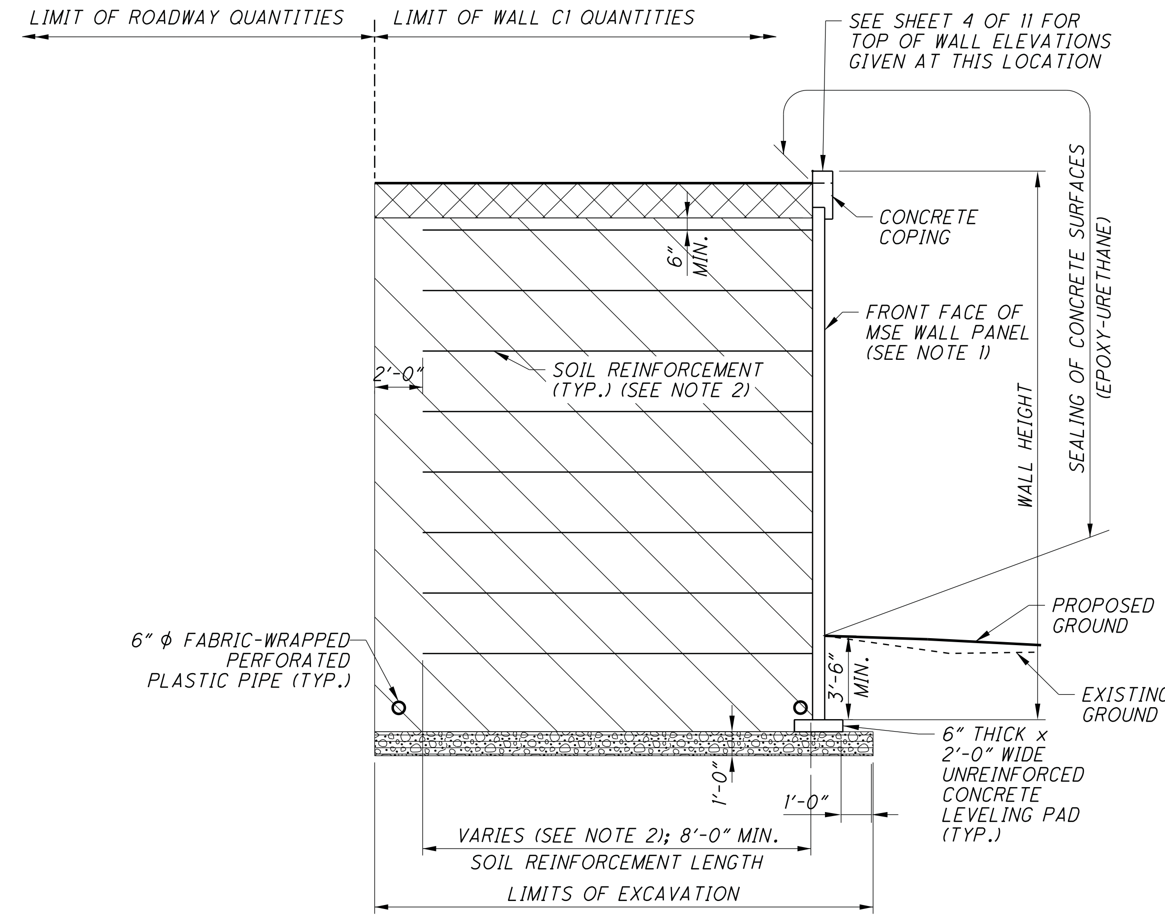
PID No. 77332/85531



SECTION C-C



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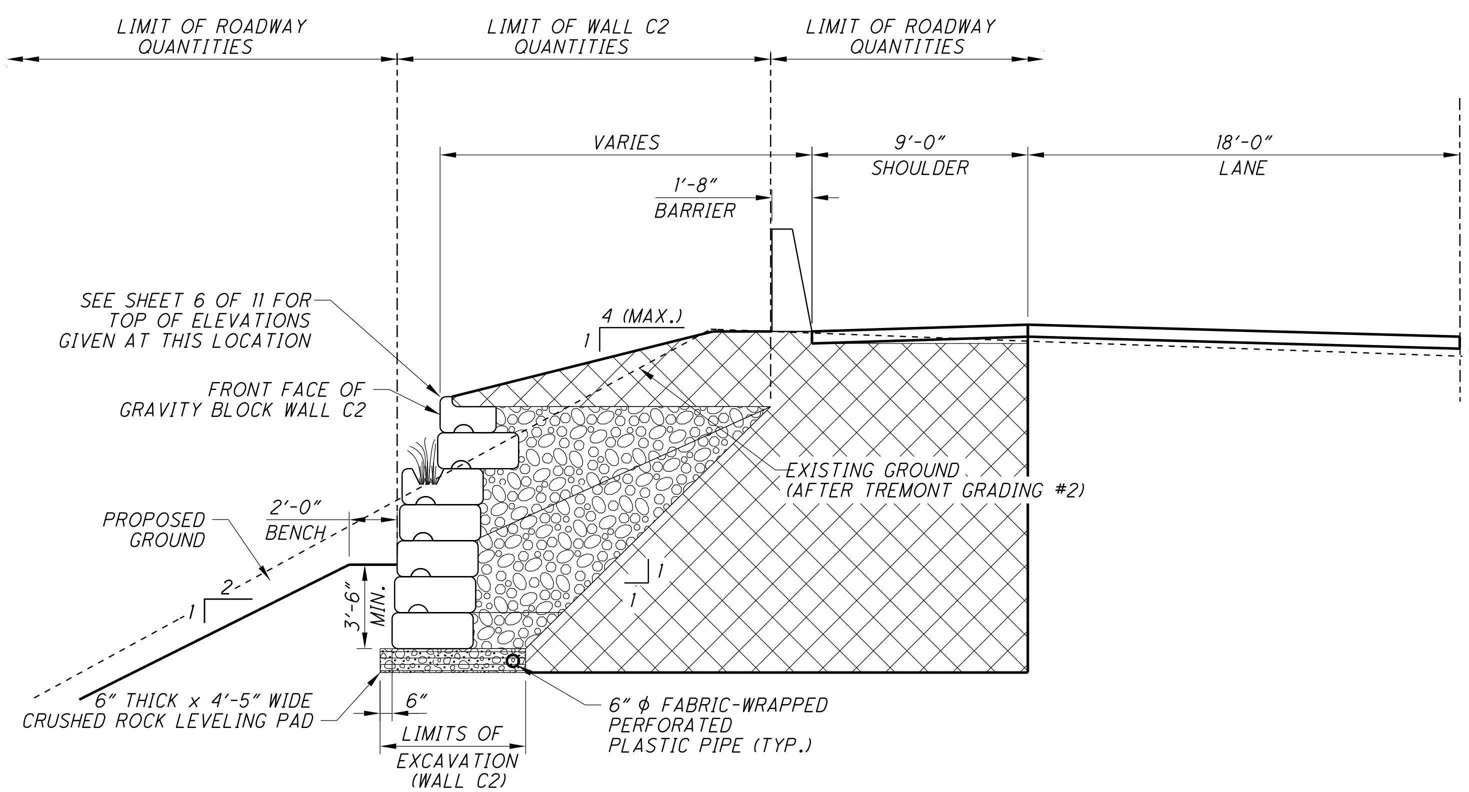
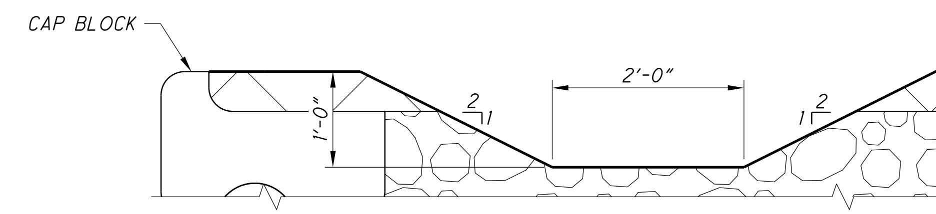


SECTION D-D



DITCH DETAIL

LEGEND:

ITEM 203 EMBANKMENT

ITEM 203, GRANULAR MATERIAL TYPE C

AGGREGATE MATERIALS FOR ITEM 304 AGGREGATE BASE OR CRUSHED AGGREGATE SLOPE PROTECTION AND FILTER AGGREGATE FOR ITEM 601 SLOPE AND CHANNEL PROTECTION

NOTES:

1. THICKNESS OF MSE WALL PANELS IS ASSUMED AT 61#2″. ACTUAL THICKNESS DEPENDS ON THE APPROVED WALL SYSTEM.
2. SOIL REINFORCEMENT LENGTH TO BE DETERMINED BY WALL SUPPLIER ON THE APPROVED WALL SYSTEM, BUT SHALL NOT BE LESS THAN 110% OF THE WALL HEIGHT OR 8′-0″, WHICHEVER IS GREATER.
3. ELEVATION OF 6″ ϕ PERFORATED PLASTIC PIPE WILL VARY TO PROVIDE INVERT ELEVATION AT OUTLET. MINIMUM SLOPE OF PIPE SHALL BE ⅛″/FOOT.
4. FOR ADDITIONAL NOTES AND LEGENDS, SEE SHEET 9 OF 11.

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Date: 9/20/2011
Model: Sheet2
File: 49633-S-BR-DET-C.dgn

NO.	REVISIONS	DATE
A	INTERIM REVIEW SUBMITTAL	09-19-11

DESIGN AGENCY: WALSH CONSTRUCTION / HNTB

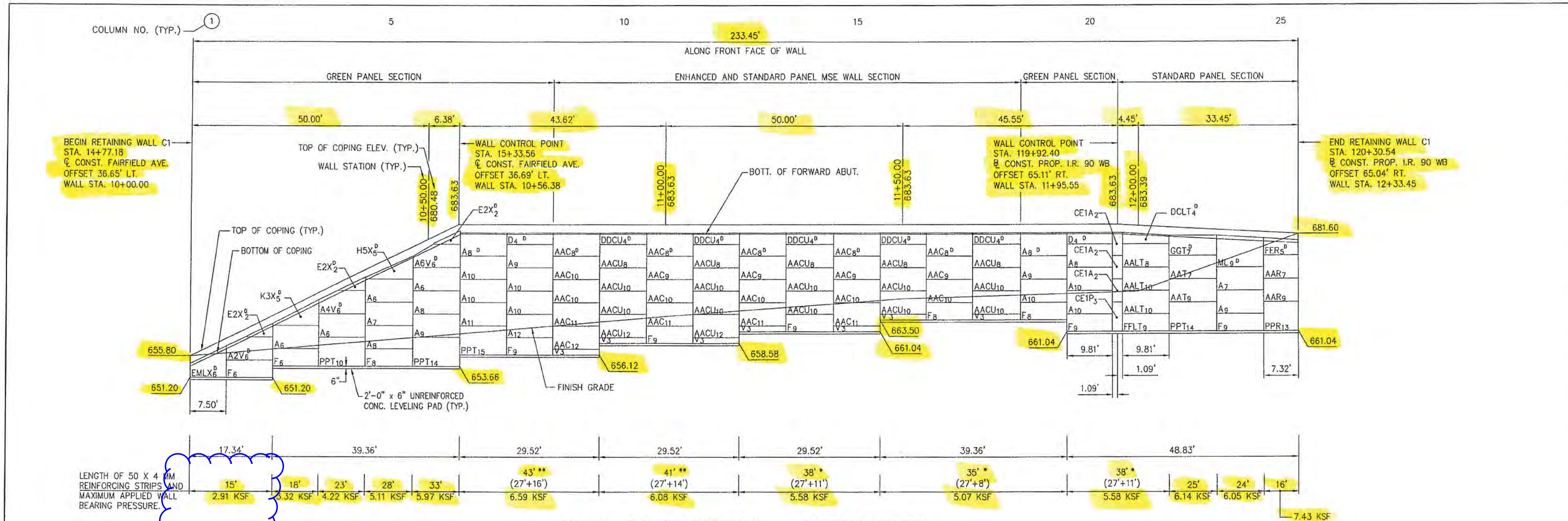
CLEVELAND'S INNERBELT BRIDGE — OHIO DEPARTMENT OF TRANSPORTATION

RETAINING WALL DETAILS - 3
WALLS C, C1, AND C2
ALONG I.R. 90 WESTBOUND, FAIRFIELD AVE. AND RAMP A6

WALL C

DESIGNED AKS | CHECKED CAB | DRAWN CDD | CHECKED CAB | REVIEWED DBT | DATE 9-13-11 | STRUCTURE FILE NUMBER

CUY-90-14.90
PID No. 77332/85531



WALL C1 ELEVATION – FRONT FACE

SCALE : 1" = 10'

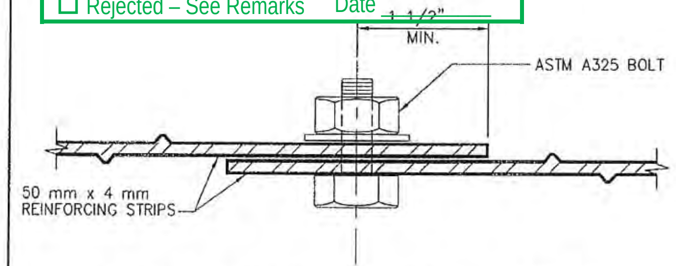
BACKWALL STRIPS FORWARD ABUT.:
1 LEVEL, 2'-0" FROM BOTT. OF FOOTER
127 PCS. 16' STRIPS @ 1'-1" O/C

LEGEND:
* SEE SPLICE CONNECTION DETAIL E (SEE BELOW)
** SEE SPLICE CONNECTION DETAIL F (SEE BELOW)

SHOP DRAWING REVIEW
HNTB OHIO, INC.
Review is only for general conformance with the design concept of the contract documents. Markings or comments shall not be construed as relieving the contractor from compliance with the project plans and specifications, nor departures therefrom. The contractor remains solely responsible for details and accuracy, for confirming and correlating all quantities and dimensions, for selecting fabricating processes, for techniques of assembly, for safety and for satisfactory performance of his work.

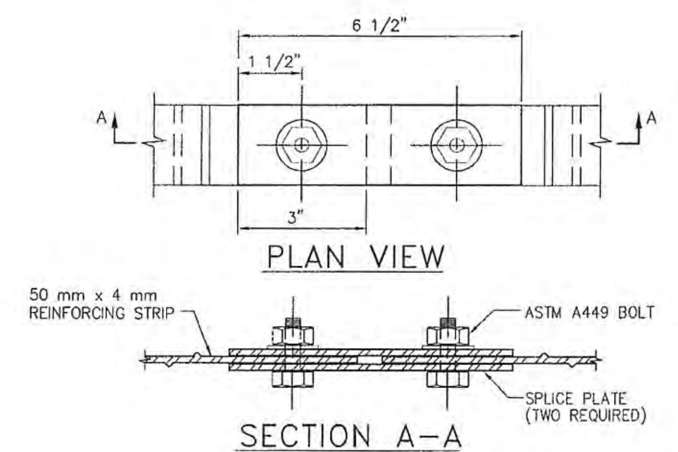
- [x] No Exceptions Taken
- [ ] Approved as Noted — By DWB
- [ ] Amend and Resubmit
- [ ] Rejected – See Remarks — Date 1/23/12

KEY TO DESIGN 5X10 (NOMINAL) PANEL LABEL:
A12RCT10^D — COPING DOWELS
BASE PANEL SERIES (ONE OR TWO LETTERS)
NO. OF TIE STRIP
SEQUENTIAL PANEL NUMBER (IF ANY)
MODIFICATION (ONE OR MORE, IF ANY)
PANEL CUT (IF ANY)
AESTHETIC FINISH DESIGNATION *** (ONE OR TWO LETTERS, IF ANY)
*** AESTHETIC FINISH DESIGNATION (IF ANY)
"C" = "C" FINISH
"CU" = FLIPPED "C" FINISH



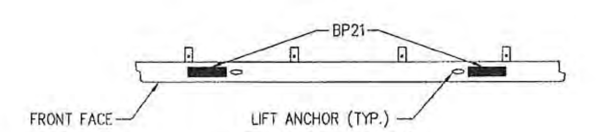
SPLICE CONNECTION DETAIL E

SCALE 1:1



SPLICE CONNECTION DETAIL F

SCALE 1:2

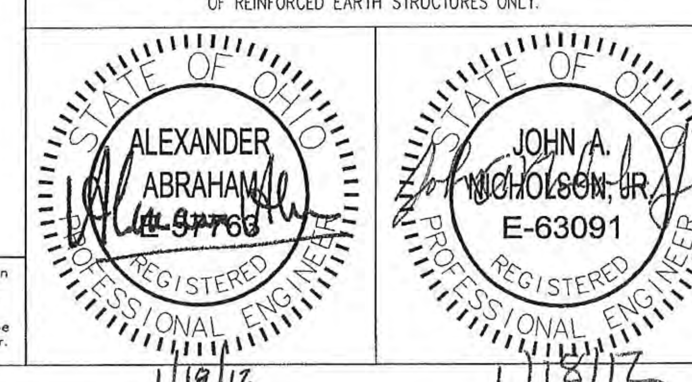


DETAIL 'A'
(2 PADS PER HORIZONTAL JOINT)

SCALE : N.T.S.

NOTE: USE (2) BP21 PADS PLACED AS SHOWN.

CERTIFIED WITH RESPECT TO INTERNAL STABILITY OF REINFORCED EARTH STRUCTURES ONLY.



NO.	DATE	DESCRIPTION

The design contained on these drawings is based on information provided by the owner. On the basis of this information, The Reinforced Earth Company has designed, and is responsible for the internal stability of the structure only. External stability, including foundation (bearing capacity and settlement) and slope stability (sliding and rotation), is the responsibility of the owner.

Reinforced Earth
1376 OLD BRIDGE ROAD, WOODBRIDGE, VA 22192
Telephone: (703) 499-9818 / Fax: (703) 499-9348

REVIEWED JN — DATE 1/12/12
PID NO. 77332/85531
DRAWN FA — REVISED
DESIGNED FA — CHECKED ND

ELEVATION – MSE RETAINING WALL C1
BRIDGE NO. CUY-90-1526 (BL-4)
ALONG I.R. 90 WESTBOUND, FAIRFIELD AVE. AND RAMP A6
CITY OF CLEVELAND, CUYAHOGA COUNTY

CUY-90-14.90

3 OF 13

RE-14668

CALC. G1: WALL C1 AT WALL HEIGHT OF 11FT STATIC EXTERNAL STABILITY

ENTER PARAMETERS IN YELLOW CELLS. SEE DIAGRAM TAB FOR CLARIFICATION.

References:		
	AASHTO 2010 LRFD Bridge Manual	for seismic loads, LRFD calcs
	NAVFAC DM 7.2 (1986)	for friction properties
	Das (1999)	for earth pressures

B/H = 0.7

Retained Soil Properties			Geometry			
Retained Friction Angle, ϕ_r	30	degrees	Height, H	11	feet	(above top of leveling pad)
Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	Width, B	8	feet	
Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	Height of GWT, H_w	0	feet	(0 means below the wall bottom)
Ignore Vertical Component of Inclined Loads for Sliding/Overturning?	No		Backslope Angle, β	6.5	degrees	
			Distance to Slope Break, X	100	feet	(0 if no slope break)
Ka override (blank for auto-calc using Das, 1999 eqn.)		(autocalc)	Backslope Height, Δy	11.4	feet	
MSE Properties			Effective Backslope Angle, β'	11.0	degrees	(0 if x < B)
Continuous Reinforcement Friction Factor, μ	0.36	(sheets, grids)	**Surcharge/Seismic Loads**			(all surcharges ignored for seismic. Surcharge above MSE ignored for sliding/overturning)
Discontinuous Reinforcement Friction Factor, μ	0.58	(strips)	Retained Soil Surcharge, q_r	250	psf	
Adhesion, a	0	psf	MSE Surcharge, q_{mse}	250	psf	
SLIDING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	120	pcf	k_h	0	g's	
SLIDING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	120	pcf	ΔK_{ae}	0.00	g's	
BEARING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	135	pcf	ΔK_{ae} override	0	(blank for autocalc)	
BEARING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	135	pcf				

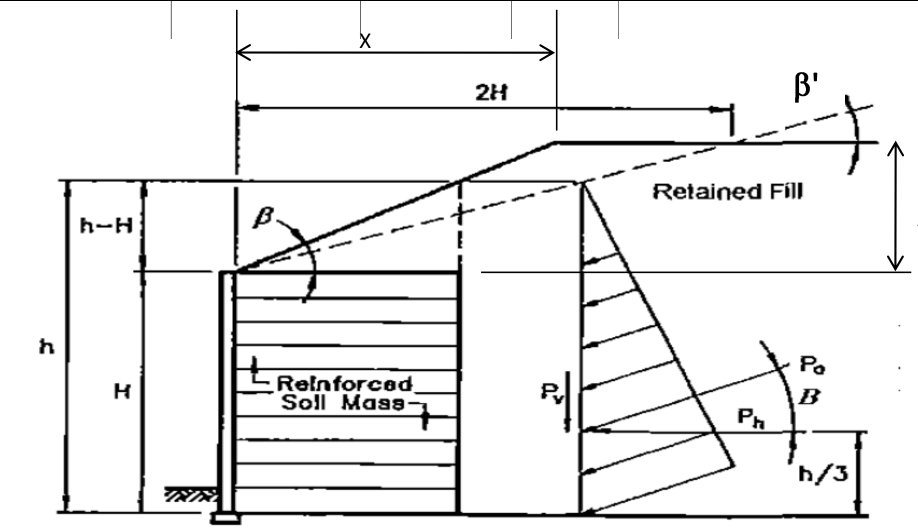


Figure 3.11.5.8.1-3—Earth Pressure Distribution for MSE Wall with Broken Back Backfill Surface

Subgrade/Bearing Properties			Passive Resistance		
Subgrade Friction Angle, ϕ_s		degrees	Ignore Passive Resistance?	Yes	
Subgrade Cohesion, c		psf	Height of Passive, H_p		feet
Foundation Depth , D		feet	Passive Friction Angle, ϕ_p		degrees
Nominal Bearing Resistance, qn for B = 8 feet	8.0	ksf	Unit Weight Above GWT, $\gamma_{m,p}$		pcf
Unit Weight Above GWT, $\gamma_{m,s}$		pcf	Unit Weight Below GWT, $\gamma_{sat,p}$		pcf
Unit Weight Below GWT, $\gamma_{sat,s}$		pcf			

RESISTANCE FACTORS		LOAD FACTORS		
Resistance	RF	Load	Symbol	LF
Sliding (MSE)	1.0	Earth (Horizontal)	γEH	1.5
Passive (MSE)	0.75	Earth (Vertical)	γEV	1.35
Bearing (MSE) (Static)	0.65	Live Surcharge	γLS	1.75
Bearing (MSE) (Seismic)	1.0	Earthquake	γEQ	1

AASHTO LRFD:

FAILURE BY SLIDING	LOAD SIDE			RESISTANCE SIDE			LRFD CHECK	
	L (lbs/ft)	LF	L*LF (lbs/ft)	R (lbs/ft)	RF	R*RF (lbs/ft)	R*RF > L*LF ?	
LOAD								
Earth (L_{EH})	2948	1.5	4422					L_{EH} =('SL&OT LOADS'!E15+'SL&OT LOADS'!E16+'SL&OT LOADS'!E17)*COS('SL&OT LOADS'!B8)
Surcharge (L_{LS})	1032	1.75	1805					L_{LS} =('SL&OT LOADS'!E18)*COS('SL&OT LOADS'!B8)
Earthquake (L_{EQ})	0	1	0					L_{EQ} ='SL&OT LOADS'!E19+'SL&OT LOADS'!E20+'SL&OT LOADS'!E21+'SL&OT LOADS'!E22*COS('SL&OT LOADS'!B8)
RESISTANCE								
Base Friction (continuous reinforcement)				4395	1	4395		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D15
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			6227			4395	NO	
RESISTANCE								
Base Friction (DIScontinuous reinforcement)				7080	1	7080		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D16
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			6227			7080	YES	

FAILURE BY BEARING B-2e = 5.9 feet	LOAD SIDE				
	L (lbs/ft)	LF	L*LF (lbs/ft)	$q_{FACTORED}$ (psf) $=\Sigma L*LF/(B-2e)$	
LOAD					
Earth (L_{EV})	12890	1.35	17402		L_{EV} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E15+'BEARING LOADS'!E16+'BEARING LOADS'!E17)+'BEARING LOADS'!E3+'BEARING LOADS'!E4+'BEARING LOADS'!E5+'BEARING LOADS'!E6
Surcharge (L_{LS})	2201	1.75	3851		L_{LS} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E18)+'BEARING LOADS'!E7
Earthquake (L_{EQ})	0	1	0		L_{EQ} ='BEARING LOADS'!E22*SIN('BEARING LOADS'!B8)
SUM			21253	3630	q_factored = D54/(I9-2*'BEARING LOADS'!B34)
RESISTANCE SIDE					
Nominal Bearing Resistance, qn for B = 8 feet				8000 psf	
Factored Bearig Resistance = qn*RF =				5200 psf	=IF(I18=0,E56*L27,E56*L28)
R*RF > ΣL*LF/(B-2e) ?				YES	=IF(E57>E54,"YES","NO")

FAILURE BY OVERTURNING

Parameter	Value	Note
e	1.87	ft from center of base reinforcement layer
1/4 B	2.00	ft from center of base reinforcement layer
e ≤ 1/4 B ?	YES	See Sections 11.10.5.5 and 11.6.3.3 in AASHTO 2010

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	11	ft	W_m (β=0)	10560	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	4.00	feet	B/2
4	Width, B	8	ft	$W_{\beta 1}$ (triangular part)	437	lbs/ft	$W_{\beta 1} = 1/2*min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta 1}$	5.33	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	54.00	feet	x+(B-x)/2
6	Height of Retained Fill, h	11.91	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	4.00	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	0	lbs/ft	W_q = 0 for sliding and overturning		x_q	4.00	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**10997**	**lbs/ft**	<- Factored			**44569**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	11.66	ft						11.6			
10	$H_2 = H+0.5*H*tan(\beta)/[1-0.5tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	$Am = (1.45-k_h)*k_h$ for $k_h < 0.45$	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**120**	pcf	F_{T1}	3003	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	3.97	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**120**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	1051	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	5.96	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	5.50	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	11.22	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	11.33	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	7.00	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<-Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<-Factored
24	k_h	0	g's	**$F_{\beta x}$**	**6227**	**lbs/ft**	<-Factored		**$M_{\beta +}$**	**28315**	**ft-lb/ft**	<-Factored
25	theta	0		**$F_{\beta y}$**	**1211**	**lbs/ft**	<-Factored		**$M_{\beta -}$**	**9688**	**ft-lb/ft**	<-Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	10.8	1.00		$Kp = tan^2(45+\phi/2)$		**Moment Arms (about toe)**			
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**1.87**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)								
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

$$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$$

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	11	ft	W_m (β=0)	11880	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	4.00	feet	B/2
4	Width, B	8	ft	$W_{\beta 1}$ (triangular part)	437	lbs/ft	$W_{\beta 1} = 1/2*\min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta 1}$	5.33	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	54.00	feet	x+(B-x)/2
6	Height of Retained Fill, h	11.91	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	4.00	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	2000	lbs/ft	$W_q = B*q_{mse}$		x_q	4.00	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**20128**	**lbs/ft**	<- Factored			**81296**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	11.66	ft						11.6			
10	$H_2 = H+0.5*H*\tan(\beta)/[1-0.5\tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	$Am = (1.45-k_h)*k_h$ for $k_h < 0.45$	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**135**	pcf	F_{T1}	3003	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	3.97	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**135**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	1051	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	5.96	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	5.50	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	11.22	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	11.33	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	7.00	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<- Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<- Factored
24	k_h	0	g's	**$F_{\beta x}$**	**6227**	**lbs/ft**	<- Factored		**$M_{\beta +}$**	**28315**	**ft-lb/ft**	<- Factored
25	theta	0		**$F_{\beta y}$**	**1211**	**lbs/ft**	<- Factored		**$M_{\beta -}$**	**9688**	**ft-lb/ft**	<- Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	10.8	1.00		$Kp = \tan^2(45+\phi/2)$			**Moment Arms (about toe)**		
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**1.07**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)								
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

$$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$$

CALC. G1: WALL C1 AT WALL HEIGHT OF 12FT STATIC EXTERNAL STABILITY

ENTER PARAMETERS IN YELLOW CELLS. SEE DIAGRAM TAB FOR CLARIFICATION.

References: AASHTO 2010 LRFD Bridge Manual — for seismic loads, LRFD calcs
NAVFAC DM 7.2 (1986) — for friction properties
Das (1999) — for earth pressures

B/H = 1.3

Retained Soil Properties			Geometry			
Retained Friction Angle, ϕ_r	30	degrees	Height, H	12	feet	(above top of leveling pad)
Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	Width, B	15	feet	
Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	Height of GWT, H_w	0	feet	(0 means below the wall bottom)
Ignore Vertical Component of Inclined Loads for Sliding/Overturning?	No		Backslope Angle, β	6.5	degrees	
			Distance to Slope Break, X	100	feet	(0 if no slope break)
Ka override (blank for auto-calc using Das, 1999 eqn.)		(autocalc)	Backslope Height, Δy	11.4	feet	
MSE Properties			Effective Backslope Angle, β'	11.0	degrees	(0 if x < B)
Continuous Reinforcement Friction Factor, μ	0.36	(sheets, grids)	**Surcharge/Seismic Loads**			(all surcharges ignored for seismic. Surcharge above MSE ignored for sliding/overturning)
Discontinuous Reinforcement Friction Factor, μ	0.58	(strips)	Retained Soil Surcharge, q_r	250	psf	
Adhesion, a	0	psf	MSE Surcharge, q_{mse}	250	psf	
SLIDING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	120	pcf	k_h	0	g's	
SLIDING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	120	pcf	ΔK_{ae}	0.00	g's	
BEARING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	135	pcf	ΔK_{ae} override	0	(blank for autocalc)	
BEARING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	135	pcf				

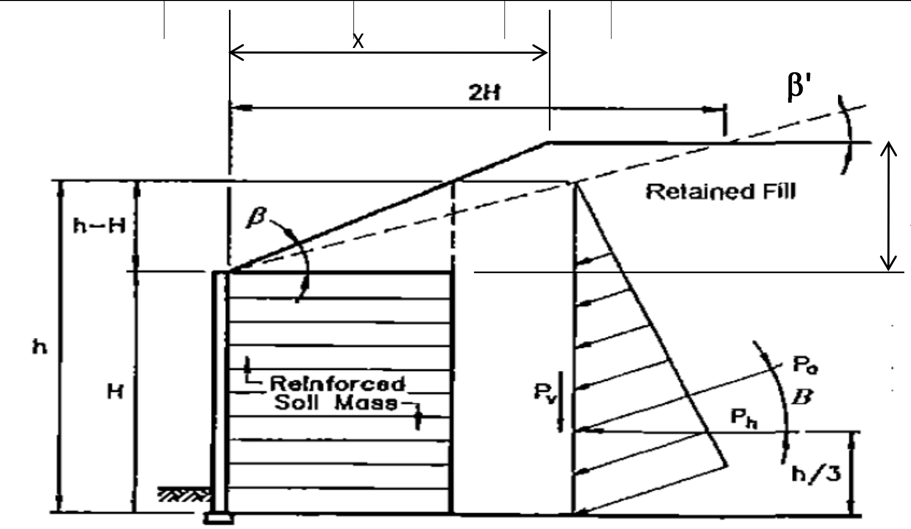


Figure 3.11.5.8.1-3—Earth Pressure Distribution for MSE Wall with Broken Back Backfill Surface

Subgrade/Bearing Properties			Passive Resistance		
Subgrade Friction Angle, ϕ_s		degrees	Ignore Passive Resistance?	Yes	
Subgrade Cohesion, c		psf	Height of Passive, H_p		feet
Foundation Depth , D		feet	Passive Friction Angle, ϕ_p		degrees
Nominal Bearing Resistance, qn for B = 15 feet	12.5	ksf	Unit Weight Above GWT, $\gamma_{m,p}$		pcf
Unit Weight Above GWT, $\gamma_{m,s}$		pcf	Unit Weight Below GWT, $\gamma_{sat,p}$		pcf
Unit Weight Below GWT, $\gamma_{sat,s}$		pcf			

RESISTANCE FACTORS		LOAD FACTORS		
Resistance	RF	Load	Symbol	LF
Sliding (MSE)	1.0	Earth (Horizontal)	γEH	1.5
Passive (MSE)	0.75	Earth (Vertical)	γEV	1.35
Bearing (MSE) (Static)	0.65	Live Surcharge	γLS	1.75
Bearing (MSE) (Seismic)	1.0	Earthquake	γEQ	1

AASHTO LRFD:

FAILURE BY SLIDING	LOAD SIDE			RESISTANCE SIDE			LRFD CHECK	
	L (lbs/ft)	LF	L*LF (lbs/ft)	R (lbs/ft)	RF	R*RF (lbs/ft)	R*RF > L*LF ?	
LOAD								
Earth (L_{EH})	3906	1.5	5859					L_{EH} =('SL&OT LOADS'!E15+'SL&OT LOADS'!E16+'SL&OT LOADS'!E17)*COS('SL&OT LOADS'!B8)
Surcharge (L_{LS})	1187	1.75	2077					L_{LS} =('SL&OT LOADS'!E18)*COS('SL&OT LOADS'!B8)
Earthquake (L_{EQ})	0	1	0					L_{EQ} ='SL&OT LOADS'!E19+'SL&OT LOADS'!E20+'SL&OT LOADS'!E21+'SL&OT LOADS'!E22*COS('SL&OT LOADS'!B8)
RESISTANCE								
Base Friction (continuous reinforcement)				8885	1	8885		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D15
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			7936			8885	YES	
RESISTANCE								
Base Friction (DIScontinuous reinforcement)				14315	1	14315		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D16
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			7936			14315	YES	

FAILURE BY BEARING B-2e = 13.8 feet	LOAD SIDE				
	L (lbs/ft)	LF	L*LF (lbs/ft)	$q_{FACTORED}$ (psf) =ΣL*LF/(B-2e)	
LOAD					
Earth (L_{EV})	26598	1.35	35908		L_{EV} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E15+'BEARING LOADS'!E16+'BEARING LOADS'!E17)+'BEARING LOADS'!E3+'BEARING LOADS'!E4+'BEARING LOADS'!E5+'BEARING LOADS'!E6
Surcharge (L_{LS})	3981	1.75	6966		L_{LS} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E18)+'BEARING LOADS'!E7
Earthquake (L_{EQ})	0	1	0		L_{EQ} ='BEARING LOADS'!E22*SIN('BEARING LOADS'!B8)
SUM			42874	3105	q_factored = D54/(I9-2*'BEARING LOADS'!B34)
RESISTANCE SIDE					
Nominal Bearing Resistance, qn for B = 15 feet				12500 psf	
Factored Bearnig Resistance = qn*RF =				8125 psf	=IF(I18=0,E56*L27,E56*L28)
R*RF > ΣL*LF/(B-2e) ?				YES	=IF(E57>E54,"YES","NO")

FAILURE BY OVERTURNING		
Parameter	Value	Note
e	1.04	ft from center of base reinforcement layer
1/4 B	3.75	ft from center of base reinforcement layer
e ≤ 1/4 B ?	YES	See Sections 11.10.5.5 and 11.6.3.3 in AASHTO 2010

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	12	ft	W_m (β=0)	21600	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	7.50	feet	B/2
4	Width, B	15	ft	$W_{\beta 1}$ (triangular part)	1539	lbs/ft	$W_{\beta 1} = 1/2*min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta 1}$	10.00	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	57.50	feet	x+(B-x)/2
6	Height of Retained Fill, h	13.71	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	7.50	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	0	lbs/ft	W_q = 0 for sliding and overturning		x_q	7.50	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**23139**	**lbs/ft**	<- Factored			**177390**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	12.72	ft						11.6			
10	$H_2 = H+0.5*H*tan(\beta)/[1-0.5tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	Am = $(1.45-k_h)*k_h$ for $k_h < 0.45$	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**120**	pcf	F_{T1}	3979	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	4.57	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**120**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	1209	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	6.86	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	6.00	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	12.24	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	12.36	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	7.63	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<-Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<-Factored
24	k_h	0	g's	**$F_{\beta x}$**	**7936**	**lbs/ft**	<-Factored		**$M_{\beta +}$**	**41022**	**ft-lb/ft**	<-Factored
25	theta	0		**$F_{\beta y}$**	**1543**	**lbs/ft**	<-Factored		**$M_{\beta -}$**	**23145**	**ft-lb/ft**	<-Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	10.8	1.00		Kp = $tan^2(45+\phi/2)$			**Moment Arms (about toe)**		
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**1.04**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)								
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

$$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$$

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	12	ft	W_m (β=0)	24300	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	7.50	feet	B/2
4	Width, B	15	ft	$W_{\beta 1}$ (triangular part)	1539	lbs/ft	$W_{\beta 1} = 1/2*\min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta 1}$	10.00	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	57.50	feet	x+(B-x)/2
6	Height of Retained Fill, h	13.71	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	7.50	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	3750	lbs/ft	$W_q = B*q_{mse}$		x_q	7.50	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**41445**	**lbs/ft**	<- Factored			**316033**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	12.72	ft						11.6			
10	$H_2 = H+0.5*H*\tan(\beta)/[1-0.5\tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*****			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	$A_m = (1.45-k_h)*k_h$ for $k_h < 0.45$	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**135**	pcf	F_{T1}	3979	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	4.57	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**135**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	1209	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	6.86	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	6.00	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	12.24	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	12.36	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	7.63	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<- Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<- Factored
24	k_h	0	g's	**$F_{\beta x}$**	**7936**	**lbs/ft**	<- Factored		**$M_{\beta +}$**	**41022**	**ft-lb/ft**	<- Factored
25	theta	0		**$F_{\beta y}$**	**1543**	**lbs/ft**	<- Factored		**$M_{\beta -}$**	**23145**	**ft-lb/ft**	<- Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	10.8	1.00		$Kp = \tan^2(45+\phi/2)$		**Moment Arms (about toe)**			
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**0.60**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)								
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

$$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$$

CALC. G1: WALL C1 AT WALL HEIGHT OF 14FT STATIC EXTERNAL STABILITY

ENTER PARAMETERS IN YELLOW CELLS. SEE DIAGRAM TAB FOR CLARIFICATION.

References:	
AASHTO 2010 LRFD Bridge Manual	for seismic loads, LRFD calcs
NAVFAC DM 7.2 (1986)	for friction properties
Das (1999)	for earth pressures

B/H = 0.8

Retained Soil Properties

Retained Friction Angle, ϕ_r	30	degrees
Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf
Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf
Ignore Vertical Component of Inclined Loads for Sliding/Overturning?	No	
Ka override (blank for auto-calc using Das, 1999 eqn.)		(autocalc)

Geometry

Height, H	14	feet	(above top of leveling pad)
Width, B	11.6	feet	
Height of GWT, H_w	0	feet	(0 means below the wall bottom)
Backslope Angle, β	6.5	degrees	
Distance to Slope Break, X	100	feet	(0 if no slope break)
Backslope Height, Δy	11.4	feet	
Effective Backslope Angle, β'	11.0	degrees	(0 if x < B)

MSE Properties

Continuous Reinforcement Friction Factor, μ	0.36	(sheets, grids)
Discontinuous Reinforcement Friction Factor, μ	0.58	(strips)
Adhesion, a	0	psf
SLIDING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	120	pcf
SLIDING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	120	pcf
BEARING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	135	pcf
BEARING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	135	pcf

Surcharge/Seismic Loads

Parameter	Value	Unit
Retained Soil Surcharge, q_r	250	psf
MSE Surcharge, q_{mse}	250	psf
k_h	0	g's
ΔK_{ae}	0.00	g's
ΔK_{ae} override	0	(blank for autocalc)

(all surcharges ignored for seismic. Surcharge above MSE ignored for sliding/overturning)

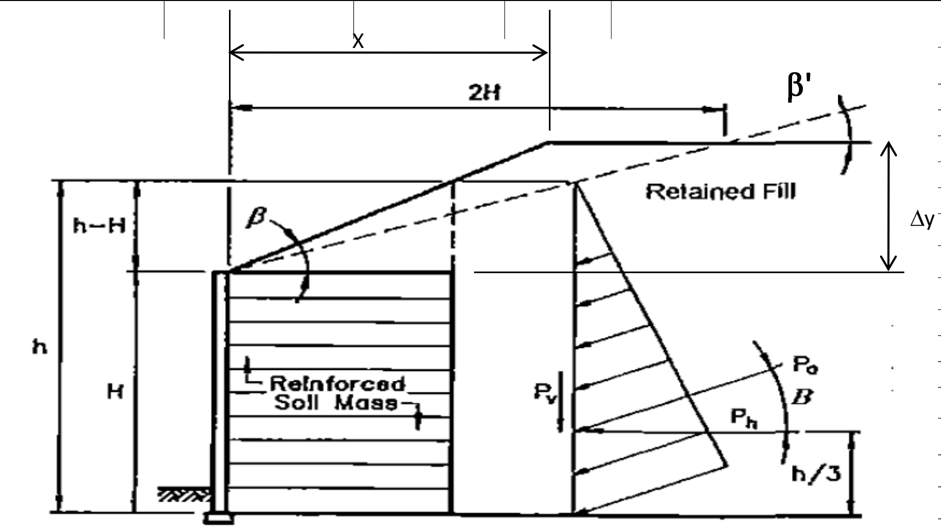


Figure 3.11.5.8.1-3—Earth Pressure Distribution for MSE Wall with Broken Back Backfill Surface

Subgrade/Bearing Properties

Parameter	Value	Unit
Subgrade Friction Angle, ϕ_s		degrees
Subgrade Cohesion, c		psf
Foundation Depth , D		feet
Nominal Bearing Resistance, qn for B = 11.6 feet	10.5	ksf
Unit Weight Above GWT, $\gamma_{m,s}$		pcf
Unit Weight Below GWT, $\gamma_{sat,s}$		pcf

Passive Resistance

Parameter	Value	Unit
Ignore Passive Resistance?	Yes	
Height of Passive, H_p		feet
Passive Friction Angle, ϕ_p		degrees
Unit Weight Above GWT, $\gamma_{m,p}$		pcf
Unit Weight Below GWT, $\gamma_{sat,p}$		pcf

RESISTANCE FACTORS

Resistance	RF
Sliding (MSE)	1.0
Passive (MSE)	0.75
Bearing (MSE) (Static)	0.65
Bearing (MSE) (Seismic)	1.0

LOAD FACTORS

Load	Symbol	LF
Earth (Horizontal)	γEH	1.5
Earth (Vertical)	γEV	1.35
Live Surcharge	γLS	1.75
Earthquake	γEQ	1

AASHTO LRFD:

FAILURE BY SLIDING

	LOAD SIDE: L (lbs/ft)	LF	L*LF (lbs/ft)	RESISTANCE SIDE: R (lbs/ft)	RF	R*RF (lbs/ft)	LRFD CHECK: R*RF > L*LF ?	
LOAD								
Earth (L_{EH})	4878	1.5	7317					L_{EH} =('SL&OT LOADS'!E15+'SL&OT LOADS'!E16+'SL&OT LOADS'!E17)*COS('SL&OT LOADS'!B8)
Surcharge (L_{LS})	1326	1.75	2321					L_{LS} =('SL&OT LOADS'!E18)*COS('SL&OT LOADS'!B8)
Earthquake (L_{EQ})	0	1	0					L_{EQ} ='SL&OT LOADS'!E19+'SL&OT LOADS'!E20+'SL&OT LOADS'!E21+'SL&OT LOADS'!E22*COS('SL&OT LOADS'!B8)
RESISTANCE								
Base Friction (continuous reinforcement)				8021	1	8021		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D15
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			9637			8021	NO	
RESISTANCE								
Base Friction (DIScontinuous reinforcement)				12923	1	12923		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D16
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			9637			12923	YES	

FAILURE BY BEARING B-2e = 9.3 feet

	LOAD SIDE: L (lbs/ft)	LF	L*LF (lbs/ft)	$q_{FACTORED}$ (psf) =ΣL*LF/(B-2e)	
LOAD					
Earth (L_{EV})	23791	1.35	32118		L_{EV} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E15+'BEARING LOADS'!E16+'BEARING LOADS'!E17)+'BEARING LOADS'!E3+'BEARING LOADS'!E4+'BEARING LOADS'!E5+'BEARING LOADS'!E6
Surcharge (L_{LS})	3158	1.75	5526		L_{LS} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E18)+'BEARING LOADS'!E7
Earthquake (L_{EQ})	0	1	0		L_{EQ} ='BEARING LOADS'!E22*SIN('BEARING LOADS'!B8)
SUM			37644	4027	q_factored = D54/(I9-2*'BEARING LOADS'!B34)

RESISTANCE SIDE

Nominal Bearing Resistance, qn for B = 11.6 feet	10500	psf	
Factored Bearnig Resistance = qn*RF =	6825	psf	=IF(I18=0,E56*L27,E56*L28)
R*RF > ΣL*LF/(B-2e) ?	YES		=IF(E57>E54,"YES","NO")

FAILURE BY OVERTURNING

Parameter	Value	Note
e	1.91	ft from center of base reinforcement layer
1/4 B	2.90	ft from center of base reinforcement layer
e ≤ 1/4 B ?	YES	See Sections 11.10.5.5 and 11.6.3.3 in AASHTO 2010

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	14	ft	W_m (β=0)	19488	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	5.80	feet	B/2
4	Width, B	11.6	ft	$W_{\beta 1}$ (triangular part)	919	lbs/ft	$W_{\beta 1}$ = 1/2*min(x,B)*(h-H)*$\gamma_{m,r}$		$x_{\beta 1}$	7.73	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	55.80	feet	x+(B-x)/2
6	Height of Retained Fill, h	15.32	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	5.80	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	0	lbs/ft	W_q = 0 for sliding and overturning		x_q	5.80	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**20407**	**lbs/ft**	<- Factored			**120134**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	14.85	ft						11.6			
10	$H_2 = H+0.5*H*\tan(\beta)/[1-0.5\tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	Am = $(1.45-k_h)*k_h$ for k_h < 0.45	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**120**	pcf	F_{T1}	4969	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	5.11	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**120**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	1351	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	7.66	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	7.00	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	14.28	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	14.43	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	8.91	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<-Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<-Factored
24	k_h	0	g's	**$F_{\beta x}$**	**9637**	**lbs/ft**	<-Factored		**$M_{\beta +}$**	**55165**	**ft-lb/ft**	<-Factored
25	theta	0		**$F_{\beta y}$**	**1873**	**lbs/ft**	<-Factored		**$M_{\beta -}$**	**21727**	**ft-lb/ft**	<-Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	10.8	1.00		Kp = $\tan^2(45+\phi/2)$		**Moment Arms (about toe)**			
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**1.91**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)				$e = \dfrac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$				
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	14	ft	W_m (β=0)	21924	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	5.80	feet	B/2
4	Width, B	11.6	ft	$W_{\beta 1}$ (triangular part)	919	lbs/ft	$W_{\beta 1} = 1/2*min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta 1}$	7.73	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	55.80	feet	x+(B-x)/2
6	Height of Retained Fill, h	15.32	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	5.80	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	2900	lbs/ft	$W_q = B*q_{mse}$		x_q	5.80	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**35913**	**lbs/ft**	<- Factored			**210690**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	14.85	ft						11.6			
10	$H_2 = H+0.5*H*tan(\beta)/[1-0.5tan(\beta)]$											
11	Broken slope width, x	100	ft				**DRIVING FORCES**					
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	$Am = (1.45-k_h)*k_h$ for $k_h < 0.45$	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**135**	pcf	F_{T1}	4969	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	5.11	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**135**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	1351	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	7.66	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	7.00	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	14.28	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	14.43	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	8.91	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<- Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<- Factored
24	k_h	0	g's	**$F_{\beta x}$**	**9637**	**lbs/ft**	<- Factored		**$M_{\beta +}$**	**55165**	**ft-lb/ft**	<- Factored
25	theta	0		**$F_{\beta y}$**	**1873**	**lbs/ft**	<- Factored		**$M_{\beta -}$**	**21727**	**ft-lb/ft**	<- Factored
26	**Passive**						**PASSIVE FORCES (HORIZONTAL)**					
27	Height of Passive, H_p	0	ft	10.8	1.00		$Kp = tan^2(45+\phi/2)$			**Moment Arms (about toe)**		
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**1.13**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)								
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

$$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$$

CALC. G: WALL C1 AT WALL STA. 12+25 STATIC EXTERNAL STABILITY

ENTER PARAMETERS IN YELLOW CELLS. SEE DIAGRAM TAB FOR CLARIFICATION.

References:		
	AASHTO 2010 LRFD Bridge Manual	for seismic loads, LRFD calcs
	NAVFAC DM 7.2 (1986)	for friction properties
	Das (1999)	for earth pressures

B/H = 0.9

Retained Soil Properties			Geometry			
Retained Friction Angle, ϕ_r	30	degrees	Height, H	22	feet	(above top of leveling pad)
Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	Width, B	19.8	feet	
Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	Height of GWT, H_w	0	feet	(0 means below the wall bottom)
Ignore Vertical Component of Inclined Loads for Sliding/Overturning?	No		Backslope Angle, β	6.5	degrees	
			Distance to Slope Break, X	100	feet	(0 if no slope break)
Ka override (blank for auto-calc using Das, 1999 eqn.)		(autocalc)	Backslope Height, Δy	11.4	feet	
MSE Properties			Effective Backslope Angle, β'	11.0	degrees	(0 if x < B)
Continuous Reinforcement Friction Factor, μ	0.36	(sheets, grids)	**Surcharge/Seismic Loads**			(all surcharges ignored for seismic. Surcharge above MSE ignored for sliding/overturning)
Discontinuous Reinforcement Friction Factor, μ	0.58	(strips)	Retained Soil Surcharge, q_r	250	psf	
Adhesion, a	0	psf	MSE Surcharge, q_{mse}	250	psf	
SLIDING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	120	pcf	k_h	0	g's	
SLIDING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	120	pcf	ΔK_{ae}	0.00	g's	
BEARING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	135	pcf	ΔK_{ae} override	0	(blank for autocalc)	
BEARING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	135	pcf				

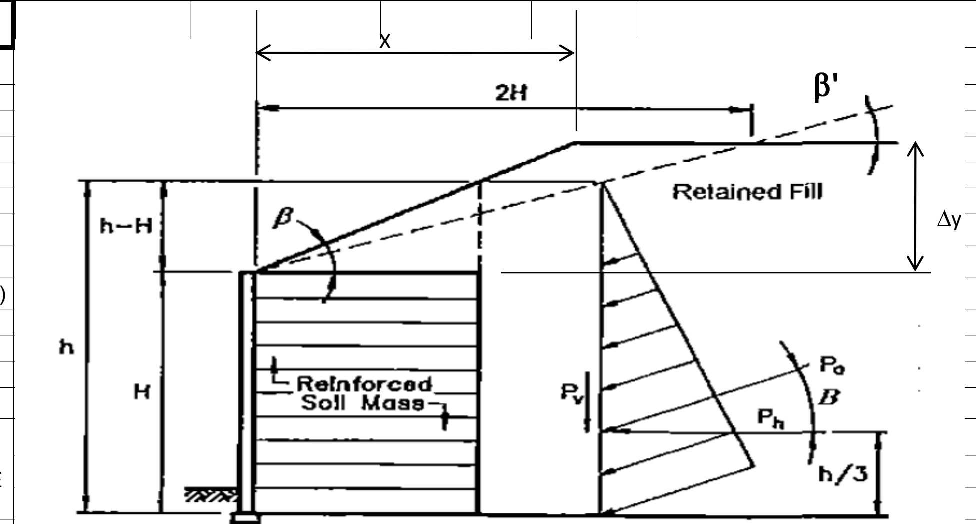


Figure 3.11.5.8.1-3—Earth Pressure Distribution for MSE Wall with Broken Back Backfill Surface

Subgrade/Bearing Properties			Passive Resistance		
Subgrade Friction Angle, ϕ_s		degrees	Ignore Passive Resistance?	Yes	
Subgrade Cohesion, c		psf	Height of Passive, H_p		feet
Foundation Depth , D		feet	Passive Friction Angle, ϕ_p		degrees
Nominal Bearing Resistance, qn for B = 19.8 feet	16.0	ksf	Unit Weight Above GWT, $\gamma_{m,p}$		pcf
Unit Weight Above GWT, $\gamma_{m,s}$		pcf	Unit Weight Below GWT, $\gamma_{sat,p}$		pcf
Unit Weight Below GWT, $\gamma_{sat,s}$		pcf			

RESISTANCE FACTORS		LOAD FACTORS		
Resistance	RF	Load	Symbol	LF
Sliding (MSE)	1.0	Earth (Horizontal)	γEH	1.5
Passive (MSE)	0.75	Earth (Vertical)	γEV	1.35
Bearing (MSE) (Static)	0.65	Live Surcharge	γLS	1.75
Bearing (MSE) (Seismic)	1.0	Earthquake	γEQ	1

AASHTO LRFD:

FAILURE BY SLIDING	LOAD SIDE			RESISTANCE SIDE			LRFD CHECK	
	L (lbs/ft)	LF	L*LF (lbs/ft)	R (lbs/ft)	RF	R*RF (lbs/ft)	R*RF > L*LF ?	
LOAD								
Earth (L_{EH})	12231	1.5	18347					L_{EH} =('SL&OT LOADS'!E15+'SL&OT LOADS'!E16+'SL&OT LOADS'!E17)*COS('SL&OT LOADS'!B8)
Surcharge (L_{LS})	2101	1.75	3676					L_{LS} =('SL&OT LOADS'!E18)*COS('SL&OT LOADS'!B8)
Earthquake (L_{EQ})	0	1	0					L_{EQ} ='SL&OT LOADS'!E19+'SL&OT LOADS'!E20+'SL&OT LOADS'!E21+'SL&OT LOADS'!E22*COS('SL&OT LOADS'!B8)
RESISTANCE								
Base Friction (continuous reinforcement)				21326	1	21326		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D15
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			22023			21326	NO	
RESISTANCE								
Base Friction (DIScontinuous reinforcement)				34358	1	34358		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D16
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			22023			34358	YES	

FAILURE BY BEARING B-2e = 16.8 feet	LOAD SIDE				
	L (lbs/ft)	LF	L*LF (lbs/ft)	$q_{FACTORED}$ (psf) =ΣL*LF/(B-2e)	
LOAD					
Earth (L_{EV})	63869	1.35	86223		L_{EV} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E15+'BEARING LOADS'!E16+'BEARING LOADS'!E17)+'BEARING LOADS'!E3+'BEARING LOADS'!E4+'BEARING LOADS'!E5+'BEARING LOADS'!E6
Surcharge (L_{LS})	5358	1.75	9377		L_{LS} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E18)+'BEARING LOADS'!E7
Earthquake (L_{EQ})	0	1	0		L_{EQ} ='BEARING LOADS'!E22*SIN('BEARING LOADS'!B8)
SUM			95600	5675	q_factored = D54/(I9-2*'BEARING LOADS'!B34)
RESISTANCE SIDE					
Nominal Bearing Resistance, qn for B = 19.8 feet				16000 psf	
Factored Bearnig Resistance = qn*RF =				10400 psf	=IF(I18=0,E56*L27,E56*L28)
R*RF > ΣL*LF/(B-2e) ?				YES	=IF(E57>E54,"YES","NO")

FAILURE BY OVERTURNING

Parameter	Value	Note
e	2.39	ft from center of base reinforcement layer
1/4 B	4.95	ft from center of base reinforcement layer
e ≤ 1/4 B ?	YES	See Sections 11.10.5.5 and 11.6.3.3 in AASHTO 2010

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	22	ft	W_m (β=0)	52272	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	9.90	feet	B/2
4	Width, B	19.8	ft	$W_{\beta 1}$ (triangular part)	2685	lbs/ft	$W_{\beta 1} = 1/2*min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta 1}$	13.20	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	59.90	feet	x+(B-x)/2
6	Height of Retained Fill, h	24.26	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	9.90	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	0	lbs/ft	W_q = 0 for sliding and overturning		x_q	9.90	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**54957**	**lbs/ft**	<- Factored			**552935**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	23.33	ft						11.6			
10	$H_2 = H+0.5*H*\tan(\beta)/[1-0.5\tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	$Am = (1.45-k_h)*k_h$ for $k_h < 0.45$	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**120**	pcf	F_{T1}	12460	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	8.09	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**120**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	2140	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	12.13	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	11.00	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	22.44	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	22.67	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	14.00	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<-Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<-Factored
24	k_h	0	g's	**$F_{\beta x}$**	**22023**	**lbs/ft**	<-Factored		**$M_{\beta +}$**	**193016**	**ft-lb/ft**	<-Factored
25	theta	0		**$F_{\beta y}$**	**4281**	**lbs/ft**	<-Factored		**$M_{\beta -}$**	**84764**	**ft-lb/ft**	<-Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	10.8	1.00		$Kp = \tan^2(45+\phi/2)$			**Moment Arms (about toe)**		
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**2.39**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)								
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

$$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$$

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	22	ft	W_m (β=0)	58806	lbs/ft	$W_m = B^*(H-H_w)^*\gamma_{m,mse}$		x_m	9.90	feet	B/2
4	Width, B	19.8	ft	$W_{\beta 1}$ (triangular part)	2685	lbs/ft	$W_{\beta 1} = 1/2^*\min(x,B)^*(h-H)^*\gamma_{m,r}$		$x_{\beta 1}$	13.20	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)^*(h-H)^*\gamma_{m,r}$		$x_{\beta 2}$	59.90	feet	x+(B-x)/2
6	Height of Retained Fill, h	24.26	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B^*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	9.90	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	4950	lbs/ft	$W_q = B^*q_{mse}$		x_q	9.90	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**91675**	**lbs/ft**	<- Factored			**919548**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	23.33	ft						11.6			
10	$H_2 = H+0.5^*H^*\tan(\beta)/[1-0.5\tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	$Am = (1.45-k_h)^*k_h$ for k_h < 0.45	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**135**	pcf	F_{T1}	12460	lbs/ft	$F_{T1} = 1/2^*K_a^*(h-H_w)^{2*}\gamma_{m,r}$	Parallel to β'	y_{T1}	8.09	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**135**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a^*(h-H_w)^*H_w^*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2^*K_a^*H_w^{2*}(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	2140	lbs/ft	$F_q = K_a^*h^*q_r$	Parallel to β'	y_q	12.13	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5^*A_m^*\gamma_{m,mse}^*H_2^*H$	Horizontal	y_{ir}	11.00	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m^*\gamma_{m,r}^*Area_{is}$	Horizontal	y_{is1}	22.44	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	22.67	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5^*\Delta K_{ae}^*\gamma_{m,r}^*H_2^2$	Parallel to β'	y_{AE}	14.00	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<- Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<- Factored
24	k_h	0	g's	**$F_{\beta x}$**	**22023**	**lbs/ft**	<- Factored		**$M_{\beta+}$**	**193016**	**ft-lb/ft**	<- Factored
25	theta	0		**$F_{\beta y}$**	**4281**	**lbs/ft**	<- Factored		**$M_{\beta-}$**	**84764**	**ft-lb/ft**	<- Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	10.8	1.00		$Kp = \tan^2(45+\phi/2)$		**Moment Arms (about toe)**			
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2^*Kp^*(H_p-H_w)^{2*}\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp^*(H_p-H_w)^*H_w^*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2^*Kp^*H_w^{2*}(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**1.48**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)								
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

$$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$$

CALC. H: WALL C1 AT STA. 12+70 SEISMIC EXTERNAL STABILITY

ENTER PARAMETERS IN YELLOW CELLS. SEE DIAGRAM TAB FOR CLARIFICATION.

References:	AASHTO 2010 LRFD Bridge Manual	for seismic loads, LRFD calcs
	NAVFAC DM 7.2 (1986)	for friction properties
	Das (1999)	for earth pressures

B/H = 0.9

	Retained Soil Properties			Geometry			
8	Retained Friction Angle, ϕ_r	30	degrees	Height, H	42	feet	(above top of leveling pad)
9	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	Width, B	39.6	feet	
10	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	Height of GWT, H_w	0	feet	(0 means below the wall bottom)
11	Ignore Vertical Component of Inclined Loads for Sliding/Overturning?	No		Backslope Angle, β	0	degrees	
12				Distance to Slope Break, X	0	feet	(0 if no slope break)
13	Ka override (blank for auto-calc using Das, 1999 eqn.)		(autocalc)	Backslope Height, Δy	0.0	feet	
14	**MSE Properties**			Effective Backslope Angle, β'	0.0	degrees	(0 if x < B)
15	Continuous Reinforcement Friction Factor, μ	0.36	(sheets, grids)	**Surcharge/Seismic Loads**			(all surcharges ignored for seismic. Surcharge above MSE ignored for sliding/overturning)
16	Discontinuous Reinforcement Friction Factor, μ	0.58	(strips)	Retained Soil Surcharge, q_r	0	psf	
17	Adhesion, a	0	psf	MSE Surcharge, q_{mse}	0	psf	
18	SLIDING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	120	pcf	k_h	0.029	g's	
19	SLIDING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	120	pcf	ΔK_{ae}	0.02	g's	
20	BEARING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	135	pcf	ΔK_{ae} override	0.017	(blank for autocalc)	
21	BEARING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	135	pcf				

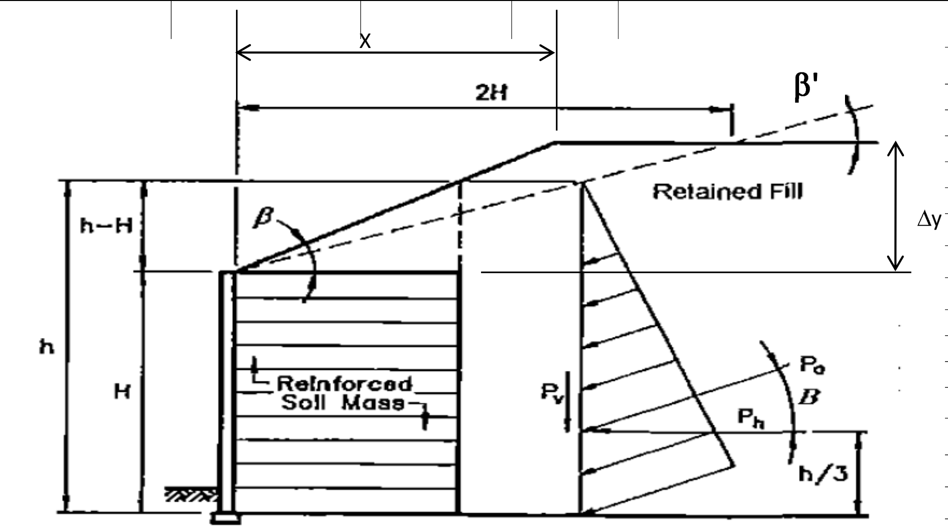


Figure 3.11.5.8.1-3—Earth Pressure Distribution for MSE Wall with Broken Back Backfill Surface

	Subgrade/Bearing Properties			Passive Resistance		
24	Subgrade Friction Angle, ϕ_s		degrees	Ignore Passive Resistance?	Yes	
25	Subgrade Cohesion, c		psf	Height of Passive, H_p		feet
26	Foundation Depth , D		feet	Passive Friction Angle, ϕ_p		degrees
27	Nominal Bearing Resistance, qn for B = 39.6 feet	25.0	ksf	Unit Weight Above GWT, $\gamma_{m,p}$		pcf
28	Unit Weight Above GWT, $\gamma_{m,s}$		pcf	Unit Weight Below GWT, $\gamma_{sat,p}$		pcf
29	Unit Weight Below GWT, $\gamma_{sat,s}$		pcf			

RESISTANCE FACTORS		LOAD FACTORS		
Resistance	**RF**	**Load**	**Symbol**	**LF**
Sliding (MSE)	1.0	Earth (Horizontal)	γEH	1.5
Passive (MSE)	0.75	Earth (Vertical)	γEV	1.35
Bearing (MSE) (Static)	0.65	Live Surcharge	γLS	1.75
Bearing (MSE) (Seismic)	1.0	Earthquake	γEQ	1

AASHTO LRFD:

FAILURE BY SLIDING	LOAD SIDE			RESISTANCE SIDE			LRFD CHECK	
	L (lbs/ft)	LF	L*LF (lbs/ft)	R (lbs/ft)	RF	R*RF (lbs/ft)	R*RF > L*LF ?	
LOAD								
Earth (L_{EH})	35247	1.5	52871					L_{EH} =('SL&OT LOADS'!E15+'SL&OT LOADS'!E16+'SL&OT LOADS'!E17)*COS('SL&OT LOADS'!B8)
Surcharge (L_{LS})	0	1.75	0					L_{LS} =('SL&OT LOADS'!E18)*COS('SL&OT LOADS'!B8)
Earthquake (L_{EQ})	6138	1	6138					L_{EQ} ='SL&OT LOADS'!E19+'SL&OT LOADS'!E20+'SL&OT LOADS'!E21+'SL&OT LOADS'!E22*COS('SL&OT LOADS'!B8)
RESISTANCE								
Base Friction (continuous reinforcement)				71850	1	71850		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D15
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			59009			71850	YES	
RESISTANCE								
Base Friction (DIScontinuous reinforcement)				115759	1	115759		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D16
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			59009			115759	YES	

FAILURE BY BEARING B-2e = 33.7 feet	LOAD SIDE				
	L (lbs/ft)	LF	L*LF (lbs/ft)	$q_{FACTORED}$ (psf) =ΣL*LF/(B-2e)	
LOAD					
Earth (L_{EV})	224532	1.35	303118		L_{EV} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E15+'BEARING LOADS'!E16+'BEARING LOADS'!E17)+'BEARING LOADS'!E3+'BEARING LOADS'!E4+'BEARING LOADS'!E5+'BEARING LOADS'!E6
Surcharge (L_{LS})	0	1.75	0		L_{LS} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E18)+'BEARING LOADS'!E7
Earthquake (L_{EQ})	0	1	0		L_{EQ} ='BEARING LOADS'!E22*SIN('BEARING LOADS'!B8)
SUM			303118	8984	q_factored = D54/(I9-2*'BEARING LOADS'!B34)
RESISTANCE SIDE					
Nominal Bearing Resistance, qn for B = 39.6 feet				25000 psf	
Factored Bearnig Resistance = qn*RF =				25000 psf	=IF(I18=0,E56*L27,E56*L28)
R*RF > ΣL*LF/(B-2e) ?				YES	=IF(E57>E54,"YES","NO")

FAILURE BY OVERTURNING		
Parameter	**Value**	**Note**
e	4.39	ft from center of base reinforcement layer
1/4 B	9.90	ft from center of base reinforcement layer
e ≤ 1/4 B ?	YES	See Sections 11.10.5.5 and 11.6.3.3 in AASHTO 2010

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	42	ft	W_m (β=0)	199584	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	19.80	feet	B/2
4	Width, B	39.6	ft	$W_{\beta 1}$ (triangular part)	0	lbs/ft	$W_{\beta 1}$ = 1/2*min(x,B)*(h-H)*$\gamma_{m,r}$		$x_{\beta 1}$	26.40	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	69.80	feet	x+(B-x)/2
6	Height of Retained Fill, h	42	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	19.80	feet	B/2
7	h = H+B*tan(β) β=	0	rad	W_q	0	lbs/ft	W_q = 0 for sliding and overturning		x_q	19.80	feet	B/2
8	Effective Backslope Angle, β'	0	rad	**W_{TOTAL}**	**199584**	**lbs/ft**	<- Factored			**3951763**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	42	ft									
10	$H_2 = H+0.5*H*\tan(\beta)/[1-0.5\tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*** **			K_a	0.333		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.017		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.041	g's	Am = $(1.45-k_h)*k_h$ for k_h < 0.45	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**120**	pcf	F_{T1}	35247	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	14.00	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**120**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	0	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	21.00	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	4339	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	21.00	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	42.00	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	42.00	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	0	psf	$0.5P_{AE}$	1799	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	25.20	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	0	psf	**F_{HORZ}**	**4339**	**lbs/ft**	<-Factored		**M_{HORZ}**	**91119**	**ft-lb/ft**	<-Factored
24	k_h	0.029	g's	**$F_{\beta x}$**	**54670**	**lbs/ft**	<-Factored		**$M_{\beta+}$**	**785522**	**ft-lb/ft**	<-Factored
25	theta	0.029		**$F_{\beta y}$**	**0**	**lbs/ft**	<-Factored		**$M_{\beta-}$**	**0**	**ft-lb/ft**	<-Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	K_p	1.00		Kp = $\tan^2(45+\phi/2)$		**Moment Arms (about toe)**			
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**4.39**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)				$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$				
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	42	ft	W_m (β=0)	224532	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	19.80	feet	B/2
4	Width, B	39.6	ft	$W_{\beta1}$ (triangular part)	0	lbs/ft	$W_{\beta1} = 1/2*min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta1}$	26.40	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta2}$ (broken slope)	0	lbs/ft	$W_{\beta2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta2}$	69.80	feet	x+(B-x)/2
6	Height of Retained Fill, h	42	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	19.80	feet	B/2
7	h = H+B*tan(β) β=	0	rad	W_q	0	lbs/ft	$W_q = B*q_{mse}$		x_q	19.80	feet	B/2
8	Effective Backslope Angle, β'	0	rad	**W_{TOTAL}**	**303118**	**lbs/ft**	<- Factored			**6001740**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	42	ft									
10	$H_2 = H+0.5*H*tan(\beta)/[1-0.5tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*****			K_a	0.333		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.017		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.041	g's	$A_m = (1.45-k_h)*k_h$ for k_h < 0.45	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**135**	pcf	F_{T1}	35247	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	14.00	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**135**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	0	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	21.00	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	4882	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	21.00	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	42.00	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	42.00	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	0	psf	$0.5P_{AE}$	1799	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	25.20	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	0	psf	**F_{HORZ}**	**4882**	**lbs/ft**	<- Factored		**M_{HORZ}**	**102522**	**ft-lb/ft**	<- Factored
24	k_h	0.029	g's	**$F_{\beta x}$**	**54670**	**lbs/ft**	<- Factored		**$M_{\beta+}$**	**785522**	**ft-lb/ft**	<- Factored
25	theta	0.029		**$F_{\beta y}$**	**0**	**lbs/ft**	<- Factored		**$M_{\beta-}$**	**0**	**ft-lb/ft**	<- Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	K_p	1.00		$Kp = tan^2(45+\phi/2)$		**Moment Arms (about toe)**			
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**2.93**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)				$e = \dfrac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$				
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

CALC. G: WALL C1 AT WALL STA. 13+90 STATIC EXTERNAL STABILITY

ENTER PARAMETERS IN YELLOW CELLS. SEE DIAGRAM TAB FOR CLARIFICATION.

References:		
	AASHTO 2010 LRFD Bridge Manual	for seismic loads, LRFD calcs
	NAVFAC DM 7.2 (1986)	for friction properties
	Das (1999)	for earth pressures

B/H = 1.0

Retained Soil Properties		
Retained Friction Angle, ϕ_r	30	degrees
Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf
Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf
Ignore Vertical Component of Inclined Loads for Sliding/Overturning?	No	
Ka override (blank for auto-calc using Das, 1999 eqn.)		(autocalc)

Geometry			
Height, H	25	feet	(above top of leveling pad)
Width, B	25.3	feet	
Height of GWT, H_w	0	feet	(0 means below the wall bottom)
Backslope Angle, β	6.5	degrees	
Distance to Slope Break, X	100	feet	(0 if no slope break)
Backslope Height, Δy	11.4	feet	
Effective Backslope Angle, β'	11.0	degrees	(0 if x < B)

MSE Properties		
Continuous Reinforcement Friction Factor, μ	0.36	(sheets, grids)
Discontinuous Reinforcement Friction Factor, μ	0.58	(strips)
Adhesion, a	0	psf
SLIDING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	120	pcf
SLIDING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	120	pcf
BEARING Calc: Unit Weight Above GWT, $\gamma_{m,mse}$	135	pcf
BEARING Calc: Unit Weight Below GWT, $\gamma_{sat,mse}$	135	pcf

Surcharge/Seismic Loads		
Retained Soil Surcharge, q_r	250	psf
MSE Surcharge, q_{mse}	250	psf
k_h	0	g's
ΔK_{ae}	0.00	g's
ΔK_{ae} override	0	(blank for autocalc)

(all surcharges ignored for seismic. Surcharge above MSE ignored for sliding/overturning)

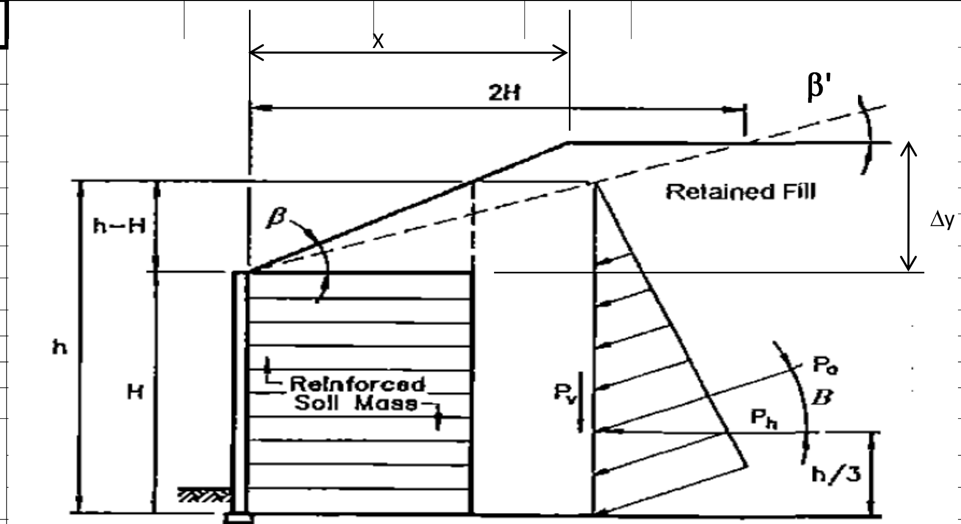


Figure 3.11.5.8.1-3—Earth Pressure Distribution for MSE Wall with Broken Back Backfill Surface

Subgrade/Bearing Properties		
Subgrade Friction Angle, ϕ_s		degrees
Subgrade Cohesion, c		psf
Foundation Depth , D		feet
Nominal Bearing Resistance, qn for B = 25.3 feet	19.0	ksf
Unit Weight Above GWT, $\gamma_{m,s}$		pcf
Unit Weight Below GWT, $\gamma_{sat,s}$		pcf

Passive Resistance		
Ignore Passive Resistance?	Yes	
Height of Passive, H_p		feet
Passive Friction Angle, ϕ_p		degrees
Unit Weight Above GWT, $\gamma_{m,p}$		pcf
Unit Weight Below GWT, $\gamma_{sat,p}$		pcf

RESISTANCE FACTORS	
Resistance	RF
Sliding (MSE)	1.0
Passive (MSE)	0.75
Bearing (MSE) (Static)	0.65
Bearing (MSE) (Seismic)	1.0

LOAD FACTORS		
Load	Symbol	LF
Earth (Horizontal)	γEH	1.5
Earth (Vertical)	γEV	1.35
Live Surcharge	γLS	1.75
Earthquake	γEQ	1

AASHTO LRFD:

FAILURE BY SLIDING	LOAD SIDE L (lbs/ft)	LF	L*LF (lbs/ft)	RESISTANCE SIDE R (lbs/ft)	RF	R*RF (lbs/ft)	LRFD CHECK R*RF > L*LF ?	
LOAD								
Earth (L_{EH})	16154	1.5	24230					L_{EH} =('SL&OT LOADS'!E15+'SL&OT LOADS'!E16+'SL&OT LOADS'!E17)*COS('SL&OT LOADS'!B8)
Surcharge (L_{LS})	2414	1.75	4224					L_{LS} =('SL&OT LOADS'!E18)*COS('SL&OT LOADS'!B8)
Earthquake (L_{EQ})	0	1	0					L_{EQ} ='SL&OT LOADS'!E19+'SL&OT LOADS'!E20+'SL&OT LOADS'!E21+'SL&OT LOADS'!E22*COS('SL&OT LOADS'!B8)
RESISTANCE								
Base Friction (continuous reinforcement)				30889	1	30889		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D15
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			28455			30889	YES	
RESISTANCE								
Base Friction (DIScontinuous reinforcement)				49766	1	49766		$R_{friction}$ =('SL&OT LOADS'!E3+'SL&OT LOADS'!E4+'SL&OT LOADS'!E5+(D36+D37)*TAN('SL&OT LOADS'!B8)+'SL&OT LOADS'!E22*SIN('SL&OT LOADS'!B8))*D16
Passive				0	0.75	0		$R_{passive}$ =IF(I24="YES",0,'SL&OT LOADS'!E31)
SUM			28455			49766	YES	

FAILURE BY BEARING B-2e = 22.5 feet	LOAD SIDE L (lbs/ft)	LF	L*LF (lbs/ft)	$q_{FACTORED}$ (psf) =ΣL*LF/(B-2e)	
LOAD					
Earth (L_{EV})	92900	1.35	125415		L_{EV} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E15+'BEARING LOADS'!E16+'BEARING LOADS'!E17)+'BEARING LOADS'!E3+'BEARING LOADS'!E4+'BEARING LOADS'!E5+'BEARING LOADS'!E6
Surcharge (L_{LS})	6794	1.75	11890		L_{LS} =SIN('BEARING LOADS'!B8)*('BEARING LOADS'!E18)+'BEARING LOADS'!E7
Earthquake (L_{EQ})	0	1	0		L_{EQ} ='BEARING LOADS'!E22*SIN('BEARING LOADS'!B8)
SUM			137305	6113	q_factored = D54/(I9-2*'BEARING LOADS'!B34)
RESISTANCE SIDE					
Nominal Bearing Resistance, qn for B = 25.3 feet				19000 psf	
Factored Bearnig Resistance = qn*RF =				12350 psf	=IF(I18=0,E56*L27,E56*L28)
R*RF > ΣL*LF/(B-2e) ?				YES	=IF(E57>E54,"YES","NO")

FAILURE BY OVERTURNING

Parameter	Value	Note
e	2.28	ft from center of base reinforcement layer
1/4 B	6.33	ft from center of base reinforcement layer
e ≤ 1/4 B ?	YES	See Sections 11.10.5.5 and 11.6.3.3 in AASHTO 2010

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	25	ft	W_m (β=0)	75900	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	12.65	feet	B/2
4	Width, B	25.3	ft	$W_{\beta 1}$ (triangular part)	4372	lbs/ft	$W_{\beta 1} = 1/2*min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta 1}$	16.87	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta 2}$ (broken slope)	0	lbs/ft	$W_{\beta 2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta 2}$	62.65	feet	x+(B-x)/2
6	Height of Retained Fill, h	27.88	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	12.65	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	0	lbs/ft	W_q = 0 for sliding and overturning		x_q	12.65	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**80272**	**lbs/ft**	<- Factored			**1033891**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	26.51	ft						11.6			
10	$H_2 = H+0.5*H*tan(\beta)/[1-0.5tan(\beta)]$											
11	Broken slope width, x	100	ft				**DRIVING FORCES**					
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	$Am = (1.45-k_h)*k_h$ for $k_h < 0.45$	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**120**	pcf	F_{T1}	16456	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	9.29	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**120**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	2459	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	13.94	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	12.50	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	25.50	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	25.76	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	15.91	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<-Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<-Factored
24	k_h	0	g's	**$F_{\beta x}$**	**28455**	**lbs/ft**	<-Factored		**$M_{\beta +}$**	**283986**	**ft-lb/ft**	<-Factored
25	theta	0		**$F_{\beta y}$**	**5531**	**lbs/ft**	<-Factored		**$M_{\beta -}$**	**139934**	**ft-lb/ft**	<-Factored
26	**Passive**						**PASSIVE FORCES (HORIZONTAL)**					
27	Height of Passive, H_p	0	ft	10.8	1.00		$Kp = tan^2(45+\phi/2)$		**Moment Arms (about toe)**			
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**2.28**	**ft**	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)				$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$				
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

	A	B	C	D	E	F	G	H	I	J	K	L
2	**Geometry**			**VERTICAL FORCES (not counting vertical components of driving forces)**						**Moment Arms (about toe)**		
3	Height, H	25	ft	W_m (β=0)	85388	lbs/ft	$W_m = B*(H-H_w)*\gamma_{m,mse}$		x_m	12.65	feet	B/2
4	Width, B	25.3	ft	$W_{\beta1}$ (triangular part)	4372	lbs/ft	$W_{\beta1} = 1/2*min(x,B)*(h-H)*\gamma_{m,r}$		$x_{\beta1}$	16.87	feet	2/3*min(B,x)
5	Height of GWT, H_w	0	ft	$W_{\beta2}$ (broken slope)	0	lbs/ft	$W_{\beta2} = (B-x)*(h-H)*\gamma_{m,r}$		$x_{\beta2}$	62.65	feet	x+(B-x)/2
6	Height of Retained Fill, h	27.88	ft	W_{sat}'	0	lbs/ft	$W_{sat}' = B*H_w(\gamma_{sat,mse}-62.4)$		x_{sat}	12.65	feet	B/2
7	h = H+B*tan(β) β=	0.113	rad	W_q	6325	lbs/ft	$W_q = B*q_{mse}$		x_q	12.65	feet	B/2
8	Effective Backslope Angle, β'	0.192	rad	**W_{TOTAL}**	**132245**	**lbs/ft**	<- Factored			**1697803**	**ft-lb/ft**	
9	Seismic Effective Height, H_2	26.51	ft						11.6			
10	$H_2 = H+0.5*H*tan(\beta)/[1-0.5tan(\beta)]$											
11	Broken slope width, x	100	ft	**DRIVING FORCES**								
12	**MSE*** **			K_a	0.353		From AASHTO Eqs 3.11.5.3-1 and 2 for θ = 90 and δ = 0					
13	Friction Factor, μ	0.36		ΔK_{ae}	0.000		From AASHTO Eq A11.1.1.1-2 for β and δ = 0 (notation is different in equation)					
14	Adhesion, a	0	psf	A_m	0.000	g's	Am = (1.45-k_h)*k_h for k_h < 0.45	**Direction of Force**	**Moment Arms (about toe, horz. component)**			
15	Unit Weight Above GWT, $\gamma_{m,mse}$	**135**	pcf	F_{T1}	16456	lbs/ft	$F_{T1} = 1/2*K_a*(h-H_w)^2*\gamma_{m,r}$	Parallel to β'	y_{T1}	9.29	feet	$H_w+(h-H_w)/3$
16	Unit Weight Below GWT, $\gamma_{sat,mse}$	**135**	pcf	F_{T2}	0	lbs/ft	$F_{T2} = K_a*(h-H_w)*H_w*\gamma_{m,r}$	Parallel to β'	y_{T2}	0.00	feet	$H_w/2$
17	**Retained**			F_{T3}	0	lbs/ft	$F_{T3} = 1/2*K_a*H_w^2*(\gamma_{sat,r}-62.4)$	Parallel to β'	y_{T3}	0.00	feet	$H_w/3$
18	Friction Angle, ϕ_r	0.524	rad	F_q	2459	lbs/ft	$F_q = K_a*h*q_r$	Parallel to β'	y_q	13.94	feet	h/2
19	Unit Weight Above GWT, $\gamma_{m,r}$	120	pcf	P_{ir}	0	lbs/ft	$P_{ir} = 0.5*A_m*\gamma_{m,mse}*H_2*H$	Horizontal	y_{ir}	12.50	feet	H/2
20	Unit Weight Below GWT, $\gamma_{sat,r}$	120	pcf	P_{is1} (triangular)	0	lbs/ft	$P_{is} = A_m*\gamma_{m,r}*Area_{is}$	Horizontal	y_{is1}	25.50	feet	$H+(H_2-H)/3$
21	**Surcharge/Seismic**			P_{is2} (broken slope)	0	lbs/ft		Horizontal	y_{is2}	25.76	feet	$H+(H_2-H)/2$
22	Retained Soil Surcharge, q_r	250	psf	$0.5P_{AE}$	0	lbs/ft	$0.5P_{AE} = 0.5*\Delta K_{ae}*\gamma_{m,r}*H_2^2$	Parallel to β'	y_{AE}	15.91	feet	$0.6H_2$
23	MSE Surcharge, q_{mse}	250	psf	**F_{HORZ}**	**0**	**lbs/ft**	<- Factored		**M_{HORZ}**	**0**	**ft-lb/ft**	<- Factored
24	k_h	0	g's	**$F_{\beta x}$**	**28455**	**lbs/ft**	<- Factored		**$M_{\beta+}$**	**283986**	**ft-lb/ft**	<- Factored
25	theta	0		**$F_{\beta y}$**	**5531**	**lbs/ft**	<- Factored		**$M_{\beta-}$**	**139934**	**ft-lb/ft**	<- Factored
26	**Passive**			**PASSIVE FORCES (HORIZONTAL)**								
27	Height of Passive, H_p	0	ft	10.8	1.00		Kp = $tan^2(45+\phi/2)$		**Moment Arms (about toe)**			
28	Friction Angle, ϕ_p	0	rad	F_{P1}	0	lbs/ft	$F_{P1} = 1/2*Kp*(H_p-H_w)^2*\gamma_{m,p}$		y_{P1}	0.00	feet	$H_w+(H_p-H_w)/3$
29	Unit Weight Above GWT, $\gamma_{m,p}$	0	pcf	F_{P2}	0	lbs/ft	$F_{P2} = Kp*(H_p-H_w)*H_w*\gamma_{m,p}$		y_{P2}	0.00	feet	$H_w/2$
30	Unit Weight Below GWT, $\gamma_{sat,p}$	0	pcf	F_{P3}	0	lbs/ft	$F_{P3} = 1/2*Kp*H_w^2*(\gamma_{sat,p}-62.4)$		y_{P3}	0.00	feet	$H_w/3$
31	Ignore Passive Resistance?	Yes		**$F_{PASSIVE}$**	**0**	**lbs/ft**			**$M_{PASSIVE}$**	**0**	**ft-lb/ft**	
32	Ignore Vertical from Inclined?	No										
33												
34	**Eccentricity, e**	**1.42**	ft	e =(J23+J24-J25/2-E4*(J4-B4/2)-E5*(J5-B4/2))/(E8+E25)								
35				(Ignores passive resistance but includes vertical shear due to inclined backfill.)								
36	NOTE:											
37	*** TABLE 840.04-1 of ODOT Supplemental Specification 840 (Mechanically Stabilitzed Earth Wall) specifies 120 pcf as the design unit weight for MSE wall backfill. This value was used for											
38	sliding resistance analyses but a value of 135 pcf (corresponding to Select Granular Backfill) was assumed in Bearing Resistance calculation.											

$$e = \frac{\Sigma M_{DRIVING}}{\Sigma F_{VERT}}$$